Journal of the Saudi Society of Agricultural Sciences 19 (2020) 65–75

Contents lists available at ScienceDirect

Journal of the Saudi Society of Agricultural Sciences

journal homepage: www.sciencedirect.com

Full length article

Assessment of phenotypic diversity of local Algerian date palm (*Phoenix dactylifera* L.) cultivars

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ARTICLE INFO

Article history:
Received 19 April 2018
Revised 4 June 2018
Accepted 26 June 2018
Available online 28 June 2018

Keywords:
Date palm
Cultivars
Phenotypic
Multivariate analysis
Algeria
Diversity

ABSTRACT

The Date palm is a strategic fruit crop in Algeria, which is one of the largest producers of dates in the world and contains about one thousand cultivars. However, the practice of monovarietal culture threatens the biodiversity of date palm leading to severe genetic erosion. This study aimed at phenotypic diversity assessment among 26 Algerian date palm cultivars grown in Ziban region. In total, 52 morphological markers measured separately on both vegetative and reproductive parts were treated using multivariate analysis. The results showed a great morphological variability among local cultivars. Overall, correlation matrix showed mainly high positive correlations between most of the vegetative and reproductive characters. Principal component analysis (PCA) defined the most discriminants characters responsible of the observed variability. In fact, among the 27 vegetative traits analyzed in this study, ten related to the different descriptors of the leaf, rachis, leaflet and spines allowed a reliable differentiation among cultivars out of the period of fructification. As regards to the reproductive traits, among the 25 descriptors used twelve traits, describing the fruit and bunch, were the most discriminants. The cluster analysis (CA) showed associations between cultivars with similar characteristic related to the palm or to the fruit and enabled the identification of three main phenotypic clusters for both vegetative and reproductive characters. Dissimilarity levels ranged from 0.064 to 1.148 for vegetative characters, and from 0.036 to 1.256 for reproductive characters. Similarities between PCA and CA clustering were observed in this study. Furthermore, the obtained results agree with farmers characterization oriented towards important agronomic traits. The data obtained here would help to create a phenotypic database and use the most discriminants descriptors found in this study for a large-scale phenotyping.

1. Introduction

The Date palm is a strategic fruit crop in North Africa and Middle East because of many socio-economic activities depends on it. The date palm is often propagated clonally by offshoots because cross-pollination results in new cultivars out-of-type with unknown characteristics (Al-Khayri, 2005; Rhouma et al., 2010). Furthermore, About 50% of the seedlings are male although they cannot be recognized until trees begin to bloom after 4–5 years (Chao and Krueger, 2007) except when using male-specific DNA markers (Cherif et al., 2013). However, in the majority of countries producing date palm, this molecular tool does not exist, and the majority of farmers cannot afford it.

Algeria is the third largest producer of dates in the world with 934,377 T (FAOSTAT, 2014) and about 940 cultivars (Hannachi et al., 1998). However, the most trade-marketable date cultivar is the famous Algerian "Deglet Noor" that represents about 52% of total date palm production (MADR, 2015). However, this practice of monovarietal culture constitutes not only genetic erosion on the diversity of date palm in Algerian oases, under climatic change, but a constant threaten on the economy of the biggest region for date's production. In fact, the majority of date palm cultivars are sensitive to Bayoud, a vascular wilt of date palm caused by *Fusarium oxysporum* f.sp. *albedinis*, widely distributed in the western parts of Algeria. In addition, the lack of information about the plant genetic resources reduces the usefulness of the potential diversity

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.jssas.2018.06.002
1658-077X/

present among cultivars by institutions and potentials users. Therefore, it is imperative to implement a strategy to strengthen cultivars preservation and to restore genetic resources of date palm as well as for commercial valorization of unknown cultivars. Hence, cultivars characterization should be the first step as it is an essential prerequisite for evaluation of date palm diversity. Many studies using morphological traits to identify cultivars have been reported (Ould Mohamed Salem et al., 2008; Ould Mohamed Ahmed et al., 2011; Simozrag et al., 2016). Genetic diversity is also explored by using either biochemical (Baaziz and Saaidi, 1988; Bennaceur, et al., 1991; Ould Mohamed Salem et al., 2001) or other molecular markers as AFLP (Boyang et al. 2002; El-Assar et al., 2005) and microsatellites (Zehdi et al., 2004; Elshibli and Korpelainen, 2008; Ahmed and Al-Qaradawi, 2009; Arabnezhad et al., 2012; Racchi et al., 2013).

Table 1
Name, label and collection site of date palm cultivars.

Accessions	Labels	Locations
Ain El Fas	AFS	Leghrouss
Arechti	ART	Sidi Okba
Bouhlas	BHL	Leghrouss
Deglet Abdallah	DGA	Chetma
Degla Baidha	DGB	Sidi Okba
Deglet Debbab	DGD	Chetma
Deglet Noor	DGN	Leghrouss
Deglet-Zian	DGZ	Tolga
Feraounia	FER	Foughala
Ghars	GHS	Tolga
Ghazi	GHZ	Tolga
Halwa	HAL	Leghrouss
Hamraya	HAM	Chetma
Horra	HRR	Leghrouss
Itima	ITM	Foughala
Kseba	KSB	Leghrouss
Lemsaref	LMS	Tolga
Mech Degla	MDG	Chetma
Safraya	SAF	Chetma
Sbaa Laroussa	SBL	Chetma
Tantboucht	TNT	Chetma
Thawri	THW	Tolga
Tichtat	TCH	Tolga
Tijaaranit	TJR	Chetma
Tinicine	TNC	Chetma
Zomeret Mimoun	ZMM	Foughala

In Algeria, characterization of date palm genetic resources using phenotypic descriptors were only based either on short phenotypic description without any statistical data (Belguedj, 2002), or used a reduced number of variables (Açourene et al., 2001; Simozrag et al., 2016). Yet, the molecular characterization of the local date palm cultivars using SSR makers were reported (Chaluvadi et al., 2014; Moussouni et al., 2017). Our study was carried out to assess the phenotypic diversity using multivariate analysis. The objectives were to use a high number of IPGRI descriptors to (a) identify discriminants descriptors that can be used in the field even outside fruit period to recognize and/or differentiate between cultivars and (b) find out the genetic relationship among the local date palm cultivars.

2. Materials and methods

2.1. Plant material and measurement

In total 26 date palm cultivars (Table 1) originated from different locations in Ziban region, Biskra (Fig. 1), (situated at 87 m above sea level, between latitudes 34°38′ and 35°5′, longitudes 4°56′ and 5°35′) were characterized in this study. Some cultivars were investigated for the first time namely, "ZOMERET MIMOUN", "LEMSAREF", "FERAOUNIA" and "TIJAARANIT".

The cultivars' sampling was randomly selected to carry out the morphometric analysis. Fifty two variables (Table 2) were analyzed, twenty seven describing vegetative part (leaves, leaflets and spines) and twenty five reproductive organs (spathes, bunches and fruits) based on International standard descriptors of the date palm (IPGRI 2005, now BIOVERSITY INTERNATIONAL). The number of replication for all measured parameters was followed as indicated in (IPRGRI, 2005). However, the number of trees per cultivar depended on their availability in the oasis. For each cultivar; five trees were selected and five leaves per tree were sampled to evaluate the vegetative parameters. For the reproductive organs, for each individual, samples of five spathes were collected and 40 fruits per bunch were randomly sampled at Tamr stage (full maturation).

Fig. 1. Map of Algeria and Biskra region. The locations of sampling (Tolga, Leghrous, Foughala, Chetma and Sidi Okba) are indicated inside the delimited area with border red line.

Table 2
Measured vegetative and reproductive characters in date palm cultivars.

Vegetative Characters	Unit	Codes	Reproductive Characters	Unit	Codes
Trunk circumference at 1 m from the soil	cm	V1	Spathe length	cm	R1
Leaf length	cm	V2	Spathe width	cm	R2
Leaf width	cm	V3	Peduncle width at the first spikelet	cm	R3
Spined part length	cm	V4	Ramified bunch's part length	cm	R4
Rachis width[a]	mm	V5	Spikelet's number/bunch		R5
Rachis thickness[a]	mm	V6	Spikelet's length[b] at the bunch's bottom	cm	R6
Spines number		V7	Spikelet's length[b] at the bunch's middle	cm	R7
Spine width at the middle	mm	V8	Spikelet's length[b] at the bunch's top	cm	R8
Spine thickness at the middle	mm	V9	Spikelet's length[c] at the bunch's bottom	cm	R9
Spine length at the middle	mm	V10	Spikelet's length[c] at the bunch's middle	cm	R10
1-spines number (single spines number)		V11	Spikelet's length[c] at the bunch's top	cm	R11
2-spines number		V12	Longest spikelet's length	cm	R12
3-spines number		V13	Shortest spikelet's length	cm	R13
Leaflets number		V14	Fruit weight	gr	R14
1-Leaflet number (single leaflet number)		V15	Fruit length	mm	R15
2-Leaflets number		V16	Fruit cavity's length	mm	R16
3-Leaflets number		V17	Fruit cavity's width	mm	R17
4- Leaflets number		V18	Pulp thickness	mm	R18
5- Leaflets number		V19	Calyx diameter	mm	R19
Leaf length at the middle	cm	V20	Seed weight	gr	R20
Leaf width at the middle	cm	V21	Seed width	mm	R21
Introse leaflets number		V22	Seed length	mm	R22
Retrose leaflets number		V23	Seed thickness	mm	R23
Antrose leaflets number		V24	Seed/fruit length ratio		R24
Terminal leaf length	cm	V25	Seed/fruit weight ratio		R25
Terminal leaf width	cm	V26			
Spacing index		V27			

[a] Between the last Spine and the first leaflet.
[b] Part without fruit.
[c] Part with fruit.

In the present study many parameters related to spines and leaves grouping, leaves disposition and spikelet's part lengths (with and without fruits) at different levels of the bunch, were used to assess the phenotypic diversity. As far as we know this is the first time that these parameters are used.

In the following, a set of spines grouped together will be labeled n-spines, i.e. a twin of spines is labeled 2-spines, and a 1-spine is simply single spine. Likewise, the leaflets number will be labeled n-leaflet.

2.2. Data analysis

Collected data were analyzed statistically using analysis of variance (ANOVA) at the level of $p < 0.001$ to check whether there is a significant variation among the cultivars for each parameter. Differences among the means, for each parameter, were determined using post-hoc Tukey's test (HSD). Parameters means values were used to perform principal component analyses (PCA) as well as the correlation analyses to test whether the variables are correlated in the population (Taylor 1990; Jolliffe 2002). Cluster analysis was carried out using Ward method to perform hierarchical clustering analysis (Saracli et al. 2013). Indeed, we search for patterns in a data set by grouping the (multivariate) observations into clusters. The objective is to find an optimal grouping for which the observations or objects within each cluster are similar, but the clusters are dissimilar to each other (Rencher 2002). This analysis will allow us to classify the studied cultivars into homogeneous and distinct groups. All analyses were performed using XLSTAT software version 2016.02.

3. Results

3.1. Variance analysis and HSD test

3.1.1. Vegetative characters

The date palm cultivars exhibited a large variation in all their vegetative components ($p < 0.001$). Post-hoc Tukey's tests (Table 3) depicted the 26 cultivars according to the studied parameters into different groups which the number varied from 2 (i.e. spined part length; V4) to 7 (i.e. rachis width; V5). For example, ARECHTI (ART) and ITIMA (ITM) cultivars displayed the greatest length (V2) while TANTBOUCHT (TNT) cultivar had the shortest spine at the middle (V10) (Tukey's test: p-value < 0.05) (Table 3).

3.1.2. Reproductive characters

The results showed significant differences for all reproductive parameters among the cultivars ($p < 0.001$). The group's number obtained by HSD test increased to 12 (Table 4). According to this test, DEGLA BAIDHA cultivar (DGB), forming a single group, had the longest spikelet (R12), while TANTBOUCHT (TNT) and TICHTAT (TCH) cultivars belonged to a separate group with the shortest fruit length (R15) (Table 4).

3.2. Correlation matrix

Mean values of morphometric characters (vegetative and reproductive) were analyzed separately and are reported in Tables 3 and 4. They revealed a great variability between the date palm genotypes for all traits either vegetative or reproductive.

3.2.1. Vegetative characters

The correlation matrix between the measured characters showed mainly positive correlations between most of them and many parameters showed high positive correlation at 0.01 probability level. However, the following parameters had a coefficient correlation more than 0.60 (Table 5). In fact, the palm length (V2) was correlated with leaflet length at the middle (V20). Also, the rachis width between the last spine and the first leaflet (V5) had a high positive correlation with rachis thickness (V6) and the rachis width between the last spine and 1-leaflet number (V15). As expected, the spines number (V7) with spine width (V8), the spine thickness at the middle (V9) and the 2-spines number (V12) and 3-spines number (V13). These latest spine

Table 3
Means values of vegetative parameters (Abbreviations as in Tables 1 and 2).

Cv	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14
AFS	166,2^{af}	409^{ab}	51,44^{bf}	45,44^{b}	33,4^{ac}	21,22^{bf}	22^{fh}	3,48^{be}	2,2^{cd}	7,96 ^{cd}	7,8^{bc}	6,2^{c}	0,6^{b}	205,2^{ad}
ART	183,5^{ac}	447,4^{a}	79,6^{ad}	53,76^{b}	35,6^{ab}	26,6^{ac}	16,4^{h}	4,66^{ae}	3,16^{bd}	7,2^{cd}	6,4^{bc}	5^{c}	0^{b}	227,6^{a}
BHL	158,8^{ag}	322^{bc}	60,34^{bf}	73,92^{ab}	22,4^{eg}	19^{cf}	32,4^{cg}	3,2^{ce}	2,40^{bd}	6,92 ^{cd}	2,8^{c}	11,8^{ac}	2^{ab}	153,8^{dg}
DGA	174,8^{ae}	427^{ab}	99,74^{a}	67,5^{ab}	28,2^{af}	25,44^{ad}	32,2^{cg}	5,8^{ac}	3,92^{ac}	7,88 ^{cd}	4^{bc}	10,8^{ac}	2,2^{ab}	184,8^{af}
DGB	208,4^{a}	387,8^{ac}	44,74^{ef}	62,52^{ab}	32,6^{ad}	27,4^{ab}	32,6^{cg}	4,8^{ae}	3,44^{ad}	11,54^{ac}	5,6^{bc}	10,8^{ac}	1,8^{ab}	225,8^{ab}
DGD	127,4^{dh}	290,4^{c}	48,92^{df}	53,58^{b}	23,2^{eg}	20,4^{bf}	39^{be}	4,4^{ae}	3^{bd}	6,26 ^{cd}	6,2^{bc}	11^{ac}	3,6^{a}	173,4^{cf}
DGN	187,7^{ac}	399,3^{ac}	92,33^{ac}	34,72^{b}	29,67^{ae}	34,67^{a}	55^{ab}	6,57^{ab}	5^{ab}	13,78^{ab}	11,33^{bc}	16,33^{a}	3,67^{a}	166,3^{cg}
DGZ	122,9^{ch}	340,1^{ac}	58,58^{cf}	54,46^{b}	33,4^{ac}	21,4^{bf}	23,8^{eh}	3,87^{be}	2,76^{bd}	7,4^{cd}	6,6^{a}	8^{bc}	0,4^{b}	179^{bf}
FER	98,33^{gh}	314,7^{bc}	44,23^{ef}	57,77^{ab}	21,67^{eg}	15,07^{ef}	25,67^{dh}	1,67f	1,03^{d}	10,64^{ad}	2^{c}	10,33^{ac}	1^{ab}	176,7^{bf}
GHS	193,3^{ac}	489,5^{ab}	66,5^{af}	87,83^{ab}	27^{bf}	23,67^{be}	39,33^{be}	5^{ae}	3,67^{ad}	11,63^{ac}	8,33^{bc}	13,67^{ac}	3,83^{a}	198,7^{ae}
GHZ	176,3^{ae}	348,7^{ac}	65,75^{af}	64,08^{ab}	24,93^{cf}	21,3^{bf}	42,25^{ad}	4,29^{ae}	3,78^{ad}	9,15^{bd}	4,5^{bc}	16,25^{a}	1,75^{ab}	162,7^{dg}
HAL	99,17^{fh}	325,3^{bc}	62,06^{bf}	56,12^{b}	29,98^{ae}	21,5^{bf}	25,4^{eh}	3,35^{be}	3,64^{ad}	10,04^{bd}	7^{bc}	8,6^{bc}	0,4^{b}	158,4^{dg}
HAM	126^{ah}	443^{ab}	44,7^{ef}	120,3^{a}	26,67^{bf}	23,67^{be}	47,33^{ac}	7,33^{a}	6^{a}	16,83^{a}	5,33^{bc}	17^{a}	2,67^{ab}	168,7^{cg}
HRR	182,6^{ad}	332,1^{bc}	59,24^{bf}	78,28^{ab}	28,6^{ae}	23,69^{be}	37,6^{ce}	3,72^{be}	2,76^{bd}	9,3^{bd}	4,4^{bc}	14,8^{ab}	1,2^{ab}	187,2^{af}
ITM	127^{dh}	448,8^{a}	56,84^{cf}	111,9^{a}	36^{ab}	22,6^{be}	57^{a}	5,18^{ad}	4,94^{ab}	7,9^{cd}	19,6^{a}	16^{a}	1,8^{ab}	214,4^{ac}
KSB	181,6^{ad}	373,5^{ac}	66,9^{af}	69,4^{ab}	27,4^{bf}	22,2^{bf}	35,2^{cf}	5,38^{ad}	4,64^{ab}	10,06^{bd}	3,4^{c}	13,8^{ab}	1,4^{ab}	167,6^{cg}
LMS	212,67^{ac}	351,5^{ac}	56,6^{cf}	96,38^{ab}	27^{bf}	23^{be}	36,25^{cf}	4,45^{ae}	3,18^{bd}	11,18^{ac}	10,5^{bc}	11,75^{ac}	0,75^{b}	216,5^{ac}
MDG	146,7^{ah}	356^{ac}	39,33^{ef}	50^{b}	13 g	16,17^{df}	20,67^{fh}	3de	2,47^{bd}	7,43 ^{cd}	4,33^{bc}	7,67^{bc}	0,33^{b}	144,3^{eg}
SAF	151,7^{ah}	423,5^{ab}	64,88^{af}	96,35^{ab}	23,5^{df}	19,08^{bf}	30,5^{ch}	3,5^{be}	2,1^{cd}	8,21^{bd}	3,75^{bc}	9,25^{ac}	2,75^{ab}	162,2^{dg}
SBL	99,33^{fh}	304^{bc}	29,23^{f}	51^{b}	18 ^{fg}	13^{f}	21^{fh}	3,67^{be}	1,33^{d}	7,17 ^{cd}	9,33^{bc}	5,33^{c}	0,33^{b}	159,7^{dg}
TCH	187,3^{ac}	370,8^{ac}	71,9^{ae}	74,66^{ab}	23,4^{ef}	20^{bf}	25,2^{eh}	3,6^{be}	2,8^{bd}	9,3^{bd}	6,2^{bc}	8,6^{bc}	0,6^{b}	141 ^{fg}
THW	156,7^{ag}	333,2^{ac}	66,58^{af}	47,18^{b}	36^{a}	22,75^{be}	19,6^{gh}	3^{ce}	3,16^{bd}	8,58^{bd}	5,6^{bc}	6,4^{c}	0,4^{b}	120,6^{g}
TJR	142,3^{bh}	381,5^{bc}	67,85^{af}	84,23^{ab}	24^{cf}	21^{bf}	35,75^{cf}	4,5^{ae}	3,43^{ad}	11,47^{ac}	7,5^{bc}	10^{ac}	2,75^{ab}	171,2^{cg}
TNS	167^{ae}	382,6^{ac}	78,1^{ae}	87,74^{ab}	31^{ae}	22,4^{be}	31^{cg}	3de	1,4^{d}	8,52^{bd}	7,8^{bc}	8,6^{bc}	2^{ab}	180,6^{af}
TNT	164,8^{ag}	364,5^{c}	93,8^{ab}	59,64^{ab}	31,4^{ae}	21^{bf}	23^{eh}	3,49^{be}	3,44^{ad}	5,74^{d}	11,4^{a}	5,8^{c}	0^{b}	168,4^{cg}
ZMM	93,5^{h}	420^{ab}	70^{af}	90^{ab}	32,5^{ae}	28,5^{ab}	30,5^{ch}	4^{ae}	3,5^{ad}	9,35^{bd}	3,5^{bc}	12^{ac}	1^{ab}	208,5^{ad}

Cv	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27
AFS	8,8^{df}	55,4^{ab}	24,4^{a}	2,6^{c}	0,4^{ab}	48,72^{cf}	1,08^{g}	67^{ad}	79^{a}	59,2^{cf}	24,2^{cf}	1,08^{fh}	0,49^{ab}
ART	33,2^{ac}	63^{a}	17,6^{ac}	3,4^{ac}	0,4^{ab}	54,26^{bd}	2,42^{be}	80^{ab}	70,4^{a}	77,2^{ac}	27,42^{bf}	0,7^{h}	0,55^{ab}
BHL	6,8^{ef}	29,8^{d}	17,6^{ac}	6,4^{ac}	1,8^{ab}	47,9^{cf}	1,4^{eg}	50,6^{bd}	72^{a}	31,2^{f}	22,32^{cf}	1,32^{dg}	0,47^{ab}
DGA	6,2^{f}	44,6^{ad}	16,6^{ac}	5,4^{ac}	3,6^{a}	64,98^{ab}	2,32^{bf}	53^{bd}	76,6^{a}	55,2^{cf}	24,86^{cf}	1,68^{be}	0,46^{ab}
DGB	29^{ad}	47,4^{ad}	22,6^{a}	6,8^{ac}	1,4^{ab}	55,02^{bd}	2,76^{ac}	83,2^{a}	62^{ab}	80,6^{ac}	27,72^{bf}	1,32^{dg}	0,33^{b}
DGD	9,4^{df}	38,8^{bd}	18,4^{ac}	5,8^{ac}	1,6^{ab}	44,76^{df}	1,62^{cg}	65,2^{ad}	73^{a}	35,2^{df}	30,8^{ae}	2,2^{ab}	0,53^{ab}
DGN	20^{af}	35^{cd}	21^{ab}	3,33^{ac}	0^{b}	67,33^{ab}	3,28^{ab}	61^{ad}	61^{ab}	44,33^{df}	34^{ac}	1,77^{be}	0,5^{ab}
DGZ	14,6^{cf}	48,8^{ac}	16^{ac}	4,2^{ac}	0,4^{ab}	45,58^{df}	3,08^{ab}	59^{ac}	59,6^{ac}	60,4^{cf}	26,72^{bf}	1,68^{be}	0,56^{ab}
FER	6,33^{ef}	38^{bd}	25,67^{ac}	4,33^{ac}	0^{b}	36,93^{f}	0,97^{g}	66,33^{ad}	58,33^{ab}	52^{cf}	20,07^{cf}	1,87^{bd}	0,31^{b}
GHS	25^{af}	47,67^{ad}	21,33^{a}	2,33^{a}	1^{ab}	52,23^{be}	3,77^{a}	55,7^{ad}	48^{ad}	94,97^{ab}	15,9^{f}	1,4^{cg}	0,58^{ab}
GHZ	22,75^{af}	37,5^{bd}	16,25^{ac}	3,75^{ac}	0,25^{ab}	49,68^{cf}	2,6^{ac}	62,5^{ad}	26,25^{cd}	74^{bc}	25,15^{bf}	1,13^{eh}	0,3^{b}
HAL	20^{bf}	35,8^{cd}	13^{ac}	5,2^{ac}	1,4^{ab}	40,7^{dfa}	2,76^{ac}	60,8^{ad}	35^{bd}	62,6^{ce}	23,94^{cf}	1,5^{cf}	0,37^{ab}
HAM	15,33^{bf}	40,33^{bd}	19,33^{ab}	3,67^{ac}	0^{b}	49,17^{cf}	1,73^{cg}	49^{ce}	69^{a}	50,67^{cf}	22,43^{cf}	1,93^{bd}	0,4^{ab}
HRR	14,6^{cf}	50,8^{ac}	14,4^{ac}	6,2^{ac}	0,6^{ab}	36,98^{f}	3,18^{ab}	80,4^{ac}	33^{bd}	73,8^{bc}	23,04^{cf}	2,16^{ab}	0,4^{ab}
ITM	42^{a}	51,4^{ac}	13^{ac}	2,8^{a}	0,6^{ab}	73,62^{a}	2,6^{ac}	73,4^{ad}	63,6^{ab}	77,4^{ac}	19,88^{df}	0,74^{h}	0,54^{ab}
KSB	17,6^{bf}	44,4^{ad}	11,6^{ac}	5,6^{ac}	0,8^{ab}	54,92^{bd}	2,94^{ab}	69,2^{ad}	28,2^{cd}	70,2^{cd}	38^{ab}	1,68^{be}	0,41^{ab}
LMS	10,75^{cf}	45^{ad}	21^{a}	11^{ab}	1,75^{ab}	43,55^{df}	3,18^{ab}	88^{a}	52^{ad}	76,5^{ac}	18,43^{ef}	1,38^{dg}	0,36^{ab}
MDG	9,67^{cf}	41,67^{bd}	14,33^{ac}	1,67^{a}	0,33^{ab}	49,33^{cf}	3,13^{ab}	37de	56^{ac}	51,33^{cf}	22,67^{cf}	1,4^{cg}	0,38^{ab}
SAF	4,25^{f}	41,25^{bd}	12,25^{ac}	7,5^{ac}	1,75^{ab}	59,63^{bc}	0,88^{g}	58,75^{ad}	51,5^{ac}	52^{cf}	23,63^{cf}	0,69^{h}	0,43^{ab}
SBL	7,67^{df}	35,67^{cd}	20,67^{ab}	4,67^{ac}	0^{b}	38,2^{ef}	1,2^{fg}	56,67^{ad}	59,67^{ab}	43,33^{df}	16f	1,6^{bf}	0,37^{ab}
TCH	3,8^{f}	43,4^{bd}	12,8^{ac}	3^{bc}	0^{b}	48,56^{cf}	1,14^{g}	51,80^{bd}	48,4^{ad}	40,8^{df}	32,72^{ac}	1,96^{bc}	0,45^{ab}
THW	28^{ae}	34,4^{cd}	6,8^{bc}	0,6^{a}	0,2^{b}	46,03^{df}	3,75^{a}	47,75^{ce}	23,1^{d}	49,75^{cf}	40,33^{a}	2,73^{a}	0,5^{ab}
TJR	5,75^{f}	43,5^{ad}	19,5^{ab}	3,75^{ac}	10^{ab}	53,05^{be}	1,55^{cg}	47,25^{ce}	65,5^{ab}	58,5^{cf}	22,57^{cf}	1,5^{cf}	0,36^{ab}
TNS	8,2^{df}	34,2^{cd}	18,8^{ab}	7,4^{ac}	3,6^{a}	55,02^{bd}	1,58^{cg}	58,8^{ad}	67,8^{a}	54^{cf}	20,36^{cf}	1,32^{dg}	0,45^{ab}
TNT	37,8^{ab}	52,6^{ac}	5,8^{c}	2^{a}	0^{b}	59,98^{bc}	2,66^{ac}	57^{bd}	54,4^{ac}	57^{cf}	31,74^{ad}	1,66^{be}	0,58^{a}
ZMM	9,5^{cf}	35,5^{cd}	22,5^{a}	12^{a}	2,5^{ab}	55,5^{bd}	3^{ab}	35^{e}	65^{ab}	108,5^{a}	39,5^{ab}	1,66^{bf}	0,3^{b}

Values in the same column with different subscript letters represent significant differences between cultivars at $p < 0.05$ by Tukey test. CV: Cultivar. V: Vegetative parameters.

groupings were also intercorrelated. These latest spine groupings were also intercorrelated. Middle spine dimensions (width; V8, thickness; V9 and length; V10) had positive correlations with 2-spines number (V12). Correlation matrix also revealed a significant intercorrelation between leaflets number (V14), 2-leaflets number (V16) and the introse leaflets number (V22) as well as the number of antrose leaflets (V24).

The parameters 4-leaflets number (V19) and 5-leaflets number (V18) were also highly correlated as well as the widths of the leaflets at the middle (V21) and at the terminal (V26) of the palm. It is of interest to point out that only negative correlation observed in this study was between to the terminal leaf width (V26) and the retrose leaflets number (V23).

3.2.2. Reproductive characters

Overall, the correlations between the studied characters (Table 6) showed positive correlations. Indeed, spathe length (R1) was positively correlated with seed width (R20). Spikelet part lengths without fruit at the bunch bottom (R6) and middle (R7) were intercorrelated, yet, only the spikelet part length without fruit at the middle was highly correlated with the spikelet's part without fruit length at the bunch's top (R8) as well as the longest (R12) and the shortest spikelet (R13). While, the spikelet part length without fruit at the bunch bottom (R6) was highly correlated with the shortest spikelet (R13). As expected, the fruit weight (R14) and length (R15), and fruit cavity length (R16) were inter-correlated and each of them had a positive correlation with pulp thickness (R18) and seed length (R22). Similarly, the calyx

Table 4
Means values of reproductive parameters (Abbreviations as in Tables 1 and 2).

Cv	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
AFS	49,80^{ce}	6,6^{b}	3,08^{ce}	50,67^{ab}	65^{bf}	13,33^{ac}	16,67^{ac}	25,67^{ad}	14,67^{ab}	16,33^{b}	23,33^{ab}	49^{ac}	27^{ad}
ART	43,33^{de}	16,33^{a}	4,54^{b}	25,56^{ce}	77,8^{ac}	14,64^{ab}	16,32^{ac}	24,74^{ad}	12,16^{b}	19^{ab}	25,1^{ab}	49,96^{ac}	24,36^{ad}
BHL	54,37^{be}	6,5^{b}	4,17^{bd}	22,63^{ce}	68,67^{af}	6,73^{ac}	9,1^{c}	17,53 ^{cd}	11,07^{b}	18,23^{ba}	18,6^{b}	36,4^{c}	19,3^{bc}
DGA	52,35^{ce}	7,93^{ab}	3,97^{be}	23,37^{ce}	54,33^{bf}	13^{ac}	16,27^{ac}	22,47^{ad}	15,93^{ab}	21,67^{ab}	26,1^{ab}	46,87^{ac}	23,1^{ad}
DGB	60,60^{be}	14,6^{ab}	6,22^{a}	42,88^{ad}	87,8^{ab}	11,6^{ac}	17,2^{ac}	31,5^{ab}	24,74^{a}	29,72^{ab}	34,6^{ab}	66,38^{a}	30,18^{ac}
DGD	59,33^{be}	7,3^{b}	4,09^{be}	33^{be}	51,89^{bf}	13,12^{c}	16,53^{ac}	24,23^{ad}	16,98^{ab}	27,81^{ab}	32,49^{ab}	64,63^{ab}	27,82^{ad}
DNR	101,33^{a}	9,83^{ab}	4,07^{bd}	66^{a}	38,67^{df}	17,67^{a}	22^{ac}	28,33^{ad}	18,57^{ab}	21,57^{ab}	28,83^{ab}	63,17^{ab}	33,4^{ac}
DGZ	32^{e}	7,67^{ab}	2,72^{ce}	17,2^{e}	63,6^{bf}	10,78^{ac}	11,88^{bc}	16,1^{a}	16,08^{ab}	20,7^{ab}	23,2^{ab}	39,54^{c}	27,18^{ad}
FER	37^{e}	8^{ab}	2,6^{ce}	43,33^{ad}	56^{bf}	8,33^{ac}	12,07^{bc}	20,23^{ad}	13,17^{ab}	17,07^{b}	20,83^{b}	41,77^{bc}	16,33^{d}
GHS	75^{ac}	8^{ab}	3,4^{be}	47,67^{ad}	49,33^{cf}	6^{ac}	15,33^{ac}	21^{ad}	18,33^{ab}	22,33^{ab}	27,33^{ab}	51^{ac}	16,67^{d}
GHZ	44,5^{e}	11,5^{ab}	3,07^{ce}	32,67^{be}	59,67^{bf}	11,3^{ac}	15,67^{ac}	20,37^{ad}	16,3^{ab}	21,53^{ab}	28,1^{ab}	51,23^{ac}	27,33^{ad}
HAL	48^{ce}	8^{ab}	2,47^{e}	21,33^{de}	34,33^{ef}	11,1^{ac}	13,77^{ac}	18,7^{bd}	20^{ab}	25,67^{ab}	31,53^{ab}	50,6^{acc}	31,33^{ac}
HAM	48^{ce}	8^{ab}	2,46^{de}	27,1^{be}	42,4^{df}	8,56^{ac}	15,14^{ac}	24,02^{ad}	16,34^{av}	22,04^{ab}	24,74^{ab}	49,52^{a}	22,7^{ad}
HRR	48,3^{ce}	9,33^{ab}	3,35^{be}	43,08^{ad}	67,5^{bf}	12,2^{ac}	19,3^{ac}	35,13^{a}	11,3^{b}	22,13^{ab}	26,15^{ab}	63,98^{ab}	22,13^{ad}
ITM	60,75^{be}	11,13^{ab}	3,1^{ce}	26,92^{be}	83,8^{ab}	17,24^{a}	26,64^{a}	29,6^{ac}	18,48^{ab}	24,16^{ab}	25,44^{ab}	57,26^{ac}	36,68^{ab}
KSB	42,67^{de}	8,33^{ab}	3,4^{be}	25,3^{ce}	71,33^{af}	6,47^{ac}	14,2^{ac}	20,1^{ad}	11,93^{b}	19,87^{ab}	20,4^{b}	42,67^{bc}	18,13 ^{cd}
LMS	37,33^{e}	8^{ab}	3,07^{ce}	33,97^{be}	72^{ae}	5,83^{ac}	9,97^{ac}	20,17^{ad}	14,77^{ab}	27,5^{ab}	31,23^{ab}	51,1^{ac}	20,67^{ad}
MDG	64,17^{be}	13,5^{ab}	4,83^{ab}	49,67^{ac}	81^{ac}	4,83^{bc}	11^{bc}	19,5^{ad}	10,83^{b}	17,33^{b}	21,67^{b}	47,83^{ac}	17,33 ^{cd}
SAF	80,77^{ab}	7,17^{b}	2,67^{ce}	33,83^{be}	76,33^{ad}	9,7^{ac}	18,7^{ac}	36,13^{a}	17,83^{ab}	18,17^{ab}	22,6^{ab}	59,63^{ac}	21,1^{ad}
SBL	64,75^{bd}	9,5^{ab}	2,95^{ce}	24,03^{ce}	54^{bf}	10,13^{ac}	14,8^{ac}	21,18^{ad}	11,2^{b}	17,8^{b}	21,98^{b}	44,28^{bc}	21,65^{ad}
TCH	41,83^{de}	7^{b}	3,14^{be}	51,43^{ab}	108^{a}	9,63^{ac}	20,33^{ac}	22,8^{ad}	17,67^{ab}	25,03^{ab}	32,27^{ab}	46,2^{ac}	21,93^{ad}
THW	46,7^{ab}	7,44^{b}	3,5^{bc}	29,18^{ae}	51,4^{ch}	9,92^{ac}	13,26^{bc}	23,8^{ad}	16,52^{ab}	21,7^{ab}	27,02^{ab}	50,46^{ac}	25,2^{ad}
TJR	81,67^{de}	8,5^{a}	4,31^{be}	39,33^{be}	30,33^{f}	18,4^{a}	20,6^{ac}	27,33^{ad}	22,17^{ab}	33,3^{a}	40,17^{a}	59,33^{ac}	39,2^{a}
TNS	43,97^{de}	5,47^{b}	4^{be}	36,3^{be}	71^{af}	7,97^{ac}	12,73^{bc}	22,9^{ad}	12,83^{b}	28,47^{ab}	31,2^{ab}	55,3^{ac}	21,17^{ad}
TNT	42,67^{de}	11,33^{ab}	3,8^{be}	28,44^{be}	77,2^{ac}	9,06^{ac}	13,66^{bc}	18,44 ^{cd}	15,08^{ab}	27,58^{ab}	31,3^{ab}	43,48^{bc}	26,16^{ad}
ZMM	44de	9^{ab}	3,59^{be}	41,7^{ae}	86^{ab}	7^{ac}	17,73^{ac}	25,33^{ad}	15,83^{ab}	19,87^{ab}	29,5^{ab}	55,27^{ac}	23,97^{ad}

Cv	R14	R15	R16	R17	R18	R219	R20	R21	R22	R23	R24	R25
AFS	13,21^{ab}	45,05^{ac}	37,85^{ac}	9,82^{be}	4,86^{ab}	9,18^{ab}	1,25^{ej}	8,72^{ab}	23,49^{be}	7,48^{ad}	0,52^{c}	0,09^{g}
ART	13,69^{a}	45,66^{ab}	39,83^{ab}	11,25^{ac}	4,9^{a}	9,51^{ab}	1,44^{df}	9,52^{ab}	26,73^{ac}	7,81^{ac}	0,59^{bc}	0,1^{fg}
BHL	5,46^{fh}	27,3^{hi}	23,33^{eg}	6^{e}	1,67^{c}	5,33^{di}	0,8^{kl}	4,33^{f}	18,67^{ef}	2,33^{j}	0,68^{ab}	0,15^{cf}
DGA	7,98^{dg}	38^{bf}	34^{ae}	9,67^{be}	1,67^{c}	3^{i}	1,37^{dg}	5,33^{ef}	27^{ac}	3,33^{ij}	0,71^{a}	0,17^{ce}
DGB	5,78^{fh}	37,82^{cf}	31,89^{af}	11,42^{ac}	2,79^{ac}	9,72^{a}	1,36^{dg}	9,24^{ab}	24,15^{bd}	7,9^{ac}	0,64^{ac}	0,24^{c}
DGD	7,84^{a}	33,53^{fi}	31,78^{eg}	11,56^{ac}	4^{ac}	4,67^{ah}	1,26^{fk}	6^{cf}	23,78^{be}	4,22^{gi}	0,71^{a}	0,16^{cf}
DNR	11,89^{ac}	43,53^{ad}	35,8^{ae}	9,21^{be}	4,32^{ac}	7,8^{af}	2,25^{b}	7,44^{be}	23,84^{be}	6,11^{bg}	0,55^{bc}	0,19^{cd}
DGZ	6,2^{eh}	32,42^{fi}	29,38^{bg}	8,42^{ce}	3,27^{ac}	7,73^{af}	0,51^{l}	6,5^{cf}	22,43^{ce}	5,02^{ei}	0,69^{ab}	0,08^{g}
FER	7,33^{dh}	35^{dh}	30,33^{ag}	10,67^{bd}	3,67^{ac}	8,67^{ae}	1,41^{dg}	10^{a}	24,67^{ad}	7^{ae}	0,7^{a}	0,19^{cd}
GHS	7,03^{eh}	41,79^{ae}	36,53^{ad}	8,28^{ce}	3,46^{ac}	6,5^{ai}	2,43^{b}	5,81^{df}	23,66^{be}	5,67^{dg}	0,57^{bc}	0,35^{b}
GHZ	5,55^{fh}	33^{fi}	28,4^{cg}	6,37^{e}	2,33^{ac}	6,33^{ai}	1,13^{fk}	4,33^{f}	21,03^{df}	3,33^{ij}	0,64^{ac}	0,2^{cd}
HAL	5,21^{gh}	32,59^{fi}	26,69^{dg}	8,9^{ce}	3,12^{ac}	8,1^{af}	1,02^{hk}	8,51^{ac}	22,43^{ce}	7,5^{ad}	0,69^{ab}	0,19^{cd}
HAM	7,21^{eh}	36,4^{dg}	29,6^{ag}	7^{e}	3,6^{ac}	4,2^{hi}	0,9^{k}	5,37^{ef}	23,33^{be}	4,82^{fi}	0,64^{ac}	0,12^{dg}
HRR	10,16^{bd}	41,5^{ae}	36^{ae}	7,5^{ce}	4^{ac}	7,5^{ag}	1,13^{gk}	8^{ad}	23,75^{be}	7^{ae}	0,57^{bc}	0,11^{eg}
ITM	7,93^{dg}	34,62^{eh}	29,21^{cg}	10,43^{bd}	3,03^{ac}	9,03^{ab}	1,26^{eh}	9,47^{ab}	21,68^{de}	8,42^{a}	0,63^{ac}	0,16^{cf}
KSB	8,81^{cf}	36,7^{cg}	31^{ag}	11^{ad}	4,33^{ac}	9,33^{ab}	1,58^{cd}	9,67^{ab}	25,33^{ad}	8,33^{a}	0,69^{ab}	0,18^{ce}
LMS	6,25^{eh}	36,31^{dg}	30,37^{ag}	11,16^{ad}	3,03^{ac}	8,11^{af}	1,11^{gk}	8,62^{ac}	21,97^{ce}	7,86^{ac}	0,6^{bc}	0,18^{ce}
MDG	4,17^{h}	31,06^{fi}	26,51^{dg}	9,2^{be}	2,33^{bc}	6,92^{ai}	2,82^{a}	7,48^{be}	20,46^{df}	6,82^{af}	0,66^{ac}	0,68^{a}
SAF	10,34^{bd}	38,7^{bf}	34,33^{ae}	10,33^{bd}	2,33^{bc}	4,67^{fi}	1,82^{c}	6^{df}	28^{ab}	5^{ei}	0,72^{a}	0,18^{cd}
SBL	8,62^{df}	48,3^{a}	40,63^{a}	9,08^{ce}	3,08^{ac}	4,25^{gi}	1,26^{ei}	4,83^{f}	29,7^{a}	3,5^{hj}	0,61^{bc}	0,15^{cf}
TCH	4,77^{h}	26^{i}	20^{fg}	7,4^{de}	2,33^{bc}	7,83^{af}	0,95^{ik}	5,83^{df}	16^{f}	4,67^{fi}	0,62^{ac}	0,2^{cd}
THW	6,74^{eh}	33,18^{fi}	26,81^{dg}	10,26^{bd}	3,38^{ac}	8,86^{ac}	1^{hk}	8,89^{ab}	20,21^{df}	8,12^{ab}	0,61^{bc}	0,15^{cf}
TJR	8,93^{ce}	33,3^{ei}	29,67^{ag}	13^{ab}	1,67^{c}	6^{bi}	1,49^{ce}	8^{ad}	24,33^{bd}	6^{cg}	0,73^{a}	0,17^{ce}
TNS	6,6^{eh}	29,3^{gi}	26,67^{dg}	12^{ac}	1,67^{c}	5^{ei}	0,9^{jk}	4,67^{f}	20^{df}	3,33^{ij}	0,68^{ab}	0,14^{cg}
TNT	8,08^{dg}	26,54^{i}	19,89^{g}	14,46^{a}	3,5^{ac}	8,75^{ad}	0,99^{ik}	9,3^{ab}	16,87^{f}	8,3^{a}	0,64^{ac}	0,12^{dg}
ZMM	8,67^{cf}	39,7^{bf}	26,33^{dg}	8,67^{ce}	2,33^{bc}	6,33^{ai}	1,08^{gk}	4,67^{f}	22,67^{be}	3,83^{gj}	0,57^{bc}	0,12^{dg}

Values in the same column with different subscript letters represent significant differences between cultivars at $p < 0.05$ by Tukey test. Cv: Cultivars. R: reproductive parameters.

diameter (R19) was highly correlated to both seed width (R21) and thickness (R23). The highest positive correlation was observed between seed weight (R20) and seed/fruit weight ratio (R25).

3.3. component analysis

3.3.1. Vegetative characters

The principal component analysis results showed the phenotypic diversity existing among 26 studied date palm accessions based on the 27 vegetative traits. The first three principal components (PC1, PC2 and PC3) accounted for 25, 02%, 15, 96% and 12, 29%, respectively of the total cumulative variation. The most important variables, positive loadings, contributing to the first principal component were palm length (V2), rachis width (V5), rachis thickness (V6), spines number (V7), middle spines width (V8) and thickness (V9), single and 2-spines number (V11;V12), and middle leaflet length (V20). The graphic representation of variables according to the plan axis (1 and 2) showed that these variables were positively correlated and formed a homogenous group (Fig. 2a). The PC2 opposed two distinguished groups of variables negatively correlated. The first one, with high positive loadings was formed by spined part length (V4), 3-spines number (V13) and 3-leaflets number (V17). While the second one, with high negative loadings was obtained by 1-leaflets number (V15), middle leaflet width (V21), terminal leaflet length (V25) and width (V26). The PC3 was mainly influenced by the following characters, leaflets number (V14), 2-leaflets number (V16) and retrose leaflets

Table 5
Pearson's correlation matrix between the different Vegetative characters (Abbreviations as in Table 2).

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26
V2	0,28																									
V3	0,38	0,36																								
V4	−0,02	0,47	−0,06																							
V5	0,17	0,38	0,43	0,05																						
V6	0,42	0,50	0,58	0,03	0,63																					
V7	0,14	0,31	0,10	0,48	0,08	0,45																				
V8	0,28	0,56	0,24	0,31	0,21	0,63	0,67																			
V9	0,17	0,48	0,29	0,32	0,34	0,62	0,66	0,86																		
V10	0,13	0,33	−0,08	0,36	0,01	0,42	0,52	0,57	0,54																	
V11	0,05	0,26	0,10	0,17	0,36	0,17	0,41	0,27	0,30	−0,03																
V12	0,15	0,26	0,03	0,49	−0,01	0,41	0,91	0,60	0,64	0,60	0,09															
V13	0,16	0,33	0,14	0,31	−0,14	0,33	0,72	0,52	0,35	0,43	0,04	0,63														
V14	0,23	0,49	0,01	0,27	0,47	0,42	0,19	0,27	0,12	0,08	0,29	0,14	0,05													
V15	0,20	0,30	0,21	−0,02	0,61	0,36	0,19	0,25	0,48	−0,03	0,55	0,10	−0,13	0,29												
V16	0,36	0,44	0,13	0,02	0,42	0,15	−0,14	0,17	0,13	−0,17	0,30	−0,20	−0,27	0,60	0,45											
V17	−0,07	0,13	−0,34	0,02	−0,14	0,12	0,15	0,11	−0,19	0,38	−0,12	0,18	0,29	0,52	−0,38	−0,07										
V18	−0,03	−0,07	−0,03	0,38	0,01	0,18	0,10	−0,02	−0,14	0,06	−0,23	0,18	0,08	0,40	−0,39	−0,25	0,35									
V19	0,07	0,15	0,32	0,30	0,10	0,20	0,04	0,00	−0,13	−0,15	−0,18	0,02	0,28	0,26	−0,33	−0,24	0,15	0,65								
V20	0,25	0,67	0,59	0,23	0,37	0,53	0,46	0,51	0,51	0,02	0,47	0,26	0,36	0,25	0,40	0,20	−0,18	−0,08	0,24							
V21	0,30	0,15	0,24	−0,11	0,37	0,52	0,17	0,26	0,46	0,14	0,18	0,25	−0,06	0,12	0,55	0,14	−0,26	−0,07	−0,06	0,14						
V22	0,46	−0,04	−0,09	0,00	0,34	0,17	0,17	0,10	0,01	0,03	0,27	0,13	−0,06	0,60	0,34	0,51	0,15	0,19	−0,07	−0,07	0,08					
V23	−0,15	0,27	0,00	0,09	0,00	0,08	0,03	0,18	−0,10	−0,08	0,14	−0,15	0,22	0,42	−0,24	0,16	0,54	0,14	0,31	0,28	−0,47	−0,08				
V24	0,14	0,51	0,09	0,32	0,45	0,42	0,13	0,17	0,26	0,17	0,11	0,25	−0,07	0,68	0,40	0,39	0,19	0,34	0,16	0,18	0,54	0,23	−0,19			
V25	0,06	−0,07	0,40	−0,32	0,36	0,44	−0,11	0,09	0,30	−0,06	−0,21	−0,05	−0,14	−0,24	0,17	−0,09	−0,39	−0,01	−0,08	0,21	0,30	−0,22	−0,26	0,04		
V26	0,10	−0,26	0,12	−0,29	0,27	0,32	−0,03	0,00	0,25	0,12	−0,06	0,10	−0,21	−0,25	0,33	−0,10	−0,38	−0,11	−0,25	−0,19	0,80	−0,04	−0,63	0,22	0,55	
V27	0,21	0,27	0,39	−0,14	0,40	0,17	0,00	0,15	0,13	−0,34	0,43	−0,20	0,11	0,04	0,41	0,42	−0,34	−0,47	−0,11	0,35	0,16	0,06	0,22	−0,18	0,09	0,044

Correlation is significant at 0.01 probability level.

Table 6
Pearson's correlation matrix between the different Reproductive characters (Abbreviations as in Table 2).

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
R2	0,08																							
R3	0,27	0,55																						
R4	0,47	0,05	0,25																					
R5	−0,35	0,28	0,24	0,10																				
R6	0,42	0,21	0,14	0,10	−0,30																			
R7	0,48	0,17	0,03	0,34	0,08	0,73																		
R8	0,48	0,15	0,18	0,36	0,13	0,47	0,71																	
R9	0,38	0,06	0,19	0,18	−0,18	0,45	0,48	0,34																
R10	0,08	−0,01	0,33	0,00	−0,10	0,28	0,21	0,11	0,61															
R11	0,16	0,06	0,33	0,23	−0,11	0,37	0,32	0,20	0,69	0,90														
R12	0,51	0,19	0,36	0,43	−0,07	0,49	0,61	0,80	0,53	0,47	0,57													
R13	0,34	0,19	0,17	0,01	−0,28	0,84	0,62	0,31	0,67	0,53	0,59	0,49												
R14	0,28	0,14	−0,01	0,19	−0,13	0,52	0,42	0,49	−0,12	−0,27	−0,12	0,27	0,20											
R15	0,33	0,23	−0,03	0,19	−0,22	0,27	0,27	0,40	−0,07	−0,39	−0,22	0,27	0,00	0,72										
R16	0,34	0,16	0,02	0,06	−0,32	0,35	0,22	0,37	−0,08	−0,32	−0,24	0,26	−0,02	0,65	0,91									
R17	0,06	0,18	0,33	−0,03	0,02	0,22	0,06	0,11	0,19	0,49	0,42	0,23	0,27	0,26	−0,06	0,00								
R18	−0,07	0,21	−0,15	0,14	−0,13	0,19	0,10	0,09	−0,16	−0,28	−0,23	0,06	0,00	0,60	0,52	0,42	0,12							
R19	−0,25	0,41	0,13	0,19	0,31	0,10	0,08	0,01	0,12	0,02	0,04	−0,02	0,18	0,14	0,01	−0,15	0,27	0,54						
R20	0,67	0,33	0,31	0,57	−0,09	−0,03	0,15	0,19	0,03	−0,22	−0,11	0,25	−0,16	0,15	0,32	0,34	0,08	0,10	0,01					
R21	−0,11	0,38	0,12	0,07	0,05	0,24	0,11	0,14	0,12	0,11	0,06	0,08	0,23	0,27	0,09	0,05	0,56	0,55	0,83	0,13				
R22	0,33	0,13	−0,05	−0,13	−0,35	0,26	0,17	0,35	−0,01	−0,29	−0,24	0,22	−0,01	0,53	0,80	0,87	0,09	0,24	−0,26	0,28	0,03			
R23	−0,08	0,40	0,08	0,10	0,09	0,14	0,13	0,16	0,16	0,12	0,08	0,13	0,20	0,22	0,11	0,02	0,49	0,57	0,84	0,19	0,95	−0,03		
R24	−0,05	−0,23	−0,01	−0,49	−0,17	−0,06	−0,24	−0,18	0,10	0,24	0,03	−0,15	0,00	−0,40	−0,52	−0,25	0,23	−0,50	−0,39	−0,13	−0,10	0,10	−0,25	
R25	0,29	0,32	0,33	0,37	0,11	−0,36	−0,19	−0,16	−0,05	−0,12	−0,10	0,00	−0,29	−0,43	−0,15	−0,11	−0,09	−0,22	−0,02	0,77	0,01	−0,13	0,09	0,06

Correlation is significant at 0.01 probability level.

number (V23). These variables were interdependent on each other (Fig. 2a) and negatively correlated to middle spine length (V10).

The graphic representation of cultivars on the plan axes (1–2) and (1–3) is presented in Fig. 2a. The projection of the cultivars on the first plan axis showed a significant opposition between three cultivars namely DEGLET NOOR (DGN), GHARS (GHS), ITIMA (ITM) and a group with four cultivars respectively BOUHLAS (BHL), HALWA (HAL), SBAA LAROUSSA (SBL), FERAOUNIA (FER), MECH DEGLA (MDG) and TICHTAT (TCH) cultivars according to the following traits: palm length (V2), rachis width and thickness (V5, V6), spines number (V7), width (V8) and thickness (V9) of the middle spines, single and 2-spines number (V11;V12), and also the middle leaflet length (V20). The second axis opposed TIJAARANIT (TJR), SAFRAYA (SAF) and HAMRAYA (HAM) cultivars characterized by a long spined part length (V4) and relatively high number of 3-spines (V13) and 3-leaflets (V17) to DEGLET ZIAN (DGZ), TANTBOUCHT (TNT) and THAWRI (THW) cultivars which had an important 1-leaflets number (V15), leaflet width at the middle (V21) terminal leaflet length and width (V25, V26). The third axis illustrated a significant opposition of ARECHTI (ART) and AIN AL FAS (AFS) cultivars distinguished by leaflets number (V14), 2-leaflets number (V16) and retrose leaflets number (V23) to GHAZI (GHZ) and KSEBA (KSB) cultivars characterized by relatively high spine length at the middle (V10).

3.3.2. Reproductive characters

The results of PCA analysis showed that the first three axes, accounted for 56.466% of the total cumulative variation. This indicated a wide spectrum of morphological variation between the 26 Algerian cultivars based on 25 reproductive descriptors.

Reproductive characters having a strong loading on the first principal component were: spathe length (R1), spikelet part without fruit length at the bunch's bottom (R6), middle (R7) and top (R8), longest (R12) and shortest spikelet lengths (R13) and fruit weight (R14). According to their graphic representation on the plan axis (1 and 2) (Fig. 2b), these variables were positively correlated and belonged to a same group. The most important variables contributing to the PC2 were divided into two opposite groups negatively correlated. The first one, with positive loadings, was composed by spikelet part with fruit length at the bunch's bottom (R9), middle (R10) and top (R11). While the second, with negative loadings, was formed by fruit length (R15), fruit cavity length (R16), pulp thickness (R18) and seed length (R22). The variables calyx diameter (R19), seed width (R21) and seed thickness (R23) were inter-correlated (Fig. 2b) and contributed to the third principal component.

The graphic representation of cultivars on the plan axes (1–2) and (1–3) is presented in Fig. 2b. The first axis opposes DEGLET NOOR (DGN), ITIMA (ITM), DEGLA, BAIDHA (DGB) and HORRA (HRR) to BOUHLAS (BHL), DEGLET ZIAN (DGZ) and TINICINE (TNC) cultivars for following parameters: the length of spathe (R1), spikelet part without fruits at different levels of the bunch (R6, R7 and R8), longest spikelet (R12), and shortest spikelet (R13) and fruit weight (R14). The second principal component showed a significant opposition between TIJAARANIT (TJR) cultivar with the longest spikelet part with fruits at the bottom (R9), the middle (R10) and top (R11) of the bunch to ARECHTI (ART), AIN EL FAS (AFS), FERAOUNIA (FER) and SBAA LAROUSSA (SBL) cultivars, characterized by very long fruits (R15), fruits cavities (R16) and seeds (R22), and very thick pulps (R18). The third axis opposes LEMSAREF (LMS), KSEBA (KSB), TANTBOUCHT (TNT) and THAWRI (THW) cultivars with a big calyx diameter (R19), large (R21) and thick (R23) seeds, probably due to the spherical shape of the fruits in the case of TANTBOUCHT (TNT) to DEGLET ABDALLAH (DGA), DEGLET DEBBAB (DGD) and HAMRAYA (HAM) cultivars.

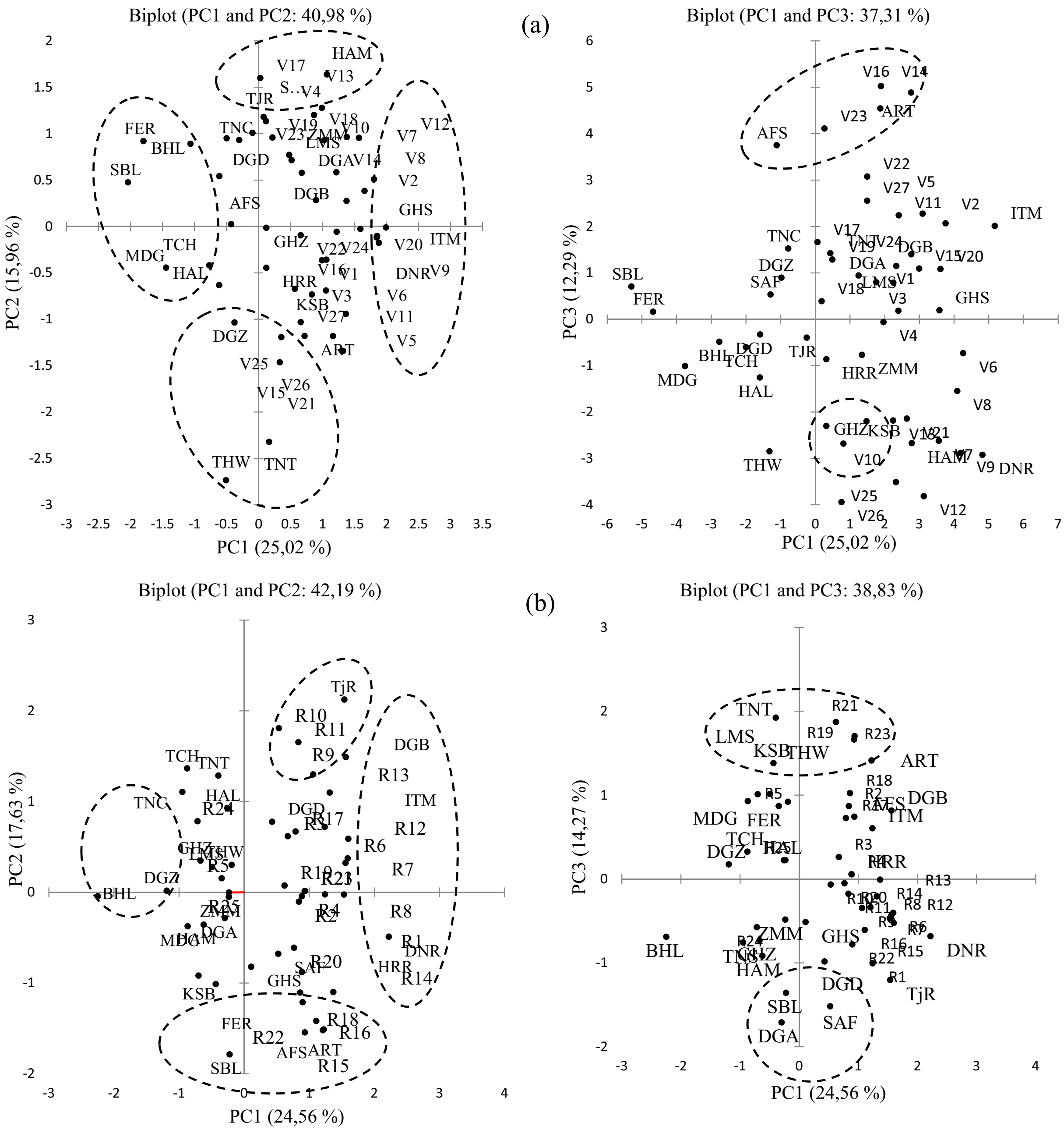

Fig. 2. Graphic representation of cultivars and the parameters (vegetative: a and reproductive: b) on planes 1–2 and 1–3 of principal component analysis (Abbreviations as in Tables 1 and 2).

3.4. Cluster analysis

3.4.1. Vegetative characters

Cluster analysis based on Euclidian distances and by using the Ward method between the 26 genotypes produced a dendrogram with three main phenotypically groups of cultivars (Fig. 3). Actually, the cultivars grouping and the closest ones revealed by this clustering were identical to those obtained by PCA.

The dissimilarity levels ranged from 0,064 to 1,148. The first cluster included ten cultivars and was divided in two sub clusters, where ZOMERET MIMOUN (ZMM) cultivar stands alone in the second subgroup. The main characteristics shared by these cultivars describing globally a high vigor resulting from a large trunk circumference (V1), well developed palms components (length; V2, rachis thickness; V6, pinnae number and grouping; V14, 3 and 4-pinnae grouping; V17 and V18, and spines dimensions and grouping (V8, V9 and V10, 2 and 3-spines grouping; V12 and V13). In addition, the lowest spacing index value was recorded in this group for two cultivars (GHAZI, GHZ and ZOMERET MIMOUN, ZMM) as well as the closest cultivars KSEBA (KSB) and GHAZI (GHZ) with the lowest dissimilarity level (d = 0.064). The second cluster regrouped twelve cultivars, characterized by a weak vegetative development expressed by a reduced trunk circumference (V1), small palms (length; V2, width; V3) and pinnae dimensions (leaf length at the middle; V20, terminal leaf length; V25). The cultivars BOUHLAS (BHL) and DEGLET DEBBAB (DGD) were the closest ones in the above-mentioned cluster (d = 0.067). The remaining accessions were grouped in the third cluster, and had a large palm (V3) with few number of spines (V7), which were short (V10) and less grouped (into 2-; V12 and 3-; V13) as well as pinnae grouping

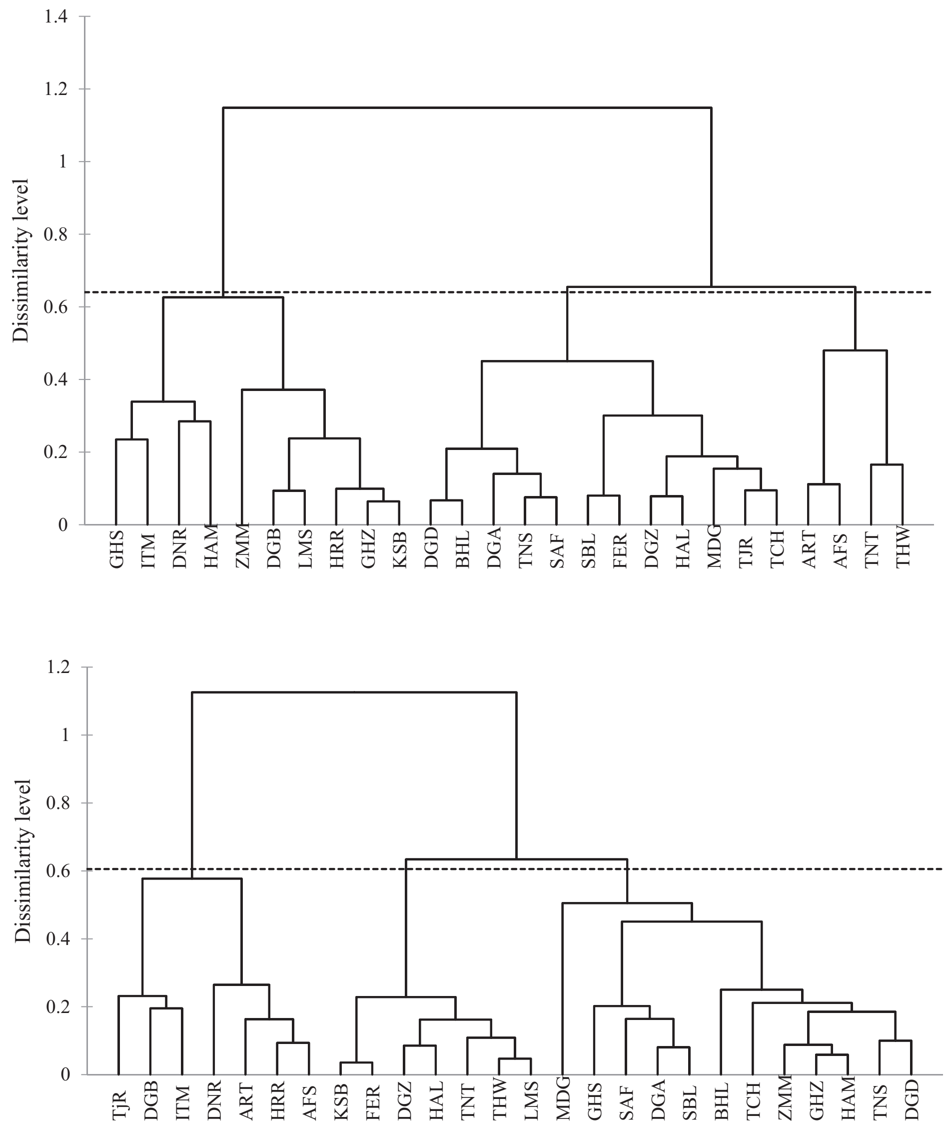

Fig. 3. Cluster analysis based on (a) vegetative and (b) reproductive characters.

into (4-; V17 and 5-; V18) so sparse leading to an important spacing index (V27).

3.4.2. Reproductive characters

Cluster analysis elaborated based on reproductive descriptors showed that the dissimilarity levels ranged from 0,036 to 1.256 and enabled the identification of three major phenotypic clusters (Fig. 3). It is important to point out that the variability was observed more within the classes (87, 71%), as for the variability (86.08%) found for the clustering based on the vegetative parameters. In fact, the first one was composed of seven cultivars characterized by a well-developed reproductive system owing the longest spathe (R1), big bunch containing a great number of spikelets (R5) with important lengths of both ramified part (R4) and spikelet's parts without fruits at different levels (R6, R7, R8). On the other hand, interesting fruit characteristics as weight (R14), length (R15) and pulp thickness (R18) were found leading to a reduced ratio of seed/fruit length (R24). A great variability was observed within the second cluster, which was divided, into three subclusters where the cultivar MECH DEGLA (MDG) represented, alone, a subcluster. Globally, the 12 cultivars included expressed some similar traits describing short parts of spikelets with fruits (R9, R10 and R11) and important ratios of seed/fruit length (R24) and weight (R25). The main traits shared by the cultivars of the third cluster, which was the most homogenous, were the short ramified bunch's parts (R6, R7, R11 and R12) containing a few number of spikelets per bunch (R5) and relatively small date based on some fruits and seeds dimensions (R15, R16 and R22). Within this group the lowest dissimilarity levels were recorded between both FEROUNIA (FER) and KSEBA (KSB) with d = 0,036 and LEMSAREF (LMS) and THAWRI (TWR) with d = 0.047.

4. Discussion

A high number of phenotypic descriptors, more than 50 quantitative markers, were used and allowed us to both appreciate the status of diversity and differentiate date palm cultivars. The study of the morphological diversity of the 26 date palm cultivars a rich local diversity in the most important date production region in Algeria.

In this study an extensive phenotypic variation for both vegetative and reproductive parts were found among the evaluated cultivars. This important phenotypic diversity observed among the studied cultivars could result from a high genotypic heterogeneity but also from environmental conditions. Previous similar studies were conducted using qualitative and quantitative morphological markers (Mason, 1915; Elhoumaizi et al., 2002; Rizk and El Sharabasy, 2007; Ould Mohamed Salem et al., 2008; Ould Mohamed Ahmed et al., 2011; Simozrag et al., 2016).

Although the fact that our results revealed that most of the measured parameters were not correlated or have very weak correlations, there were more observed significant correlation between the reproductive parameters then for the vegetative ones. The obtained no correlation relationships or the very weak ones were expected. For example, for the vegetative characters it is supposed that the trunk circumference at 1 m from the soil is not related to 1-spines number (0.05), neither to 5- leaflets number (0.07), nor to the spined part length (−0.02) (Table 5), which was confirmed by the correlation relationships between these parameters.

Likewise, for the strong correlations, most of them were expected, between some characters expressing the vigor of the tree. Indeed, the leaf length that was defined by a long spined part and needed a strong rachis, which the width and thickness were highly correlated, to support the big number of leaflets carried. The palm length was associated to the leaflet length. The correlations showed that the leaflets, spines behaved similarly. Therefore, when the number of both leaflets and spines increased, their grouping per two or three or more increased too. Also, as expected, the parameters related to the spine part expressed the same tendency. Thus, the spine number and density were highly correlated to spine thickness and width. In addition, the presence of single leaflets and single spines were closely related. On the other hand, the length of spikelet parts at different levels of the bunch was proportional to their positions on it. Thereby, the longest spikelet was located at the top while the shortest one at the bottom. The same tendency was observed for fruit characteristics. In fact, heavy fruits had an important fruit dimensions, length and width of both fruit and its cavity and their pulp were very thick as in the case of dates of ARECHTI (ART) and AIN EL FAS (AFS). According to our results they were mostly, found on spikelet having short part with fruits.

Principal Component analysis results showed that among the 27 vegetative traits used in this study, ten allowed a reliable differentiation among cultivars. These parameters concerned palm length (V2), rachis thickness (V6), spine number (V7), middle spine width (V 8) and thickness (V9), middle leaf length (V20) and terminal leaf width (V26), leaflets number (V14) and grouping (into 2; V16 and 3-leaflets; V17). As regards the reproductive parameters, among the 25 descriptors used twelve traits, describing the fruit and bunch, were the most discriminants. These characters are: lengths of both spikelet parts without and with fruits at different bunch levels: base, middle and top (R6, R7, R8, R10 and R11), the longest spikelet (R12), fruit weight and length (R14, R15), cavity length (R16), calyx diameter (R19), seed width (R21) and thickness (R23). Similar findings have been reported in genetic diversity studies of Moroccan and Mauritanian germplasm collection (Elhoumaizi et al., 2002; Ould Mohamed Salem et al., 2008; Ould Mohamed Ahmed et al., 2011).

It must be emphasized, however, other traits such as: grouping spines (2; V12 and 3-spines; V13) and leaflets (into 2; V16, 3-leaflets; V17), longest and shortest spikelet lengths (R12, R13), spikelet parts with and without fruits lengths at the bunch bottom, middle and top (R6, R7, R8, R9, R10 and R11), were found in this study as discriminate descriptors too and can be used to characterize cultivars more precisely.

In the current study, the dendrogram generated by hierarchical cluster analysis based on reproductive parameters had relatively higher distances (high dissimilarity level interval) indicating a significant genetic variability within the cultivars of the same clusters. In a point of fact, the farmers used most commonly the fruits as a way to distinguish between cultivars than palms. Furthermore, many characters used by the farmers to identify known cultivars were found in this study as the most discriminants.

The results showed that some cultivars were assigned to the same cluster based either on vegetative or reproductive characters, which implies the closeness of their phenotypes. Indeed, HALWA (HAL) and DEGLET ZIANE (DGZ) cultivars were the most similar among all the studied ones and had the lowest dissimilarity levels on the basis of their vegetative (d = 0.087) and reproductive (d = 0.085) characters. As well, other cultivars DEGLA BAIDHA (DGB), DEGLET NOOR (DGN), ITIMA (ITM) and HORRA (HRR), were grouped in the same clusters based either on vegetative or reproductive characters. The above results, pointed out the strong relationship between the vegetative and reproductive parts. One of illustrative example to mention here is that the long and dense palms with a thick rachis are needed to develop and carry a big bunch and very interesting date's characteristics. Thus, such descriptors could be used when selecting genotypes to be included in the breeding programs. Thereby, the cultivars having the above mentioned characters may be classified as high yielding genotypes and, thus, could be used in breeding programs to improve cultivars with desirable traits.

Additionally, it must be highlighted that some cultivars were clustered independently of their date's type. For example, DEGLA BAIDHA (DGB) and ITIMA (ITM) cultivars, shared many characteristics related to their palms and fruits despite their fruits color and consistence differences. Similarly, despite the fact that ITIMA (ITM) cultivar has a soft date with brown color, while DEGLA BAIDHA (DGB) cultivar has a dry date, with beige color, they were clustered in group 1. However, many cultivars having the same fruits consistency were gathered by the two elaborated dendrograms.

The projection of cultivars in PCA plots as well as hierarchical cluster analysis permitted the characterization and clustering of several cultivars sharing same characteristics. Moreover, the homogenous groups obtained as a result of the PCA projection and the dendrogram cluster, were, in the most cases, similar. Indeed, the results showed that the cultivars represented on a PC axis were, also, included in the same cluster. Nevertheless, this tendency was observed much more when using vegetative descriptors (e.g. FERAOUNIA; FER and SBAA LAROUSSA; SBL), than the reproductive ones (e.g. ITIMA; ITM and DEGLA BAIDHA; DGB) and where the dissimilarity level was the highest.

The traditional knowledge of the farmers is acquired through many generations. Many characters used by the farmers to identify known cultivars were found in this study as the most discriminant. In fact, regarding to the discriminant vegetative and reproductive characters, there was conformity with farmers' characterization. Likewise, HAMRAYA (HAM) is well known by the farmers of the Ziban region, for being the most resistant cultivar to dryness. The results of the phenotypic characterization showed that spined part (the longest one) is well developed for this cultivar and the palm width recorded was one of the lowest in order to reduce transpiration and conserve water. Another interesting example to highlight is that GHARS (GHS) and ITIMA (ITM) cultivars palms, well known by their falling aspect, were revealed, by this study, among the longest ones. Likewise, the cultivar MECH DEGLA (MDG) short palms and the few number of spines, almost single, distinguished it from the others cultivars. Therefore, we could assume that some vegetative descriptors might be used, out of fruiting period, to distinguish between cultivars, which is rather tricky operation. Of course, reproductive characters, in turn, mainly those related to the spathe and fruit are and should be used because of the easiness to describe them. Actually, DEGLET NOOR (DGN) cultivar, which recorded the longest spathe (101.33 cm), is recognized by the farmers because of its elongated spathe appearance; and this characteristic is also used to identify the male of this cultivar. Actually, in groves, the fruit is the most used organ to identify and to name cultivars owing to the high morphological variation perceptible by the farmers. Among these fruit descriptors the size of dates is one of them According to our results, ''SBAA LAROUSSA'' (SBL) cultivar had, the longest fruit, where ''SBAA'' (in Arabic) means'' finger''. This cultivar is grouped with AIN EL FAS, ARECHTI (ART) and FERAOUNIA (FER) cultivars whose fruits were well known by the farmers for being among the biggest dates in the Ziban region. However, qualitative parameters, like pinnae and date color, could also be used to distinguish between cultivars, i.g. The spines of DEGLET NOOR (DGN) cultivar had the same orientation, which will prevent the climber during the date's harvest.

5. Conclusion

The results of this study confirmed that many traits related either to vegetative and reproductive organs could be a useful tool to assess phenotypic diversity and constitute a complementary approach for other characterization methods. Nonetheless, molecular markers should be used for more accurate identification of date palm cultivars and to highlight correlations between cultivars and agronomic traits of interest. Also, this study brought out the richness of Algerian date palm cultivars. However, this biodiversity is seriously threatened by diverse factors mainly the commercial one. Furthermore, during our prospections almost of the other cultivars' accessions were old and/or neglected so enable to produce offshoots and for many cultivars there are only few trees (that still available in the groves. The setup of *in situ* collections is highly recommended to preserve this biodiversity, as well as a well-planned strategy to promote other cultivars, in the region, for commercialization than DEGLET NOOR (DGN).

Conflict of interest

None.

Acknowledgements

This research was supported by the Algerian Ministry of Higher Education and Scientific Research. Special thanks go to master students who helped in collecting field data.

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