Article

Fl. Medit. 33: 67-81
https://doi.org/10.7320/FlMedit33.067
Version of Record published online on 1 June 2023

H. Nekhla, L. El Ghadraoui, L. lahrizi, L. El Hanafi, A. Zahri, A. Harrach & F.-E. Saouab

Fruit phenotypic diversity in *Chamaerops humilis* (*Arecaceae*), in semi-arid and sub-humid regions of Morocco

Abstract

Nekhla, H., El Ghadraoui, L., lahrizi, L., El Hanafi, L., Zahri, A., Harrach, A. & Saouab, F.-E.: Fruit phenotypic diversity in *Chamaerops humilis* (*Arecaceae*), in semi-arid and sub-humid regions of Morocco. — Fl. Medit. 33: 67-81. 2023. — ISSN: 1120-4052 printed, 2240-4538 online.

The aim of this work is to determine the phenotypic variability of fruits of *Chamaerops humilis* (*Arecaceae*) according to the climatic conditions. Three hundred accessions were sampled from three climatically different regions of Northern Morocco: Sefrou, Fez, and El Hajeb. They were examined, in order to evaluate the morphological variability of *C. humilis* fruits and identify its morphotypes, in order to ensure a better valuation of the species and to maintain its sustainable development. Nine characters have been examined, including five quantitative characters and four qualitative. Comparison of means tests and principal component analysis were used to assess the variation in the morphological characters of dwarf palm fruits based on the regions. Hierarchical clustering was performed to identify *C. humilis* morphotypes. There was variability in dwarf palm fruit morphological characters in the three regions studied. The results revealed a great variation between individuals for the majority of the studied populations. The data collected from the field showed that the population originating from El hajeb presents fruits of large size, weight and shape that varied between oval and round-oblong, with an orange-brown color at maturity. On the other hand, the populations originating from the regions of Fez and Sefrou are characterized by less developed fruits, with smaller size, and a color generally red-brown and sometimes brown concerning the mature fruits.

Key words: *Chamaerops*, morphological variability, climatic conditions, North Africa.

Introduction

Chamaerops humilis L., also known as dwarf palm, is a shrub that normally in nature reach more than 1 m in height and a trunk less than 1m (Damerdji 2011). It grows naturally in arid areas with a hot and dry climate. It is very tolerant to drought and also very resistant to cold. It can survive at low temperatures up to -12°C (Hasnaoui 2008). In addition, it is a thermophilic species that supports high temperatures above 30°C. *C. humilis* is considered as an index of degradation of forest formations, as it contributes to the structure of many ecosystems, because of its adaptation to environmental and anthropic constraints. This species is most often found on calcareous soils, although it can develop on all kinds of soils, it is often found in a sunny and dry location where the substrate is sandy or rocky, but never covering dune areas (Merlo & al. 1993).

The fruits of *Chamaerops humilis* are oblong drupes with brown epicarp with fine grooves. Physiological and morphological maturity occurs in September or October (Uhl & Dransfield 1988). It is the most beneficial part of this plant, as it contains significant quantities of chemical compounds (saponins, coumarins, polyphenols, tannins, flavonoids, etc.), essential nutrients and functional properties that can be exploited for various useful applications (Giovino & al. 2015).

C. humilis and its fruits, occupy an important place in the daily life of the populations, whose use is anchored in the common memory of the populations, this plant is a good example since it contributes to the development of several fields has to say: Fruits and leaves of *C. humilis* have internal use against diabetic disease, digestive disorders and against kidney stones (El hilaly & al. 2003; Benali & al. 2013; Medjati 2014) Similarly, *C. humilis* fruits have shown important antioxidant and antimicrobial activity (Giovino & al. 2015).

Ecologically, the fruits of this plant are a food source for some animal species. At the food level, the fruits are consumed because of their nutritional and sensory assets (Merlo & al. 1993).

Climate is one of the most important environmental factors affecting plant physiology and ecology. Climate change and altered biogeochemical cycles can alter the environmental determinism of plant species, first affecting their physiology, then their phenology and finally their distribution (Parmesan 2006). The primary climate variables that affect plant life are light, temperature, and precipitation (Jamieson & al. 2012). The effect of each of these variables influences the productivity of plant species. This was shown in a study conducted by (Akabassi & al. 2021) on *Picralima Nitida* (Stapf) T.Durand & H.Durand which showed that climatic zones have a significant influence on the morphological characteristics and fruit production of the species studied. In addition to climate, soil type also has an effect on morphological variation in forest species (Chadare & al. 2008).

In spite of the assets that *C. humilis* represents, it remains among the most neglected species at different ecological, nutritional, therapeutic and other levels. Moreover, this plant heritage is exposed to an increasing anthropic pressure and subjected to severe ecological effects (Hammi & al. 2007). This leads to the regression of its area of distribution. This repetitive pillage constitutes a veritable menace to the preservation and renewal of this biological resource, as well as to the ecological equilibrium of the mediums. Giovino & al. (2023) state that Morocco is very important for *C. humilis* biogeography because from this area the species showed two probable patterns of independent spread and further differentiation. The southern populations from Morocco are isolated from the resting ones and in particular high-altitude populations are well distinct from the morphological and genetic points of view (Giovino & al. 2021). It is, therefore, necessary to explore this fragile resource which is in advanced degradation, to maintain its sustainable development. It is within the framework of this perspective, that we have conducted the present work, which consists in determining the morphological variability of the fruiting characters *of C. humilis* according to the climatic conditions of the regions. And to identify the fruit morphotypes that are important to maintain the sustainable development of this species in Morocco.

Material and Methods

Study Area

The present work was carried out in three semi-arid and sub-humid regions of North Morocco: Sefrou, Fez and El Hjeb (Fig. 1). These areas are characterized by precipitation ranging from 438 to 612 mm, average annual temperatures ranging from 27.5 to 35°C and a diversified soil nature (Nekhla & al. 2021). Each area characteristics are summarised in Table 1.

Sampling

Sampling was conducted between August and October 2018 when the *Chamaerops humilis* fruits were in the maturing phase. Purposive sampling was used to select the plants from which we collected fruit in each region. To decrease the chance of sampling close relatives, sampled palms were separated by at least 200 meters (Okello & al. 2018). From each sampled plant, 10 fruits were randomly collected. Fruits collected from each plant were pooled and stored in a single bag (Okello & al. 2018). For morphology some characters used were based on a list of descriptors available for the date palm species (Rizk & Sharabasy 2007). Fruits collected were prepared by cleaning them and drying them in the open air (Okello & al. 2018). The weight of the fruits was measured using an analytical balance

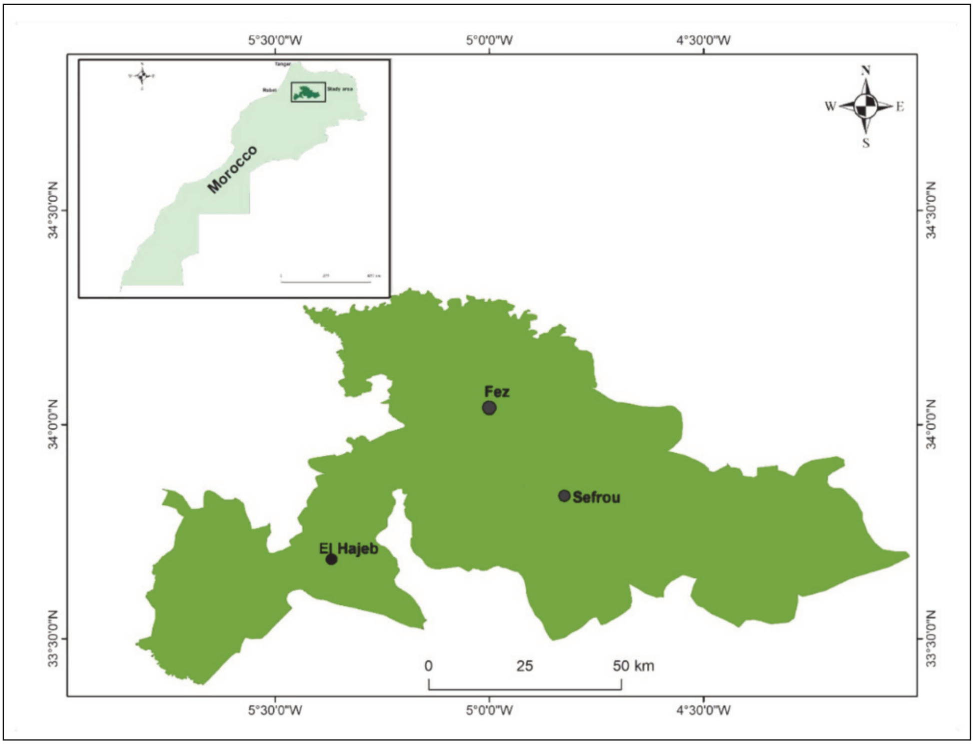

Fig. 1. Location of sampling stations.

Table 1. Attributes of the study sites of *Chamaerops humilis* fruit samples collection.

Region	Sefrou	Fez	El Hajeb
Coordinates	33°49′54″ N 4°49′40″O	34°02′13″N 4°59′59″ O	33°41′45″ N 5°22′00″ O
Rainfall (mm)	468	438	612
Altitude (m)	850	400	1050
m C°	2.6	4	2
Climate	Semi-arid to temperate winter	Semi-arid to temperate winter	Sub-humid to cool winter
Soil type	Clay-Silty	Clay –Silty Sandy	Bedrock

m: average of the minimums of the coldest month; N: North; O: West.

(Sartorius Entris 64-1S). A digital caliper (Carrera Precision Instrument, reading at 0.01 mm) was used to measure the length, width, and thickness of the fruits (Salako & al. 2019). In this study the morphological parameters employed are those used by Rizk & Sharabasy (2007). A total of 10 fruit characters were used; five quantitative and five qualitative.

Quantitative characters:
Length (L-Fr);
Width (Wi-Fr);
Thickness (T-Fr);
Weight (We-Fr);
Caliber (C-Fr).

Qualitative characters:
Shape (round oblong, ovate);
Apex (depressed, acute);
Base (truncate, acute);
Unripe colour (green, orange);
Mature colour (reddish brown, brun brown, orange-brown, orange)

Photographs of the plants contain the fruit, and of the fruits picked were taken to document their morphology and any difference was noted.

Data Analysis

For each quantitative character, we determined mean, standard deviation, coefficient of variation, minimum and maximum were determined using SPSS version 19 software. The analysis of variance (ANOVA) was performed for each character to determine the difference in the mean between the three regions. The post-hoc test (Tukey test) was used to precisely and specifically determine the significative difference between the groups for the different phenotypic characters. The correlation between different characters studied was estimated by Pearson Correlation Coefficient to assess the morphological variability of the dwarf palm fruit according to geographical regions

The collected data were subjected to principal component analysis (PCA) to determine the nature and degree of diversity among the individuals studied, and hierarchical ascending classification (HCA) to define the resemblance measures between the individuals, using R-STUDIO version 1.3.1093 software.

Results

Descriptive statistical analysis

The examination of the results indicates that there was high variability for *Chamaerops humilis* fruits (%) in the population of Fez, also there was low variability in the fruit caliber (%) in the population of El Hajeb.

As shown in Table 2, we notice that most of the quantitative characters differ significantly from one station to another bringing out important information. The El Hajeb population owns fruits of large size: length (mm), width (mm), thickness (16. 75± 1.52 mm), weight (g), and caliber (mm). However, the populations of Fez and Sefrou have fruits of approximately equal sizes: length to mm, width to mm, weight to , caliber to mm, respectively. In contrast, the thickness of the fruit varies from one population to another. It is to mm respectively for the station of Sefrou and Fez.

Correlations between characters

The Correlations for quantitative characters are presented in table 3. The majority of these correlations are highly significant ($r > 0.6$). The highest correlations are those associating morphological characters with climatic conditions. All recorded correlations are positive. A strong positive correlation was recorded between thickness, height and weight ($r = 0.7$) ($p \leq 0.001$), ($r = 0.7$) ($p \leq 0.001$). Similarly, length and width had a strong correlation ($r = 0.7$) ($p \leq 0.001$).

Qualitative characters

The qualitative characters were able to effectively discriminate phenotypically the studied populations. Fruit shape and mature fruit color showed important variability, whereas less diversity was observed in terms of fruit apex and base shape. The sampled *Chamaerops humilis* fruits had a shiny skin that was fused with the flesh. The mesocarp was orange in color and fibrous in texture (Fig. 2f). Fruits sampled at El Hajeb were diversely round-oblong and ovoid in shape with truncated bases and depressed apices (Fig. 2d). Fruits from Sefrou and Fez presented the most diverse characters with different shapes, bases and apices (Fig. 2 a, b). The colour of unripe fruits was green, and the maturing fruits carried the orange color (Fig. 2 c, e). The color of ripe fruits is different across the three sample sites. Almost all fruits sampled at El Hajeb were orange-brown at maturity

Table 2. Statistical indexes of measured quantitative fruit characters of *Chamaerops humilis* in the populations of Sefrou, Fez, and El Hajeb.

Character \ Population		Sefrou	Fez	El Hajeb
Lengh (mm)	*Mean*	19.89 *** ± 2.12	19.18 *** ± 2.11	21.63 *** ± 1.71
	Min – Max	15.5 − 23.55	12.91 − 23.06	18,01 − 25,37
	CV%	**10.667**	**11.021**	**7.896**
Width (mm)	*Mean*	15.61 *** ± 1.82	15.67 *** ± 1.71	18.34 *** ± 1.49
	Min – Max	12.02 − 19.92	11.61 − 18.95	14.24 − 22.36
	CV%	**11.633**	**10.906**	**8.114**
Thickness (mm)	*Mean*	11.00 *** ± 1.72	13.07 *** ± 1.63	16.75 *** ± 1.52
	Min – Max	9.89 18.45	9.4 17.04	13.81 21.36
	CV%	**12.272**	**12.468**	**9.052**
Weight (g)	*Mean*	2.65 *** ± 0.67	2.23 *** ± 0.71	3.90 *** ± 0.71
	Min – Max	1.09 4.1	1.03 3.85	2.23 5.75
	CV%	**25.278**	**31.829**	**18.223**
Caliber (mm)	*Mean*	17.75 *** ± 1.77	17.42 *** ± 1.83	20.00 *** ± 1.34
	Min – Max	14.19 21.40	12.26 20.91	17.46 ± 23.47
	CV%	**9.978**	**10.479**	**6.687**

(86%) as shown in Table 4. While the fruits sampled in Sefrou were either brown-reddish (67%), brown (33%). As well as the fruits sampled in Fez were brown (52%) and brown-reddish (48%).

Morphological diversity

The results in Table 5 show that the first three components explained nearly 86.67 % of the total variability; they were used to analyse the morphological variability of the accessions.

The correlogram of Fig. 3 shows the correlations between the principal components of the

Table 3. Pearson correlations between quantitative characters.

	Lengh	Width	Thickness	Weight	Caliber	Rainfall	Altitude
Lengh	1						
Width	0.719 ***	1					
Thickness	0.507 **	0.618 ***	1				
Weight	0.453 *	0.594 **	0.724 ***	1			
Caliber	0.577 **	0.664 ***	0.735 ***	0.676 ***	1		
Rainfall	0.452 *	0.589 **	0.702 ***	0.717 ***	0.575 **	1	
Altitude	0.395 *	0.423 *	0.614 ***	0.623 ***	0.458 *	0.837 ***	1

$*** \; p < 0.001; ** \; p < 0.01; * \; p \leq 0.05$

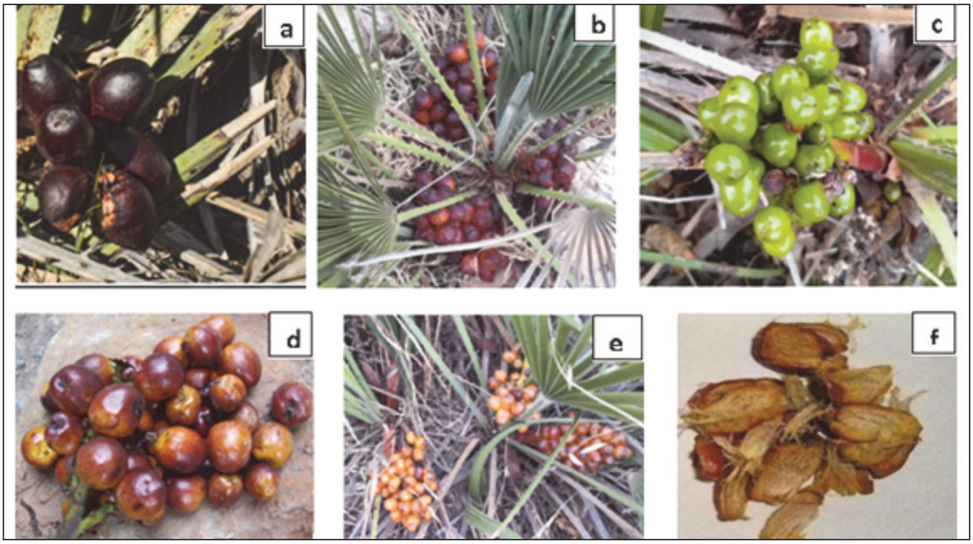

Fig. 2. Different aspects of *Chamaerops humilis* fruits in different regions: (a) Mature fruits in Fèz, (b) Mature fruits in Sefrou, (c) Immature fruits green in colour, (d) Mature fruits in El Hajeb, (e) fruits at the beginning of maturation, (f) Orange and hairy mesocarp.

Table 4. Fruit qualitative characters in the different populations.

Character	Category	Sefrou %	Fes %	El Hajeb %
Fruit shape	Ovate	69	83	46
	round-oblong	31	17	54
Fruit apex	Depressed	66	63	100
	Acute	34	37	–
Fruit base	Truncate	85	79	100
	Acute	15	21	–
Fruit colour-unripe	Green	100	100	100
Fruit colour-mature	Brown-reddish	67	48	–
	Brown	33	52	–
	Orange-brown	–	–	86
	Orange	–	–	14

PCA and the initial variables, we can see that the good correlation related to intensive colour and size of the circle. The majority of correlations are highly significant. The component 1 is well correlated with morphological and climatological parameters, however the second and third components are least correlated with some morphological. The component 1 explained 65.88 % of the variability, which was positively correlated with (L-Fr), (Wi-Fr), (T-Fr), (We-Fr) and (C-Fr). It is also defined on the positive side by altitude and precipita-

Table 5. Value of variations accumulated for Axis 1, Axis 2 and Axis 3 and Axis 4 resulting from the analysis.

	Axe 1	Axe2	Axe 3	Axe 4
Eigenvalues	4.61	0.92	0.53	0.30
Total variance (%)	65.88	13.16	7.63	4.34
Cumulative total variance (%)	65.88	79.04	86.67	91.02

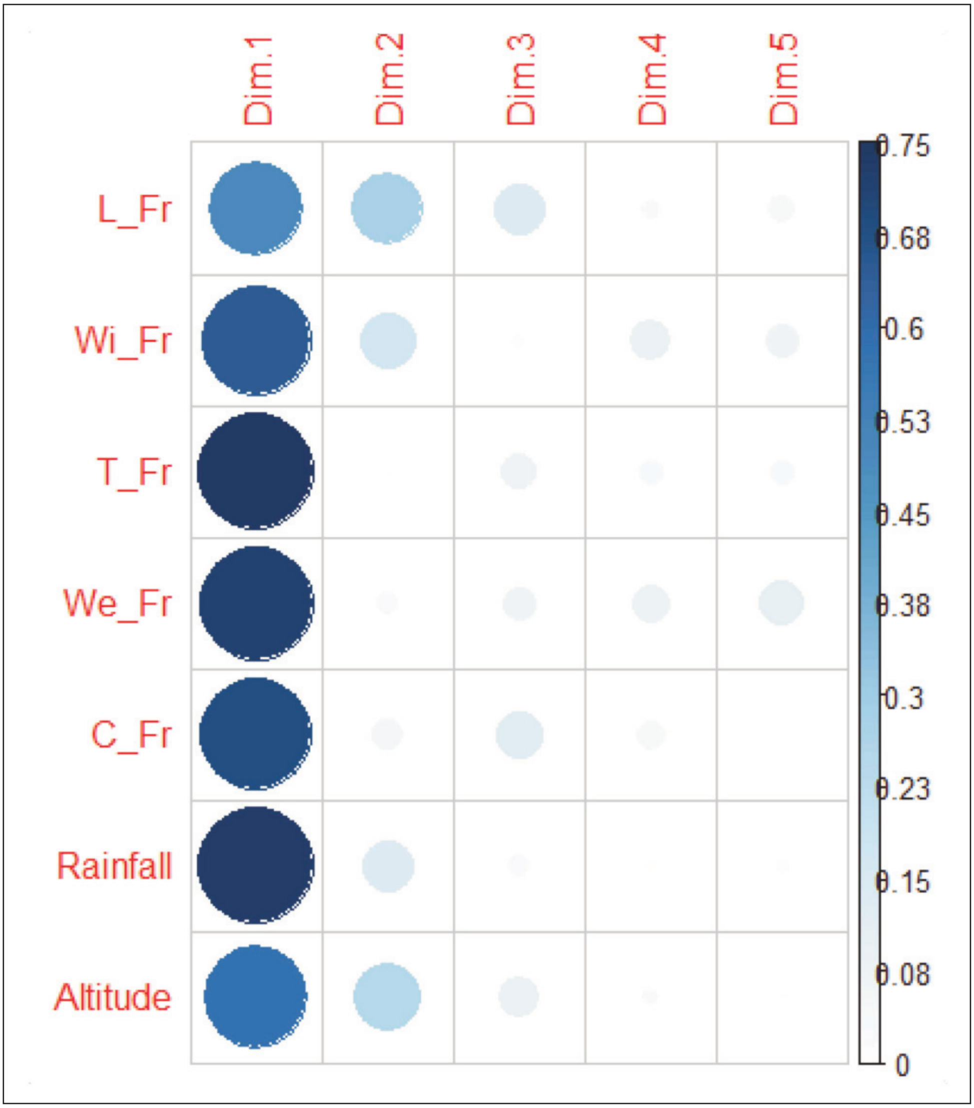

Fig. 3. Correlation between variables and principal components of the PCA.
L_Fr: Length of fruit, **Wi_Fr**: width of fruit, **T_Fr**: Thickness of fruit, **We_Fr**: weight of fruit, **C_fr**: Caliber of fruit.

tion (Fig 3 and 4). These results explain the separation and resemblance of the individuals.

Projection of individuals and variables on axis 1, 2 according to "climate".

Figure 5 shows the distribution of individuals according to climate. The PCA allowed us to represent three population groups that are clearly discriminated. The

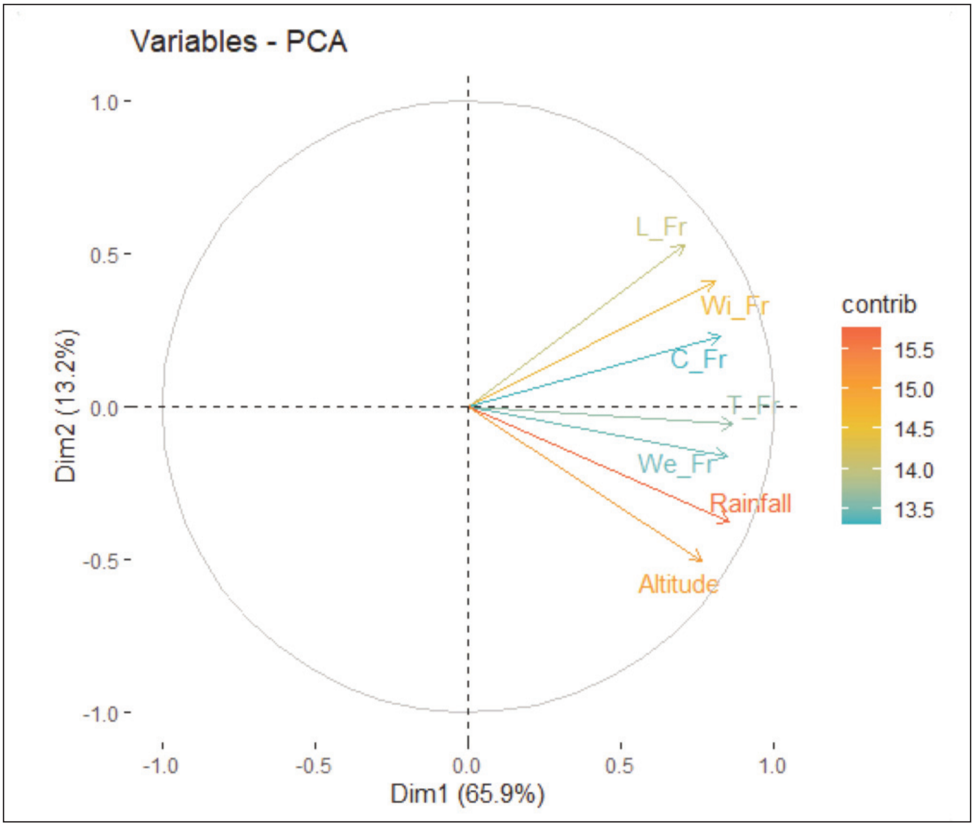

Fig. 4. Contribution of the variables to principal axes (Dim1, Dim2).
L_Fr: Length of fruit, **Wi_Fr**: width of fruit, **T_Fr**: Thickness of fruit, **We_Fr**: weight of fruit, **C_Fr**: Calibe of fruit.

first category is identified by the population of Fez. The second group belongs to the population of Sefrou, the two stations Fez and Sefrou are characterized by a semi-arid climate and the third group is distinguished by the population of El Hajeb which is characterized by a sub-humid climate.

The graphical representation (Fig. 6) showed that the morphological characters and climatic parameters that are correlated with axis 2 correspond to the fruits of El Hajeb. This shows that the population of El Hajeb is characterized by climatological conditions compatible for the development of morphological characters of the fruits of the plant in comparison with the populations of Sefrou and Fez. These results may strengthen the hypothesis of an effect of geographical sites on the morphological characterization of the species and also show that the bioclimatic stage seems to play a preponderant (decisive) role in the discrimination of the provenances studied. All this will give us the impression that the structuring of natural populations of *Chamaerops humilis* in Morocco reflects the existence of phenotypic structures adapted to the type of climate.

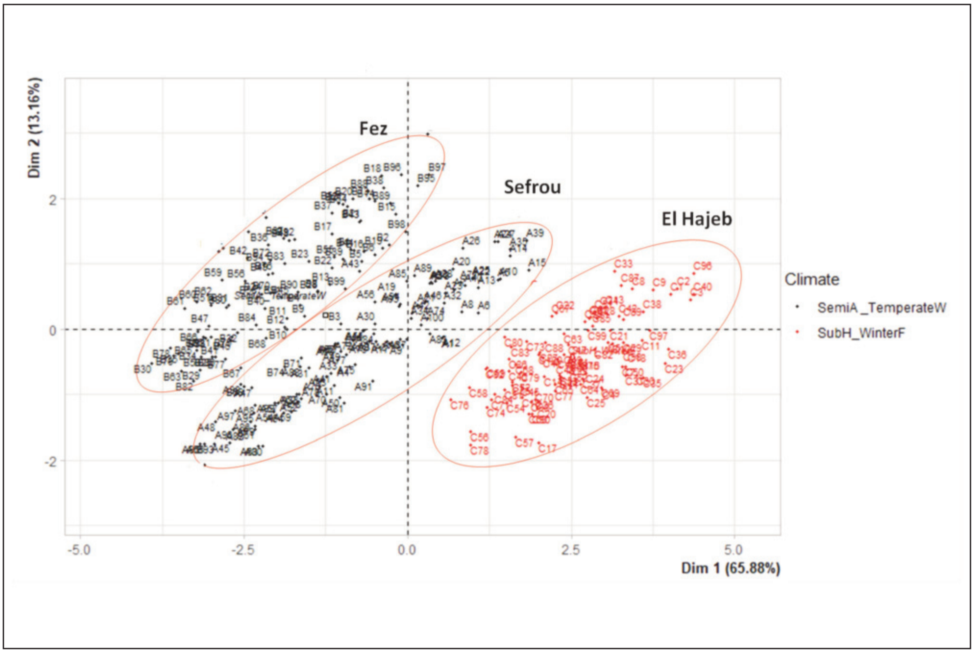

Fig. 5. Dispersion of individuals according to the climate factors.

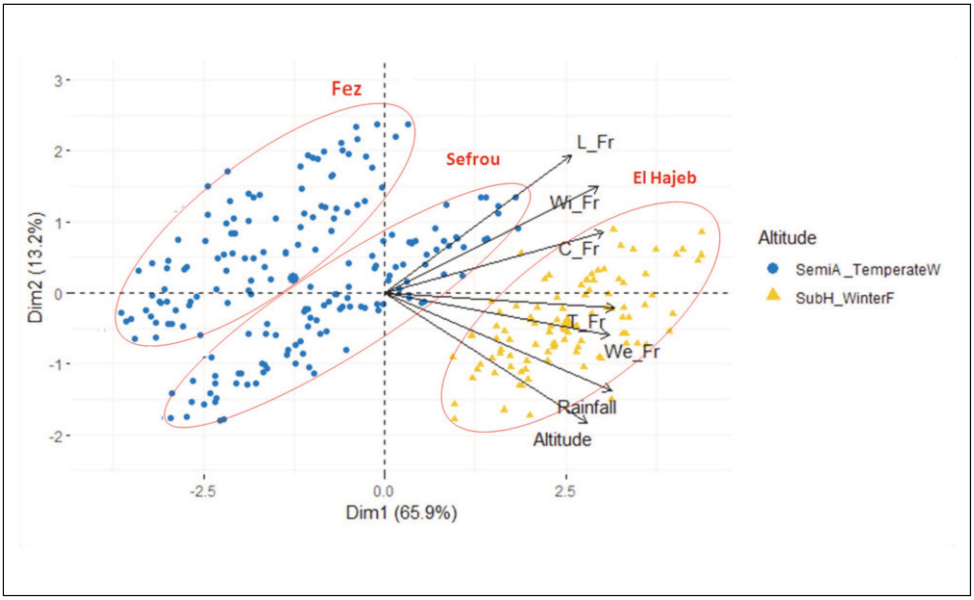

Fig. 6. Biplot of the populations and parameters studied in the axes (1, 2).
L_Fr: Length of fruit, **Wi_Fr**: width of fruit, **T_Fr**: Thickness of fruit, **We_Fr**: weight of fruit, **C_fr**: Caliber of fruit.

Hierarchical classification

The sampled individuals were classified into three morphotypes using hierarchical clustering (Fig. 7). Morphotype C corresponds to the El Hajeb population, which is characterized by individuals with large fruits (Length, Width, Thickness, Weight, and Caliber). Morphotypes A and B correspond to the population of Sefrou and Fez, these morphotypes are characterized by fruits of smaller size. The approximation of morphotypes A and B is explained by geographical proximity. In view of these results, the studied populations present an important heterogeneity between individuals and their morphological parameters.

From the dendrogram analysis, samples of each region appear to have no overlap with samples from other regions. But this cannot be taken into consideration to determine the clusters since advanced markers would be needed to genotype (Haider & al. 2015).

Discussion

A great diversity was observed at the level of quantitative characters in the sample of the individual study of the fruit according to different geographical origins. A great variability was also observed in the qualitative characters of *Chamaerops humilis* fruit. This result is in agreement with those obtained in previous studies showing that the geographical of the plant material was sufficient to obtain a reasonable structuring in the groups (Barnes 1977; Julier & al. 1995). The statistical analysis revealed three populations which are morphologically distinct from each other, with Sefrou and Fez having the most diverse

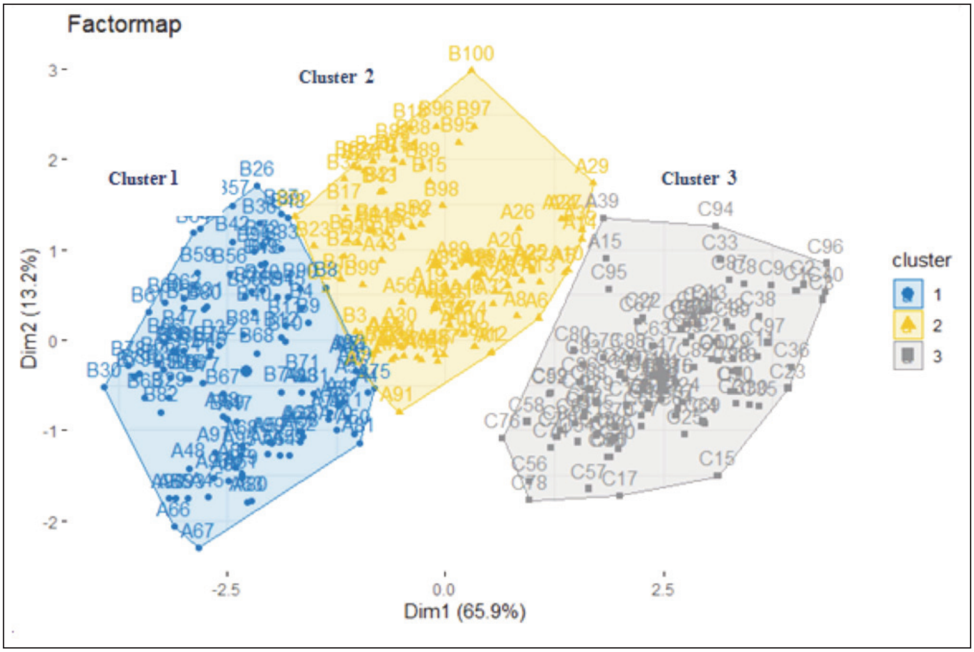

Fig. 7. Morphotype of *Chamaerops humilis* from the hierarchical ascending classification.

fruits. The mature fruits varied from orange-brown, reddish-brown, to brown. *C. humilis* fruits are generally green when unripe, these results are in accord with (Stauffer & al. 2017) who reported that unripe fruits are green in colour, but when they become ripe they turn orange-brown, reddish-brown to brown.

In this study, we found that fruit weight varied from 2.23 to 3.90 g. Low fruit weight in semi-arid stations (Sefrou and Fez) could be related to phenotypic plasticity due to resource limitation (Sultan 2003).Our obtained results are in agreement with other studies that indicated that fruit size seemed to be larger in areas without water stress (Stauffer & al. 2017).

Most fruits have an oval shape, depressed at the apex and truncate at the base. On the contrary there are fruits that have a round-oblong shape, they distinguish the region of El hajeb. This indicates that the fruits in the regions studied are heterogeneous. *Chamaerops humilis* is morphologically varied, as seen by the clustering of samples into separate groups. Therefore, the different morphotypes determined in our study might not be directly influenced by their environmental factors. Within samples from the same population, cluster analysis revealed phenotypic diversity and heterogeneity.

This variability is intimately related to the environmental conditions of the species which gives it the capacity to modify some of its biological characteristics to face the climatic conditions which prevail in its environment of life.

In fact, the majority of the minimal data obtained for fruit were collected in the least watered and hottest area, as for the populations of Fez and Sefrou, and the opposite for the population of El Hajeb. This variation can also be related to the roots extension absorbing the maximum of mineral elements that are essential for the nourishment of plants and for the biochemical reactions inside cells. These results are in agreement with Schwinning and Ehleringer (2001) showing that the depth of the root system play a major role in water use trade-offs for arid ecosystems.

To this essential factor, other secondary contributors can also be added, such as the anthropogenic effects and parasitic attacks which can affect flowering and fruit ripening (Jones 2015; Agbo & al. 2018). The examination of the morphological variability is an essential task to determine results that meet the interests of rural populations, variety selection and species conservation (Jones 2015). Our study showed a variation in morphological characteristics of *Chamaerops humilis* fruit due to environmental conditions, but further work is needed to study molecular diversity to assess the variation caused by the genotype.

Conclusion

This work evaluated the variability in morphological characters of *Chamaerops humilis* fruit and identified its morphotypes. The results show that there is variability in fruit characters by region. The study of morphological characters of *C. humilis* fruit accessions through the correlation matrix indicates the close relationship between morphological characters and climate parameters. Moreover, the PCA revealed differences between the studied characters and allowed us to bring out three well distinguished populations of dwarf palm. The group of the El Hajeb region was the most interesting, expressing the best values for fruit seize (length, width, thickness and weight). The distribution of individuals in each region correlates with environmental parameters.

Therefore, further study at the technological and molecular levels is needed to elucidate these similarities and differences. This variation is generally explained by the close relationship between the distribution of individuals and climate parameters.

References

Agbo, R., Missihoun, A., Dagba, R., Assogbadjo, A. & Clément, A. 2018. Morphological Variability of *Detarium microcarpum* Guill. & Perr. (*Caesalpiniaceae*) in Benin, West Africa. – Asian J. Res. Agric. Forest. **1(2):** 1-12. https://doi.org/10.9734/AJRAF/2018/41234

Akabassi, G. C., Padonou, E. A., Assogbadjo, A. E. & Noël Zirihi G. N. 2021: Effect of Climate and Habitat on Morphological Characteristics and Fruit Production of *Picralima nitida* (Stapf.) in West Africa. – Res. Square https://doi.org/10.21203/rs.3.rs-878443/v1

Haider, M. S., Khan, I. A., Jaskani, M. J., Naqvi, S. A., Hameed, M., Azam, M., Khan, A. A. & Pintaud, J. C. 2015: Assessment of morphological attributes of date palm accessions of diverse agro-ecological origin. – Pak. J. Bot. **47:** 1143-1151.

Barnes, D. K. 1977: Alfalfa germplasm in the United States: Genetic vulnerability, use, improvement, and maintenance. – Washington DC.

Benali, O., Benmehdi, H., Hasnaoui, O., Selles, C. & Salghi, R. 2013: Green corrosion inhibitor: inhibitive action of tannin extract of *Chamaerops humilis* plant for the corrosion of mild steel in 0.5 M H_2SO_4. – J. Mater. Environ. Sci. **4(1):** 127-138.

Chadare, F. J., Hounhouigan, J. D., Linnemann, A. R., Nout, M. J. R., van Boekel, M. A. J. S. 2008: Indigenous knowledge and processing of *Adansonia digitata* L. food products in Benin. – Ecol. Food Nutrition **47(4):** 338-362. https://doi.org/10.1080/03670240802003850

El Hilaly, J., Hmammouchi, M. & Lyoussi, B. 2003: Ethnobotanical studies and economic evaluation of medicinal plants in Taounate province (Northern Morocco). – J. Ethnopharmacol. **86(2-3):** 149-158. https://doi.org/10.1016/S0378-8741(03)00012-6

Giovino, A., Marchese, A. & Domina, G. 2020: Morphological and genetic variation of *Chamaerops humilis* (*Arecaceae*) in relation to the altitude. – Caryologia **73:** 85-98. https://doi.org/10.13128/caryologia-1011

—, Marino, P., Domina, G., Rapisarda, P., Rizza, G. & Saia, S. 2015: Fatty acid composition of the seed lipids of *Chamaerops humilis* L. natural populations and its relation with the environment. – Pl. Biosyst. **149:** 767-776. https://doi.org/10.1080/11263504.2013.870249

—, Guarino, C., Marchese, A., Sciarrillo, R., Domina, G., Tolone, M., Mateu-Adrés, I., Khadari, D., Schillaci, C., Guara-Requena, M. & Saia, S. 2023: Genetic variability of *Chamaerops humilis* (*Arecaceae*) throughout its native range highlights two species movement pathways from its area of origin. – Bot. J. Linn. Soc. **201:** 361-376.

Hammi, S., Simmoneaux, V., Alifriqui, M., Auclair, L. & Montes, N. 2007: Evolution des recouvrements forestiers et de l'occupation des sols entre 1964 et 2002 dans la haute vallee des Ait bouguemez (Haut Atlas central, Maroc). – Sci. Hangements Planét. Sécheresse **18:** 271-277. https://doi.org/ff10.1684/sec.2007.0101

Jamieson, M. A., Trowbridge, A. M., Raffa, K. F. & Lindroth, R. L. 2012: Consequences of climate warming and altered precipitation patterns for plant-insect and multitrophic interactions. – Pl. Physiol. **160(4):** 1719-1727, https://doi.org/10.1104/pp.112.206524

Jones, B., 2015: Social and environmental impacts of charcoal production in Liberia. – PhD Thesis, University of Michigan, Ann Arbor.

Julier, B., Porcheron, A., Ecalle, C. & Guy, P. 1995: Genetic variability for morphology, growth and forage yield among perennial diploid and tetraploid lucerne populations (*Medicago sativa* L). – Agronomie **15:** 295-304.

Medjati, N. 2014: Contribution à l'étude biologique et phytoécologique du *Chamaerops humilis* L., dans la partie occidentale de l'Algérie. – Ph.D. Thesis, University of Tlemcen, Tlemcen

Merlo, M. E., Alemán, M. M., Cabello, J. & Peñas, J. 1993: On the Mediterranean fan palm (*Chamaerops humilis*). – Principes **37(3):** 151-158.

Nekhla, H., Ghadraoui, L. E., Ousaaid, D., Harrach, A., Tarmoun, K., Squalli, W. & Mansouri, I. 2021: Ethnobotanical Survey of *Chamaerops humilis* L. in the Rural Commune of Sidi Youssef Ben Ahmed, Sefrou Province, Morocco. – Trop. J. Nat. Prod. Res. **5:** 1586-1590. https://doi.org/10.26538/tjnpr/v5i9.10.

Okello, J., Okullo, J. B. L., Eilu, G., Nyeko, P. & Obua, J. 2018: Morphological variations in *Tamarindus indica* Linn. Fruits and seed traits in the different agroecological zones of Uganda. – Int. J. Ecol. **2018:** 8469156. https://doi.org/10.1155/2018/8469156

Parmesan, C. 2006: Ecological and evolutionary responses to recent climate change. – Ann. Rev. Ecol. Evol. Syst. **37:** 637-669. https://doi.org/10.1146/annurev.ecolsys.37.091305.110100

Rizk, R. M. & Sharabasy, S. F. E. 2007: Descriptors for Date palm (*Phoenix dactylifera* L.) characterization and evaluation in genebanks. – Pl. Genet. Res. Newslett. **150:** 42-44.

Salako, V. K., Kégbé, A. M., Chadaré, F. J., Kafoutchoni, K. M., Amagnidé, A., Gbedomon, R. C., Assogbadjo, A. E., Agbangla, C. & Glèlè Kakaï, R. 2019: Potential for domestication of *Borassus aethiopum* Mart., a wild multipurpose palm species in Sub-Saharan Africa. – Genet. Res. Crop Evol. **66:** 1129-1144. https://doi.org/10.1007/s10722-019-00777-7

Schwinning, S. & Ehleringer, J. R.,2001: Water use trade-offs and optimal adaptations to pulse-driven arid ecosystems. – J. Ecol. **89:** 464-480. https://doi.org/10.1046/j.1365-2745.2001.00576.x

Stauffer, F. W., Ouattara, D. N., Roguet, D., da Giau, S., Michon, L., Bakayoko, A. & Ekpe, P. 2017: An update to the African palms (*Arecaceae*) floristic and taxonomic knowledge, with emphasis on the West African region. – Webbia **72:** 17-30. https://doi.org/10.1080/00837792.2017.1313381

Sultan, S. E. 2003: Phenotypic plasticity in plants: a case study in ecological development. – Evol. Develop. **5:** 25-33.

Uhl, N. W., Dransfield, J. & Sheehan, M. R. 1988: Genera Palmarum. A classification of palms based on the work of Harold E. Moore, Jr. – Lawrence.

Addresses of the authors:
Houria Nekhla[1*], Lahcen El Ghadraoui[1], Laila lahrizi[1], Laila El Hanafi[1], Aziz Zahri[1], Ahmed Harrach[2] & Fatima-Ezzahra Saouab[3],
[1]Laboratory of Functional Ecology and Environmental Engineering (LFEEE), Faculty of sciences and technologies, Sidi Mohamed Ben Abdellah University, PB 2202, Fez 30000, Morocco.
[2]Laboratory of Condensed Matter Chemistry (LCMC), Faculty of Science and Technology, Sidi Mohammed Ben Abdellah University, PB 2202, Fez 30000, Morocco.
[3]Laboratory of Biotechnology, Environment, Food and Health (LBEFH), Faculty of sciences Dhar el Mahraz, Sidi Mohamed Ben Abdellah University, PB 2202, Fez 30000, Morocco.
*Corresponding author: hourianekhla@gmail.com