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GERMINATION AND HISTO-MORPHOLOGICAL FEATURES OF ARGAN (*ARGANIA SPINOSA* (L.) SKEELS) SEEDS

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Abstract

The argan tree (*Argania spinosa* (L.)) Skeels is a multiple uses tree, only representative of the family Sapotaceae in Algeria with a wide range of socioeconomic and ecological services. Nevertheless, the tree is regressing in the area due to intensified use and seed germination problems. The objectives of this study were to investigate endocarp structure as well as to determine the seed morphological traits variation and its effects on germination. The ripe fruits were collected from natural populations growing southwest of Algeria. The seeds were categorized according to shape and weight, they were analyzed in relation to five morphological traits, the germination rate of different seed classes was evaluated. The endocarp's anatomical structure was studied using scanning electron microscopy. The results revealed that seed weight varied from 0.775 to 5.68g, the mean length, width, circularity index and seeds chamber number were 1.96 cm, 1.37 cm, 0.71 and 2, respectively. Medium weight seeds showed the highest germination rate (73%), as for shape, ellipsoid seeds were abundant (58.30%), and offered the best germination rates followed by narrowly ellipsoidal ones with 69.52 and 61.29%, respectively. The endocarp was thick and formed a leathery or stony covering around the seed, its surface was composed of polygonal heterogeneous cells. The shell was multilayered sclerenchyma tissue, the sclereids cells were strongly lignified. The thickness and hardness of the endocarp, combined with the mass of the seeds and their shapes, could contribute to the variation of the germination of argan seeds. The results obtained might help the selection of seeds for reforestation programs seedlings.

Key words: Characterization, Endocarp, Germination, Histology, Morpho-physiological.

Introduction

Argania spinosa L. Skeels is a multipurpose tree belonging to the Sapotaceae family, it is an endemic species distributed in south-western Morocco and parts of Algeria. In the southwest of Algeria this taxon covers the extreme margins of the southeast distribution area (Tindouf), where it grows in wadis beds and springs. In this threatened desert region, this taxon provides environmental and economic benefits to local people; their deep root system protects the soil against erosion, controls desertification, where it is the second forest species after *Acacia radianna*, it forms the dispersed populations of the Tindouf Hamada, which announce the Sahara, where their area of distribution, shows a relatively large geographical area located in the north of the wilaya (Baumer & Zeraia, 1999). Furthermore, by shading all kind of cultures, maintains soil fertility in an arid climate and creates a favourable microclimate for many fauna and flora. Argan oil is valued for its medicinal properties. Its nutritional virtues and its vocation in cosmetology have the effect of captivating international markets.

The climate in this area is of Saharan type and receive very little rainfall, an average of 50 cm per year. Thus, these stands settle less than ecological conditions of those of Morocco, forming the most continental and eastern station, resistant to climatic hazards.

This multi-use tree is often described as an endangered species since several physical and anthropogenic factors reduce the density and surface of the argan forest ecosystem (Msanda *et al*., 2005), this situation has also recently been enhanced by very weak, or even no natural regeneration and several consecutive arid years, which raises concern about its long-term sustainability, suggesting a need for the development of a preservation strategy by a specific reforestation-oriented programs.

Argan seeds have high dormancy level due to a hard endocarp (Berka & Harfouche, 2001). Knowledge of the morphological characteristics of seeds is important to activities designed to maintain biodiversity and for understanding and describing germinative processes (Oliveira *et al*., 2006). Therefore, this study was carried out to characterize seeds morphological traits, as well as their variation. The aims were to determine histological aspects of the endocarp, which was a key factor in germination, and to study how seeds biometric characteristics affecting the germination.

Material and Method

Location of seed source: We collected ripe Argan seeds in July 2021, from Touaref Bouam, located in the city of Tindouf in Southwest Algeria (8° 07′- 3° 40′ latitude and 25° 30′-29° 40′ longitude), where Argan trees were frequent in the natural population. The collection site is located at an altitude of 500 m above sea level (Fig. 1). The region has a Saharan climate with minimal annual rainfall, resulting in drought throughout the year, high average temperatures, and wide fluctuations in day and night temperature. The soil in the study area is sandy loam.

Collection, processing and germination tests of seed: Three samples of mature fruits were harvested directly from trees or collected from the ground. After drying fruit in the air to facilitate the removal of the pulp, stones were stored in paper bags and transported to the laboratory.

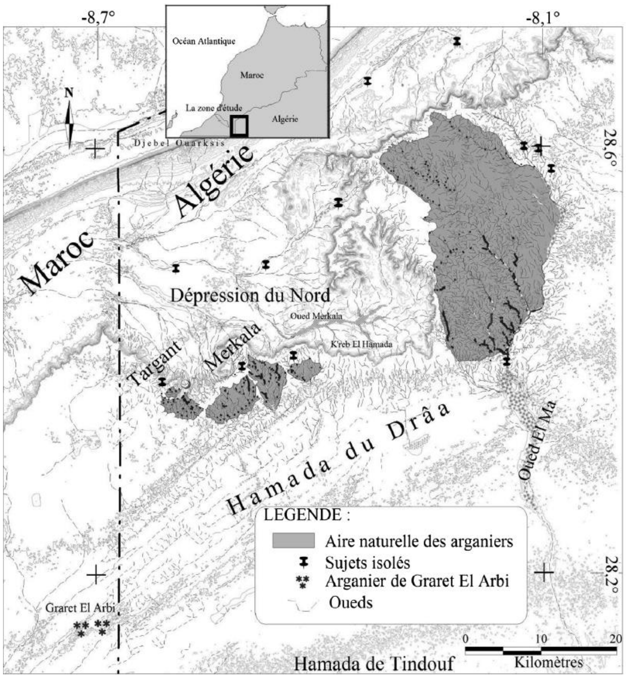

Fig. 1. Cartographic location of the argan tree of Tindouf and Graret El Arbi (Kechairi & Abdoun, 2016).

Sixty stones were used for biometric determinations. The seeds were analysed in relation to the weight, length, width, chambers number, calculated circularity index (width/length) and anatomical structure of endocarp. Seed weight was measured using an electronic balance; the dimensions of the length and width were measured using a digital caliper (precision 0.01 mm). The terminology used to morphological descriptions follows the guidelines of Bani-Aameur *et al*. (1999). Seeds were individually weighed and categorized into three different classes (light, medium and heavy). A HITACHI TM-1000 (Japon) scanning electron microscope was used to record the SEM images of the microstructure of the endocarp surfaces and their longitudinal section. Different nuts were used to determine the layer structure and thickness of the Argan seed coat.

The germination tests compared two biometrics traits seeds heaviness and shape with two replications of 30 seeds. After surface disinfection by immersion in 2% sodium hypochlorite the soaked seeds were sown 20 cm glass Petri dishes lined with a filter paper with a sub layer of wet cotton and was regularly re-wetted with distilled water when required. The dishes were placed in a controlled environment chamber at 25 ± 1°C (Miloudi & Belkhoudja, 2009). The germination rate was recorded daily for 45 days, and the germination was calculated. The differences in seed size, weight and the germination percentage were statistically analysed following analysis of variance (ANOVA) using the software Ri3863.2.3.

Results

Morphological characters of stones: In order to know the main characteristics of argan seeds, a morphometric characterization was carried out. Results are presented in (Table 1). It indicates that great phenotypic diversity in seed. The results of descriptive morphometric analysis revealed that the seeds differed not only in size but also in mass. The fruits of sample 2 had the largest average length (15.85 mm) and highest mean values of weight and width (2.656, 1.406), respectively than those of sample 1 and 3, although the other parameters overlapped between the three samples. Generally, chambers number are similar, it varied between 2 to 3, two-chambers stones were more frequent (57.08%) than three-chambers stone (41.66%). The mean circularity index of nuts of second sample is important.

The coefficients of variation (CVs) indicated the highest variability in the first sample (CV= 28.6% for length, 18.72% for width), whereas the lowest variability was noted in the third sample (CV= 11.64% for width, 26. 12% for weight. Variation along the circularity index was the least (< 17%).

Table 1. Mean, minimum, maximum and coefficient of variation (CV%) of the weight, length, width, chambers number and width / length of the argan seeds.

	Sample 1	Sample 2	Sample 3
	N = 60	N =60	N =60
Weight of stones (g)			
Mean	2.352	2.656	2.225
Minimum	1.071	1.411	0.775
Maximum	4	5.68	3.476
CV %	28.6	27.07	26.12
Length of stones (cm)			
Mean	1.727	1.92	1.751
Minimum	1.11	1.29	1.2
Maximum	2.7	2.72	2.73
CV %	28.6	14.85	18.77
Width of stones (cm)			
Mean	1.367	1.406	1.358
Minimum	0.8	1.08	0.88
Maximum	1.71	1.99	1.76
CV %	18.72	12.06	11.64
Rtio of width/ length			
Mean	0.808	0.744	0.795
Minimum	0.559	0.5444	0.485
Maximum	1	0.9645	1
CV %	14.23	15.31	16.78
Number of chambers			
Mean	2.367	2.383	2.483
Minimum	2	1	2
Maximum	3	3	4
CV %	20.53	23.29	21.6

The dimensions mentioned in (Fig. 2) showed that the values were very heterogeneous, as indicated by the coefficients of variation which described the dispersion of the observed values, this heterogeneity was especially remarkable at the levels of weight and length (Fig. 3). These variations illustrated breeding potential to capture for enhancing argan fruits and stone characteristics (Bani-Aameur & Ferradous, 2001).

The classification of the nuts according to their circularity index revealed that the spheroid shape was clearly predominant, it represented the half of the seed forms of Tindouf, followed by ellipsoid which represents 40.41%. The narrow ellipsoid were only 10.41%.

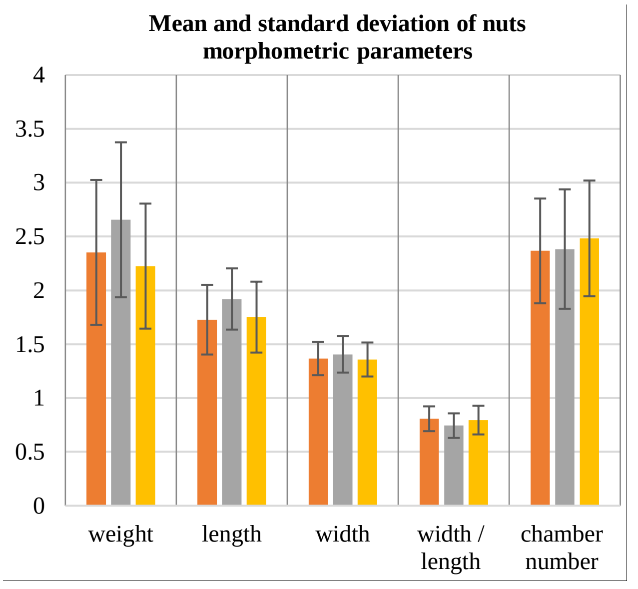

Fig. 2. Mean and standard deviation of weight, length, width, chambers number and width / length ratio of argan seeds.

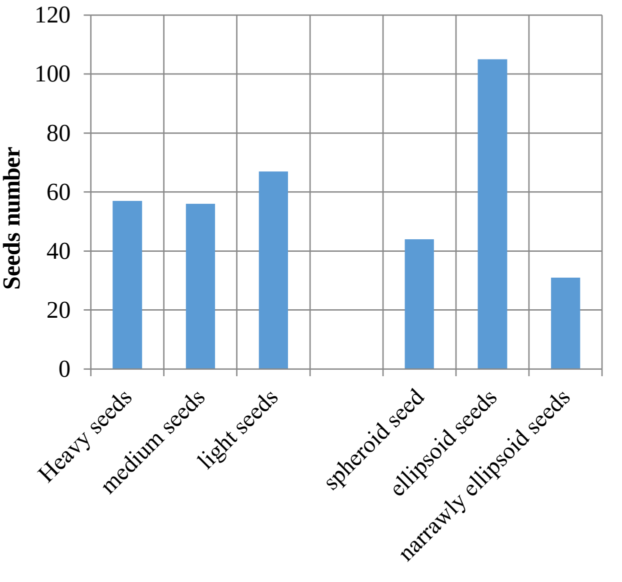

Fig. 3. Stones distribution according to shape and weight.

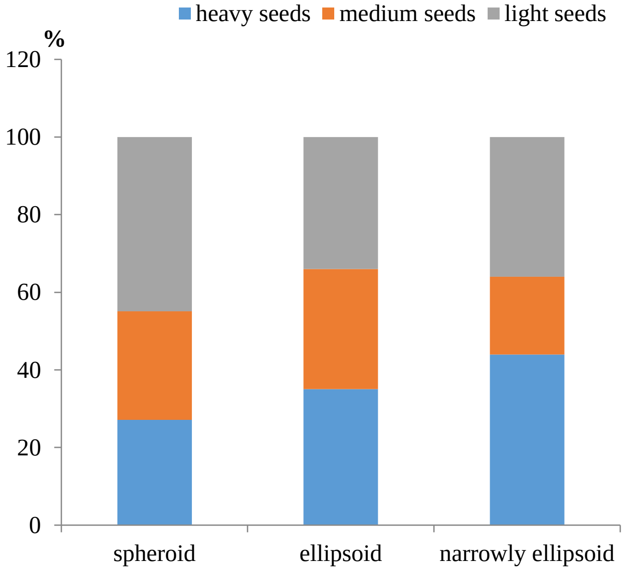

Fig. 4. Nuts distribution according to the shape.

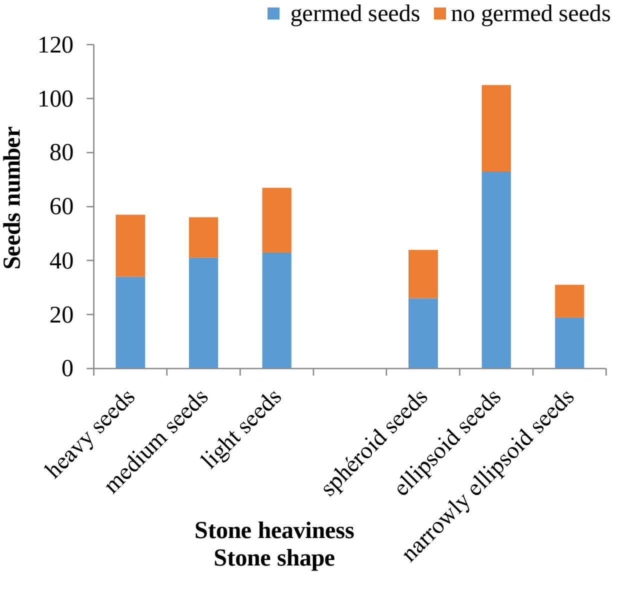

Fig. 5. Comparison of the number of germinated and non-germinated seeds between three classes of weight and shape.

However, analysis of the distribution of nuts weight according to the shape showed that the most seeds with higher fruit weight had spheroid shape (Fig. 4). Narrowly ellipsoid form had the largest seed weight (44%).

The comparisons of the morphometric characteristics of Argan seeds between different samples are given in (Tables 2 and 3). ANOVA revealed significant differences ($p<0.005$) for all morphometrics parameters among the three samples.

Differences in germination percentage between three different weight and shape classes were not significant, these results suggested that form and weight without changing seed quality in terms of germination.

The figure 5 shows a relationship between the percentage of germination and the form of stones. We recorded 69.52% germination for ellipsoid seeds, followed by those with narrowly ellipsoid shape with a rate of 61.29%. Germination rate for medium weight seeds exceeded 73%, and for heavy seeds the rate did not exceed 60%.

Anatomy analysis of the endocarp: The fruits were round to oval, ovoid berry and had a thick shell enclosing a nut embedded in a bitter yellowish-brown pulp.

Our observations of the external structure showed that the fruits of *Argania spinosa* (L.) Skeels were anatomically consisted of two essential parts: the pericarp and the seed. The pericarp formed the outer part surrounding the seed. It was subdivided into three regions those can be defined as follows: the epicarp forming the thin bark enveloping the fruit; the fleshy mesocarp constituting the pulp containing an unpleasant milky latex and enveloping the hard, woody endocarp, which was differentiated from the inner layer of the ovary, was the outermost part of the seed; it constituted the layer of tissue immediately adjacent to the kernels.

During development, it dehydrates completely, and becomes hard as the fruit matures, forming a hull that takes the shades of the brown colour, compact and highly lignified. The integument "testa" is located under the endocarp, it is a fine speckled film wrapping the kernel, and when the latter is removed from the locule, it separates from the endocarp and is often attached to the kernel (Fig. 6).

The endocarp covers one to three seeds (kernels), the latter is composed of white and unctuous endosperm containing the embryo. The endocarp was lignified and thereby served as a protective barrier for the embryo against the external environment and climatic hazards (hygrometry, sunlight), so it is one of the main determinants of germination, vigour and longevity of seeds.

The seed surface microstructure and the sections of endocarp were observed under scanning electron microscope (SEM) and shown in (Fig. 7). The seeds of each plant species have a specific endocarp profile.

Table 2. Comparisons of the morphometric characteristics of Argan seeds.

Source of variation	Df	S. S	M.S	F-Value	Pr (>F)
Weight	2	5.879	2.940	6.449	0.001*
Length	2	1.33	0.665	6.792	0.001*
Width	2	0.081	0.04	1.564	0.212*
Number of loge	2	0.478	0.239	0.861	0.424*
Width/length	2	0.136	0.068	4.629	0.011*

*Significantly different at $p<0.05$

Table 3. Variance analysis of germination of argan seeds.

Source of variation	Df	S. S	M.S	F-Value	Pr (>F)
Sample	2	1878.13	939.06	26.35	0.0001*
Seeds heaviness	2	95.46	47.73		
Seeds shape	2	95.46	47.73		

*Significantly different at $p<0.05$

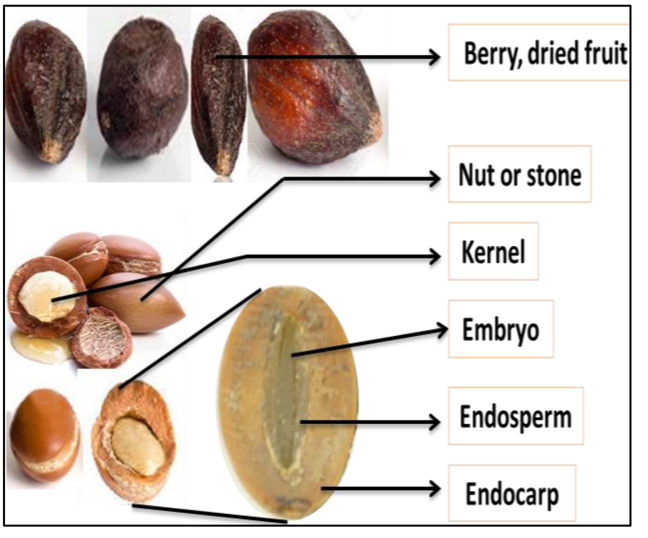

Fig. 6. Fruit and cross section of argan tree nuts.

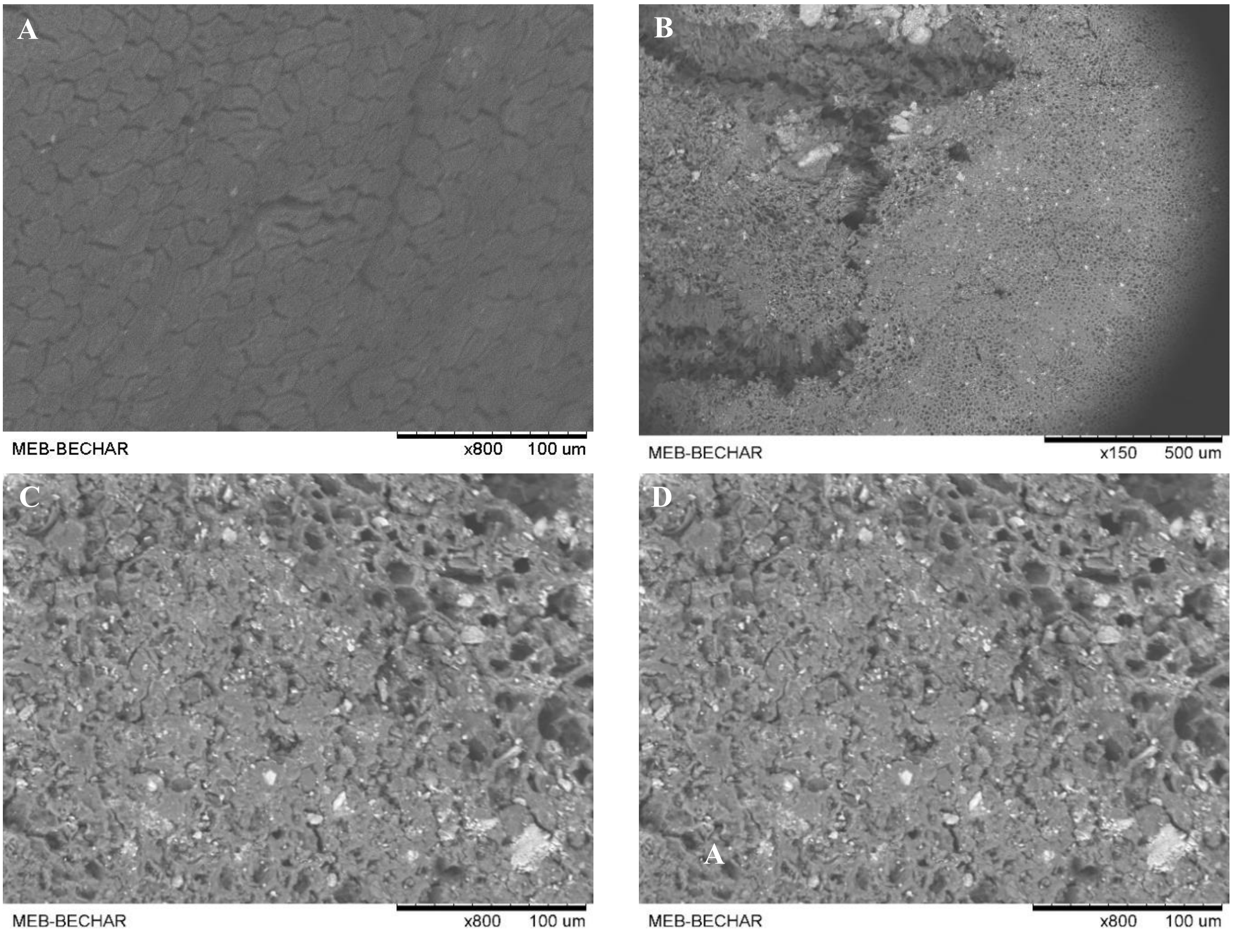

Fig. 7. Plate showing the SEM micrographs of the outer surface of argan endocarp (A) Surface structure; (B) cracks in the surface; (C, D) deposits in the surface.

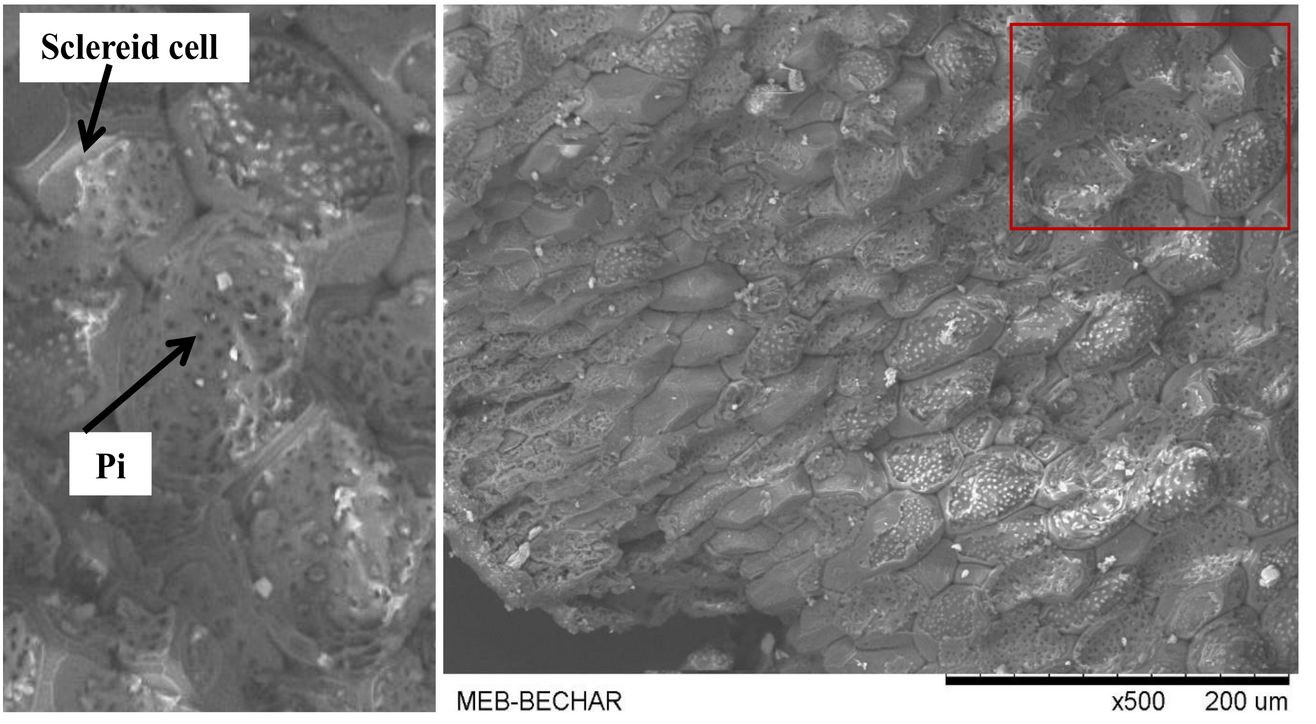

Fig. 8. Microstructure of the cells: Pits in lignified cell walls of the argan endocarp.

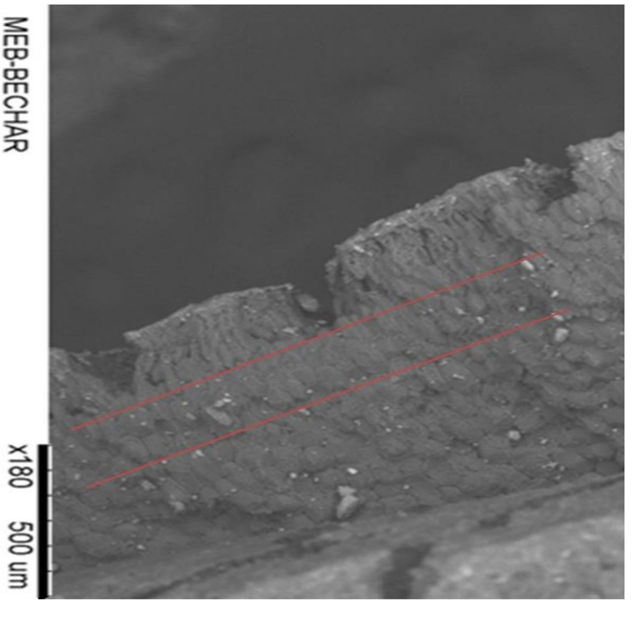

Fig. 9. SEM micrograph of argan endocarp. Cross section shown three layers.

The distinct characteristic features of surface endocarp is their heterogeneous wholly lignified cells with concave depressions towards the cell edges, the surface relief is studded with polygonal approximated cells, in general, it appear no uniform in dimensions and is irregularly arranged. The surface of the outer layer of the argan endocarp presented an exceptional sculpture, it is rough with very small, rounded perforations.

Surface cell containing different deposits scattered, as well as the cells arrangements produce spaces between the individual cells associated with formation of pores on the shell's surface. The Argan seed coat is made up of sclerenchyma Tous cells (Fig. 8), that is sclereid cells and sclereid filiform with a thick cell wall. The endocarp is very hard and generally varies in thickness from 5 to 9 mm, depending on the specific region of measurement (Fig. 9).

The thickest values are generally found in the lower part of the nut, while its upper part has thinnest shell. It consists three fairly defined layers:

The endocarp of the argan tree is a sclerified tissue, in which the outer layer is characterized by elongated cells arranged side by side perpendicular to the surface, form a compact tissue, they are organized and arranged in a palisade like the palissadic tissue of the leaf blade; the pseudo-stratified central layer, consisting of isodiametric sclerites closely packed together; the last zones are thicker, the cells are larger, irregular in size and shape, from spheroid to stubbed, and almost the cellular layer is organized in " stretcher and header ".

Towards the inside of this inner layer, there are the vascular bundles, where the filiform sclereids are long, elongated with branching structure and apparent interlocked with the vascular bundles, which are visible as white structures and show the conspicuous reticular markings; sometimes annular and spiral (Fig. 10).

After four days imbibition and incubation at 25°C, we note the presence of the slits. Sprouted seeds were severely cracked compared to ungerminated seeds, cracks varied in depth and ranged in size from 80 to 560 um (Fig. 11).

These figures suggest that the presence of the pores does not render the endocarp of a hard seed permeable to water. During germination, the surface of the seed was honeycombed and very rough, as well as the cells became rough (Fig. 11 C, D).

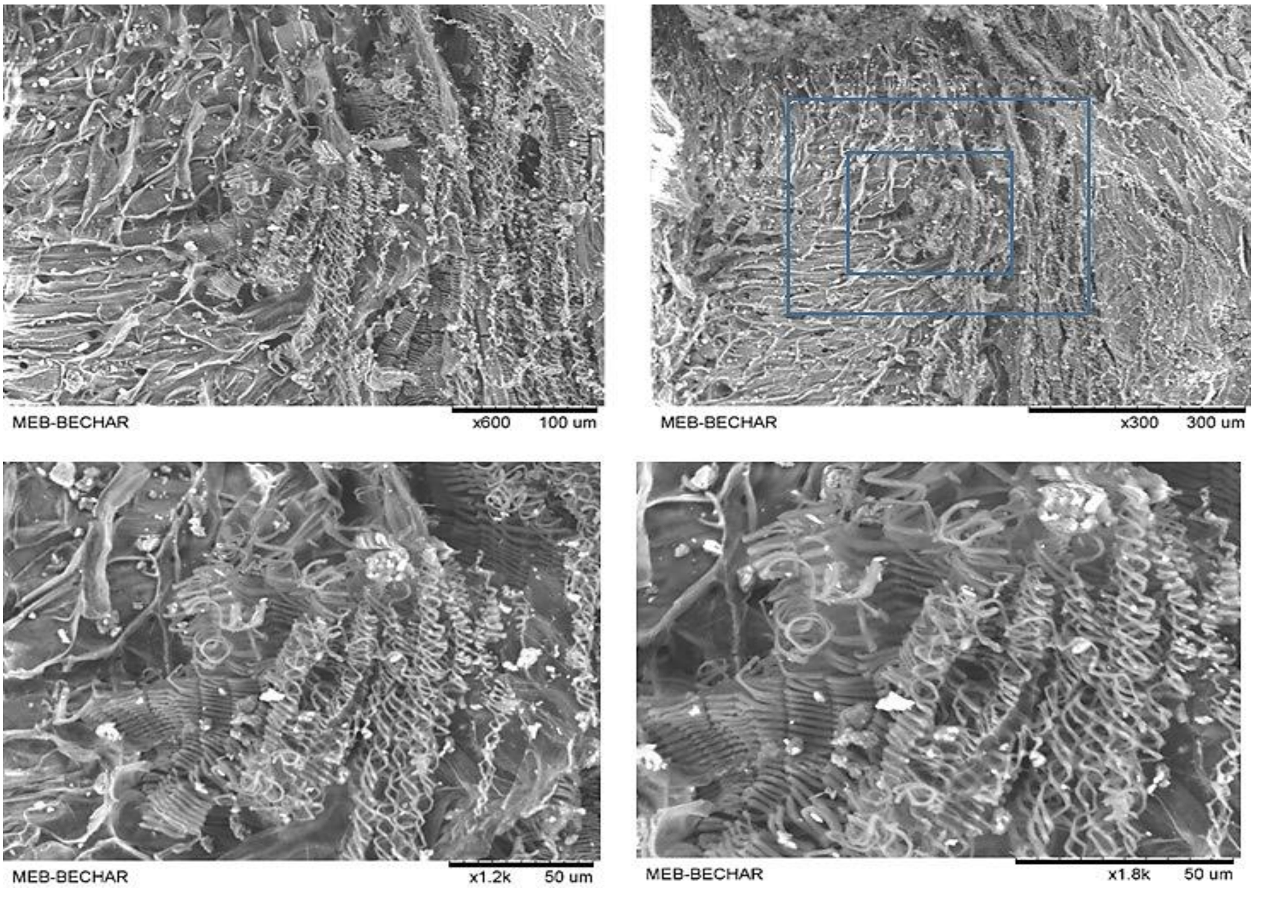

Fig. 10. SEM micrographs showing filiform sclereids and vascular bundles.

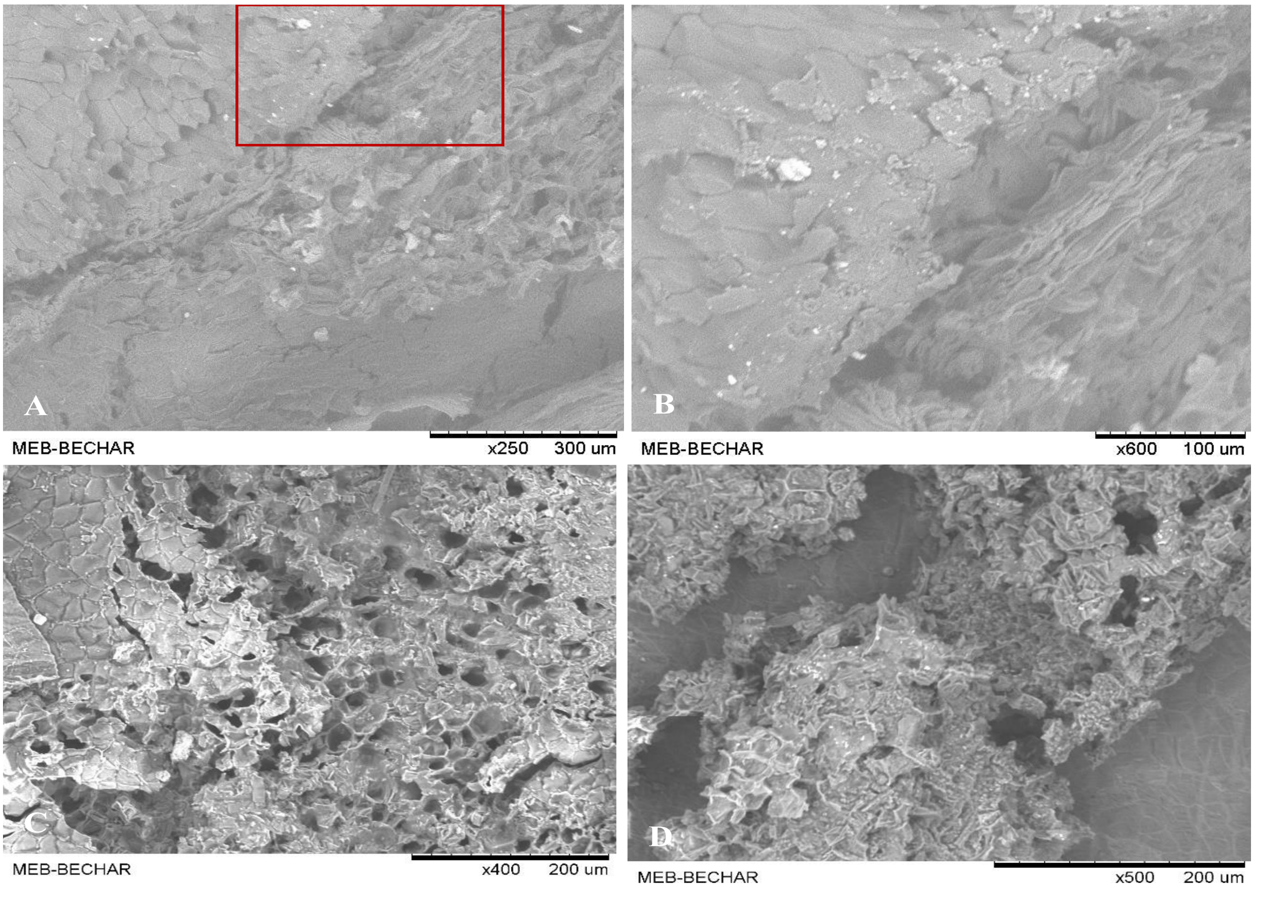

Fig. 11. SEM micrographs of the endocarp surface after imbibition (A, B) Appearance of pores; (C, D) appearance of cracks.

Discussion

Morphological analysis is a first approach for assessing genetic diversity, which is essential in plant breeding. Variation in seeds characteristics exist between and within plant species (Gera *et al*., 2000; Moles *et al*., 2005), within populations (Simons & Johnston, 2000). The identification of this genetic variability for certain morphological traits is the most important step in the description of genetic resources (Radhouane, 2004).

The genus *Argania* is a highly polymorphic species (Louali *et al*., 1994), this polymorphism is manifested in the morphology of the twigs, leaves and fruits, which offer diversity of choice to users. Argan fruits have been of great interest, the nuts provide an oil widely appreciated for its nutritional and organoleptic quality, used as cooking oil as well as in recent years there has been much interest in argan oil for cosmetics. With increasing interest and widespread use of the species the choice of varieties to exploit is likely to increase along with a focus on the socio-economic development and its sustainable development impacts. Therefore, the description of phenotypic traits in order to measure variability is essential, where Bani-Aameur *et al*., (1999) assert that A helpful first step in evaluating diversity for plant species conservation is the establishment of phenotypic descriptors.

In this study, the intra population variation of seed morphological traits were observed (Table 2). The seeds characters showed a wide diversity in weight, and shape. Regarding argan seed features, the most important variability within samples was observed in seed weight. In some species the seed size is often positively correlated with the size and survival of seedling, germination rate and latency time (Parker *et al*., 2004; Loza-Cornejo *et al*., 2008). Seed size and weight is one of the most important characteristics related to plant adaptation, dispersal, germination and colonization abilities (Levin Simon & Muller-Landau, 2000; Adjei *et al*., 2011; Kai *et al*., 2018).

Among the three samples, seeds of the first sample presented higher average values (0.808) of size and mass (2.352), in relation to seeds of the other samples. The variation in seed characteristics may be due to the environmental factors during the fruit flowering and development, where the flowering-fruiting cycle lasts for a period of 9-16 months. Chernane *et al*., (2000) found that fruit width, fruit weight and pulp increased significantly during the rainy year. Some authors have also reported the effect of site and genotype (Bani-Aameur *et al*., 1999).

According to the data reported in the literature, the ecosystem was a highly significant factor, where the East-West moisture gradient, relative to the strong continentality (from sub-humid to arid with distance from the sea) was negatively affects the diversity of phenotypic traits of fruits and nuts (Bani-Aameur, 2004).

In our population, the frequencies of argan nut shape and the coefficients of variability are similar to those found in Moroccan regions of similarity with similar climatic characteristics.

The number of lodges ranges from 1 to 4 with a predominance of seeds with two lodges exceeding 57%. Which coincides with the data obtained by Bani Aameur *et al*., (1999) with the exception of the rare presence of lodges reported by the authors. Seed sizes are influenced by the environment (Völler *et al*., 2012), genetic variation (Zas & Sampedro 2015) or interaction of the two (Michael *et al*., 2013).

Seed physiological performance, which will affect the different phases of seedling growth, depends on seed vigor. The differences in seed weight within species may have important consequences on subsequent seedling vigour and plant performance (Baraloto *et al*., 2005; Kołodziejek, 2017). Seed weight has been characterized as an influential character, our results show that medium weight seeds have the highest germination rate, this rate is minimal in light seeds.

The seed vigour mostly performs in both seedling and establishment and is correlated with greater survival rates, seedling emergence rates, and speed (Macedo, 2013; Chipenete *et al*., 2021). that characteristic describes early stages of seedlings development, which may directly and indirectly affect plants ability to capture nutrient resources from the environment and interfere with intra- and interspecific plant competition (Mondo *et al*., 2013). According to Makinde *et al*., (2020), some seedling vigour parameters increased in correlation with increasing seed seize. Therefore, the description of the fruit traits highlights the problem of understanding the biology of reproduction, especially plant that grow in arid and unpredictable climate.

Seed germination characteristics differentiated between and among populations (Mamo *et al*., 2006; Drvodelić *et al*., 2011; Batkhuu *et al*., 2020) and individuals of several plant species (Cruz *et al*., 2003; Freire *et al*., 2015; Bhatt *et al*., 2022). Plant individuals' ability to germinate, grow, survive, and compete is impacted by intraspecific variation in seed mass (Mira *et al*., 2017; Tsobeng *et al*., 2020).

Each species has its own characteristics and all for each stage of the life cycle, because the germination is the key step in the reproduction by seed. Plant individuals' germination, development, survival, and capacity for competition are all impacted by intraspecific variation (Susko &Lovett-Doust, 2000).

Seed mass and size are a crucial trait that affect seed germinability and seedling growth (Kuniyal *et al*., 2013; Zas *et al*., 2013; Souza & Fagundes, 2014). Many studies show a positive impact of seed dimensions on germination (Westoby *et al*., 2002; Navarro & Guitian 2003; Khan, 2004), where the better germination exhibited by the heavier seeds due to the high nutrient stored availability that can be allocated to initial seedling development and establishment (Khan & Shankar, 2001; Souza & Fagundes, 2014; Chaichi *et al*., 2022) with decrease in metabolic rates (Zolfaghari *et al*., 2013) and ability to survive under environmental hazards, including protection against water stress or scarcity (Zhao *et al*., 2015; Khurana & Singh, 2000). Survival of young plants in arid environments is mainly determined by procedures that guarantee germination and growth of seeds at the proper time and in the appropriate place (Gutterman, 2001; Gutterman, 2002).

The interaction between seed size and additional environmental elements like moisture, temperature, light and soil quality can affect germination requirements and seedling emergence in ecosystems (Lorena Ruiz *et al*., 2016; Castillo-Díaz *et al*., 2021; Veselá *et al*., 2021). To decide on habitat protection and restoration methods that are well-informed take into account these interconnections and the requirements for germination sites.

The *Argania spinosa* is found on the temporary water axes represented by the wadis where the humidity is sufficient to favour the installation of rich and deep soil. Biotic and abiotic factors limit germination and growth of argan, for overcoming these obstacles, successful introductions depend on knowledge of the most favourable conditions for argan growth and establishment.

The seed coat is part of the traits that acts as an adaptive reaction to the environment, and it is a significant constraint on seed growth because it acts as a physical impediment to the cotyledonal tissue's ability to express its genes, thus the weight ratio of kernels on the weight of walnuts varies according to the provenance of 13 to 15% (Ait Hammou *et al*., 2013), and according to the genotype it varies from 7 to 16% (En-Niari *et al*., 2013).

The endocarp acts as an embryo protective barrier against the aggressions of the external environment, so it is one of the key factors affecting the capacity for seed vigor, germination and longevity potential (Francisco *et al*., 2001). According to Sebaa & Harche (2014), quantitative analysis has shown that cell wall layers of endocarp are composed of polysaccharides: the pectine (galactane and arabinan) with amounts of hemicelluloses (xylans). Coniferyl lignins are abundant in the majority of the lignified tissues adult argan endocarps.

The sclerenchyma tissue of endocarp was formed of sclereids, which are thick-walled and lignified cells, and hence, the hardness of the drupe in this species, indicates that it has a primary structural function, where offers mechanical strength and, therefore make the structure less prone to mechanical injury and permeability. The lignocellulosic matrix that travels through the argan endocarp and is considered the main constituent, confers on its various roles in the function of the fruit, thus forming a hard protective layer surrounding the seed to protect nutrient-rich cotyledons against enzymatic attack, microbial pathogens, and other stressors that are biotic and abiotic. seed coat lignin involves in maintaining seed coat integrity and protecting seed coat against physical and weathering damage (Bellaloui *et al*., 2017; Huth *et al*., (2016)), and gives cell wall polysaccharides decay resistance by preventing microbial breakdown (Vanholme *et al*., 2010).

As for the Argan tree, Miguel *et al*., (2017) postulated that goats ruminating could be able to disperse large seeds by regurgitating the nuts of argan fruits. By properties of the endocarp, the stony shell defies the stoutest teeth and protect the seed from predation while retaining its viability. Once dispersed, these seeds can survive for many years, and if ecological conditions become germinative, they escape from their woody envelope by cracking and bursting of the endocarp due to environmental exposure.

The orientation of the elementary cellulose fibrils is designed to provide a diverse architecture in the cell walls. Sebaa & Harche (2014) provide further evidence that cellular microfibrils have arcuate patterns. As a result, these configurations (arcs) had an effect on the mechanical parameters, mainly on the stiffness and extensibility of the wood cell wall (Mott *et al*., 2002; Fratzl *et al*., 2004).

For Argan oil extraction, most popular accounts (and scientific paper: Nouaim *et al*., 2007) say there are nuts easy to break and others difficult to break. This perceptible character may be considered as the main reasons for the diversity of germination behaviour. Moreover, differences in the germination were not related to differences in the thickness of seed coat, argan endocarps hardness differs among nuts although their thickness was similar.

There was dependence between hardness and mass of seeds may contribute to the variation in the germination of argan seeds. Where in the present study, the hard seed coat of the heavy weight seeds caused low germination rates. The hard seeds might delayed/ prevent water penetrates seeds to soften the endocarp to split. Hamani *et al*., (2018) reported that germination ability is enhanced by removing the seed coat, where the kernels have a lower latency time than the nuts. Which indicated that the hardness, as well as the thickness, of the endocarp might hindered the seed from germinating, and it is regarded as a causing either mechanical resistance to radicle extension, or low impermeability to water and/or gases.

Absorption of water by seed is required for germination. However, the hard and stony shell is regarded as a widespread cause of seed dormancy. Before incubation, seeds were kept for four days in water to soften the endocarp and kernels swell. During incubation of seeds, the structure of the outer layers of endocarp has strongly modified by a large swelling and mucilaginous appearance. An attenuation of physical dormancy by seed imbibition is aimed at optimizing sexual reproduction, this was related to enzyme activation, integument swelling, and softening (Mudasir *et al*., 2012). Mucilage would facilitate germination and ensure seed protection from harmful chemicals (Haughn & Chaudhury, 2005, Yang *et al*., 2010).

The porous structure of argan endocarp allows the permeability and diffusion of oxygen (Fig. 8), and therefore a germination ability which corresponds to the water uptake by the dry seed and the restoration of an intense metabolic activity. (Fig. 11) shows that the cells are digested after water absorption during germination, and the surface become fullerene-like formation, some larger voids, with diameters in the range of 100 and 400 μm have been observed, these pores have been assumed to improve the water absorption.

In this phase, the embryo enters into vegetative activity, grows and tears the envelopes. In the argan tree, the tearing of the endocarp can take place only at the level of a particular tissue, it is the lines of welding of the carpellary edges (septicidal separation of the locules) separating the chambers. The argan tree does not have a uniform seed coat, the presence of a less hard layer separating the locules of the nuts (placental boundaries) with a weak resistance and less compact compared to the rest of the endocarp which is hyper-ligneous, it allows the hydric exchanges between the seed and the external environment, which favours breaking of the shell, where the cells are heavily impregnated. It is possible that these coatings at the welds of the two lodges are less resistant to enzymatic attack.

The chamber number and the structure of the tissue separating the locules are among the intrinsic factors that can significantly influence germination by the absorption of water and the restriction of the mechanical resistance to the expansion of the embryo, this indicates the possibility of morphophysiological dormancy.

Conclusion

Our study revealed significant differences between the minimum and maximum values of the morphological variables of the seeds studied. The results of the morphological diversity and the structuring of argan stones from southwestern Algeria show that the parameters analysed present a variability, where the most discriminating characters are revealed as the chambers number, width and the index of circularity vary significantly from sample to sample. The endocarp was hard with a thickness of 7 mm, its surface was characterized by the presence of deposits and pits, it consists of several layers of very lignified cells. The differences in stones morphological features where the seeds shape and weight may considerably influence hardness and thickness of the endocarp which in turn may largely influence the physiological mechanism of germination. Observations on the morphological diversity and germination variation of argan seeds offer insights to be refined and constitute an asset for selection work offering avenues to contribute to preservation and improvement programs for this species facing the risk of extinction, for which concrete conservation measures in situ and ex situ are urgently needed to preserve genetic diversity.

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