Pak. J. Bot., 56(2): 621-629, 2024. DOI: http://dx.doi.org/10.30848/PJB2024-2(20)

ECOLOGICAL DYNAMICS AND DIAGNOSIS OF DIEBACK OF *PISTACIA ATLANTICA* DESF. – ANACARDIACEAE IN THE MESSAÂD REGION (DJELFA, ALGERIA) USING THE ARCHI METHOD

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Abstract

This research aims to study the morphological and the resilience capacity of the Atlas pistachio tree (*Pistacia atlantica* Desf.) in the region of Messaâd (Djelfa province), Algeria. A total of 512 trees were measured (total height, bole height, diameter) in Oum El Khechab (303 trees) and El Khoua (209 trees) groves. A horizontal projection of the crowns was carried out by measuring 4 radii, in equal directions and angles, the first radius of which was fixed randomly. The study of dieback and resilience of *P. atlantica* was carried out using the ARCHI diagnostic method. The method made it possible to determine the ARCHI types in each grove: healthy trees (Ht), resilient trees (Rt), descending crown tree (Dct), stressed trees (St), trees in irreversible decline (Di), and dead trees (Dt). The results reflect the presence of a regular structure stand dominated by two diameter classes (big wood, very big wood) in Oum El Khechab and an irregular structure stand dominated by three classes (Perch, small wood, very big wood) in El Khoua. For the vertical structure, we noted the dominance of trees with heights between 5 and 10 m in Oum El Khechab, and trees less than 3 m high in El Khoua. The diameter of the crown, its projected area, its proportion and its degree of bulging were determined by the diameter class in each grove. The application of the ARCHI method on the Atlas pistachio tree in Messaâd revealed the dominance of the ARCHI type healthy tree (Ht) with 60.07 %, resilient tree (Rt) with 21.12 % and stressed tree (St) with 16.50 % in Oum El Khechab grove. Concerning El Khoua grove, was observed the dominance of healthy trees (Ht) with 35.89 %, resilient trees (Rt) with 23.44 % and trees in irreversible decline (Di) with 16.27 %.

Key words: Atlas pistachio, Algeria, Messaâd region, Crown parameters. Dieback, Resilience, ARCHI method.

Introduction

The Atlas pistachio tree (*Pistacia atlantica* Desf.) member of family Anacardiaceae, commonly called El Betoum is endemic to North Africa, where it forms tree steppes in the arid and semi-arid bioclimate according to some authors (Ozenda, 1983; Belhadj, 2002; Belhadj *et al*., 2008) and/or the Mediterranean according to other authors (Monjauze, 1980; Quézel & Médail, 2003). It has a broad ecological plasticity, adapting to all types of soil except sand, and requiring only low rainfall of about 150 mm/year and sometimes less (Benhassaini & Belkhodja, 2004). The species is characterised by very slow growth but has the advantage of being the only one that can organise a preforest ecosystems in arid and semi-arid regions (Monjauze, 1980; Yaaqobi *et al*., 2009).

Pistacia Atlantica is one of the species protected in Algeria by executive decree number 12-03 of January 4, 2012 (J.O.R.A, 2012). It finds its optimum in arid and semi-arid regions, notably the High Plains where it thrives in oueds and dayas (Monjauze, 1980; Ifticene-Habani and Messaoudene, 2016). More or less extensive stands can be found here and there in the Hoggar and in the Saharan Atlas, where the pistachio tree is only halted in its expansion by the competition it faces from other species that are much better adapted to cold and humidity (Harfouche *et al*., 2005).

Like any living being, the tree goes through crises of varying magnitudes. Thus, starting from a normal state, under the influence of various factors, there may be deviations from normal followed by a return to normal or an irreversible decline, which will lead to the death of the tree (Drenou, 2013). To account for this dynamic, the ARCHI diagnostic method is used. The method is based on a reading of the architecture of trees. The principle is to conduct two series of observations. The first concerns the symptoms of crown degradation (foliar deficit, abnormal coloration, mortality, etc.); the second relates to the crown restoration process (development of suckers, covering of wounds, resumption of growth, etc.) (Drenou, 2009; Drenou, 2013).

In addition, studies on the ecological and morphological aspects of the species are numerous (Benhassaini *et al*., 2007; Belhadj *et al*., 2008; Bouabdelli *et al*., 2015; Berrichi *et al*., 2017), while those on the dynamics of Atlas pistachio stands are rare. To this end, an approach was established to characterize the structural dynamics and the resilience capacity of the *Pistacia atlantica* in the southern Algerian steppe (Djelfa region).

Material and Methods

Study area: Messaâd region is located about 76 km south of Djelfa and covers an area of about 13962 hectares. It is part of the central highlands (Nadjem, 2019). The region lies between 34°08' to 34°12' north latitude and 3°24' to 3°34' east longitude (Cherair, 2016). It is bounded to the south by Oued Defelia and Djebel Sba El Hadid, to the northeast by Oued Tamdit, and to the west by Oued Khettacha (Cherair, 2016) (Fig. 1).

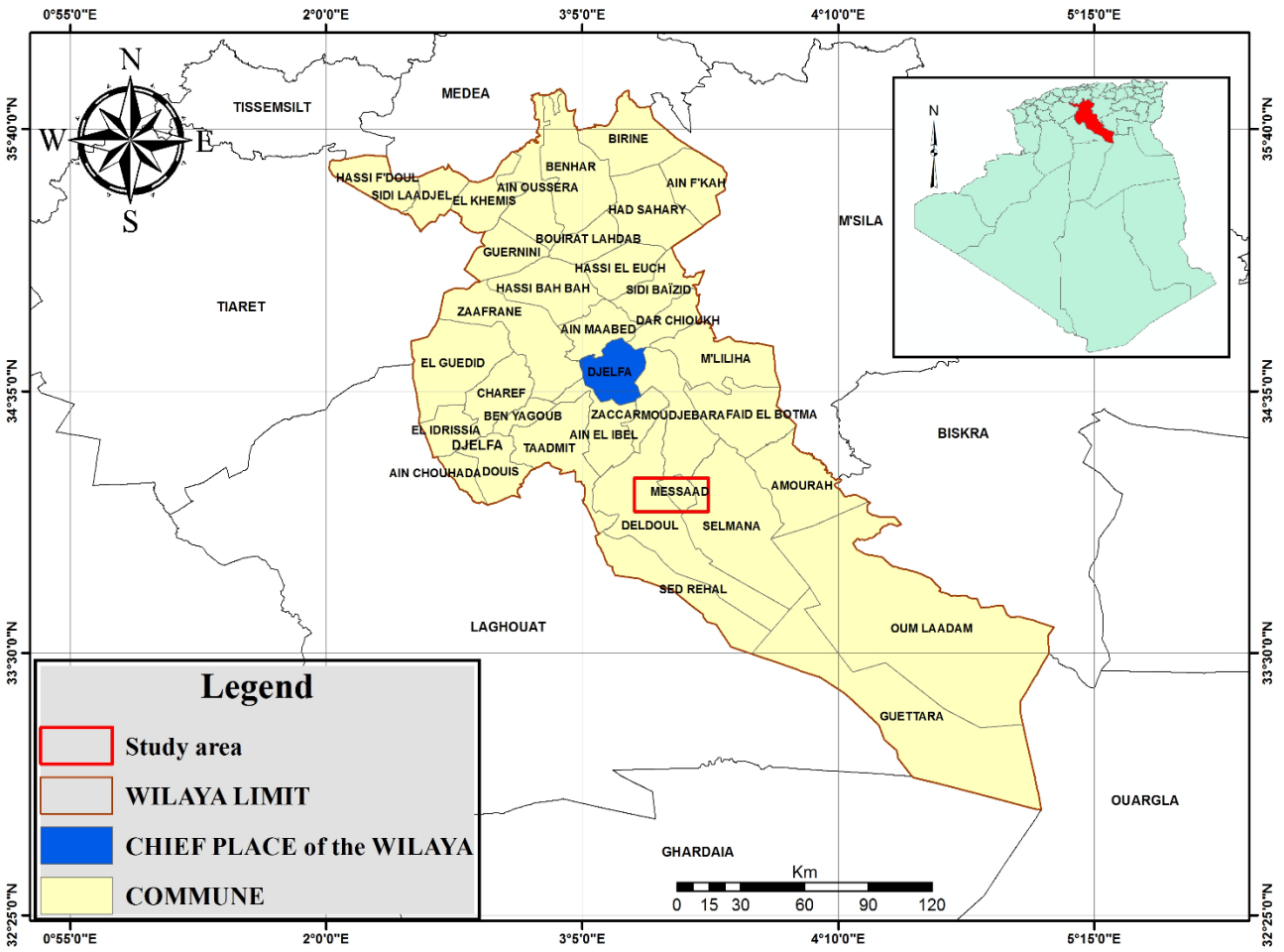

Fig. 1. Geographical location of the study area.

The study area, which is characterised by an endorheic hydrographic network, is part of a vast structural complex of the Saharan Atlas (Nedjimi & Homida, 2006). It is located in the last mountains of the Atlas range (Cherair, 2016). The geological substratum is constituted by Barenian sandstones with the interaction of thin layers of versicoloured clay (Cherair, 2016). The Barenian sandstones are overlain by formations belonging to the late Tertiary, but mostly Quaternary (Nedjimi & Homida, 2006).

The dominant vegetation in the region is the arid steppe. It is a transitional region between two types of vegetation, the formations of the high plateaus and the formations of the pre-Saharan regions. *Stipa tenacissima* L and *Artemisia herba alba* Asso groupings regress to a *Hammada scoparia* (Pomel) and *Thymelaea microphylla* Meisn grouping (Ghafoul *et al*., 2019). Climatically, the study area receives an average annual precipitation of 152.20 mm during the period (1990 – 2022). The hottest month is July with 37.16°C, and the coldest month is January with 2.07°C. It is located in the lower arid bioclimatic stage with a cool winter with a Q_2 equal to 14.81 (Khader *et al*., 2022).

Methodological approach: Subjective sampling is adopted to select the groves that best meet our work objective. For this purpose, two groves were chosen, namely the daya of Oum El Khechab and the daya of El Khoua (Table 1).

Table 1. Geographical coordinates of the groves studied.

Oum El Khechab	El Khoua
33°47'40.2"N3°48'38.3"E	33°50'09.5"N3°41'31.5"E

The first grove covers an area of approximately 60 ha and is located between 33°79' N and 3°81' E. This grazed grove is located at an altitude of approximately 691 m. The second grove covers 30 ha and is located between 33°83' N and 3°69' E, 39 km south of Messaâd and 11 km north of the town of Oum El Khechab. It is located at an altitude of approximately 661 m. Within each grove, dendrometric measurements of *P. atlantica* trees were carried out. These measurements concerned the diameter at 1.30 m, the total height and the bole height.

In total, we characterised 512 trees, 303 in Oum El Khechab and 209 in El Khoua. In order to facilitate the analysis, we grouped the studied trees based on diameter classes, height classes and bole height classes.

The diameter classes retained are: Ø ≤10 cm: Perchs (PER), 10 <Ø≤ 22.5 cm: Small wood (SW), 22.5 <Ø≤ 42.5 cm: Medium wood (MW), 42.5 < Ø≤ 62.5 cm: Big wood (BW), 62.5cm: Very big wood (VBW).

These diameter classes are selected by Guerine & Hadjadj (2019) for Atlas pistachio in Ain Benkhelil (Naâma) region, Hadjadj *et al*., (2019) for cork oak in the Hafir forest (Tlemcen) and Hadjadj *et al*., (2020) for *Fraxinus dimorpha* in the Ksours mountains.

For the height classes, we chose the following classes: Class 1:h ≤ 5m, Class 2: 5 <h≤ 10m, Class 3:10 <h≤ 15 m, Class 4:15 <h≤ 20 m, Class 5:h> 20 m.

Finally, the selected bole height classes are as follows: Class1: h_{bole} ≤ 1.50 m, Class 2: 1.50 <h_{bole}≤ 3 m, Class 3:h_{bole}>3m.

To make the horizontal projection of the crowns, we adopted the method proposed by Rondeux (1993), Pouderoux *et al*., (2001) and Grenier *et al*., (2007). The projected crown area could be made by measuring at least 4 radii, in directions making equal angles. The first radius was set randomly.

In the case of 4 radii (Ri), the area of the horizontal projection (Sp) results from the following root mean square:

$$\mathrm{Sp} = \pi * \sum_{i=1}^{n} Ri^2 /4$$

From this formula we deduced the crown diameter (d_{ho}):

$$d_{h0} = \sqrt{\frac{4}{\pi}\mathrm{Sp}} \quad = 2\sqrt{\sum_{i=1}^{n} Ri^2/4}$$

For a tree characterised by a total height h, a diameter at 1,30 m d, a crown diameter d_{ho} and a crown length h_{ho} we can get:

The crown proportion = h_{h0}/h and the degree of crown bulge = d_{h0}^2/h_{h0}

For the architectural diagnosis of *P. atlantica*, we adopted the ARCHI method, which is a visual diagnosis method of tree decline and resilience based on a reading of the architecture of the crowns (Drenou, 2014; Drenou & Caraglio, 2019). The ARCHI observation keys define six types, namely (Drenou*et al*., 2011, 2012) Healthy tree (Ht), Resilient tree (Rt), descending crown tree (Dct), Stressed tree (St), Irreversible dieback tree (Di) and Dead tree (Dt) (Table 2).

Statistical analysis of data: Some statistical parameters were determined to analyse the homogeneity or heterogeneity of the dendrometric parameters collected. these are the standard deviation (σ) and the coefficient of variation (CV). These two statistical parameters are indicators of dispersion and distribution of individuals around the mean (Grenier, 2007). The higher the value of the coefficient of variation, the greater the dispersion around the mean (Desroches & Neff, 1983; Bahouayila, 2016).

All dendrometric parameters were processed by principal component analysis (PCA). This is an extremely powerful tool for synthesizing information, very useful when there is a large amount of quantitative data to process and interpret (Besse, 1992; Jolliffe, 2002; Guerrien, 2003; Hadjadj, 2017).

Table 2. ARCHI types according to Drenou *et al*., (2011).

ARCHI types	Symptoms
Healthy tree (Ht)	Builds its crown by successive reiterations of its unity architectural
Resilient tree (Rt)	Forms orthotropic replacements (in red) to restore the original crown
Descending crown tree (Dct)	Builds a second crown below the original crown
Stressed tree (St)	Shows impoverished ramification, abnormal crown mortality and often responds by producing vigorous substitutes
Irreversible dieback (Di)	Is a blocked situation because the suckers are unable to replace the dying structures
Dead tree (Dt)	With dead cambium at 1,30 m above the crown

Results

Diametric structure of *P. atlantica*: The overall analysis of the distribution of stem numbers by diameter class in Oum El Khechab grove (Fig. 2) showed a clear dominance of the very big wood (VBW) and big wood (BW) classes with 50% and 19% respectively, which represented 69% of the whole grove. The perch class (PER) represented 9% of the stand with 27 trees, while the two small and medium wood classes (SW and MW) were equally represented with 32 trees (11%) each.

In general, this is an aged stand of Atlas pistachio trees with a regular structure dominated by 2 classes: big wood and very big wood).

El Khoua grove was characterised from a typological point of view by the dominance of small wood (37.8%), very big wood (25.4%) and perchs (22.5%). The other diameter classes have low proportions between 6.2% (medium wood) and 8.1% (big wood).

This is a young stand since perches and small wood make up 60.29% of the stand. Our stand, therefore, corresponds to a pure pistachio preforest with an irregular structure dominated by classes: perchs, small wood and very big wood.

We noted that the low densities of the intermediate classes, i.e., small wood (32 trees, or 11%) and medium wood (32 trees, or 11%) in Oum El Khechab grove and the medium wood (13 trees, or 6,2%) in El Khoua grove, reflected the difficulties encountered by the *P. atlantica* stand in Messaâd region to regenerate naturally by seeding. This natural regeneration only occurs within the clumps of jujube (*Ziziphus lotus* (L.) Lam.), which allow the seeds to germinate and protect them from grazing (Photo. 1). Indeed, this plant plays the role of a nurse plant, as reported by several authors, as it provides ideal natural environment (Monjauze, 1980; Belhadj, 2007, Guerine & Hadjadj, 2019).

Vertical structure of *P. atlantica*: The vertical structure reflects the distribution of individuals by height classes. It provides information on the potential of the site and the dynamism of the stand (Letreuch-Belarouci, 2009; Hadjadj & Letreuch-Belarouci, 2015; Hadjadj & Letreuch-Belarouci, 2018). The height of the stand at Oum El Khechab varied from 1.50 to 24.75 m. The average value for the whole grove was 11.46 m. The distribution of trees by height class showed the dominance of class 2 with 92 trees, followed by class 3 with 87 trees and class 4 with 74 trees. The respective frequencies are 30.4%, 28.7% and

24.4%, making a total of 83.5%. The class of shrubs (class 1), whose height did not exceed 3 m, had only 32 trees, or 10.6%. Trees with a height of more than 20 m represented the lowest proportion, i.e., 5.9%.

The height of the trees in El Khoua grove varied between 0.8 and 24 m, with an average of 7.90 m. This grove was characterised by the dominance of trees with heights of less than 3 m (class 1) with 107 individuals, which represented 51.20% of the stand.

The other classes occupied low to very low proportions (Fig. 3). Class 4, which contained trees between 15 and 20 m tall, occupied 17.70% of the stand, followed by class 2 with 15.8%. Trees between 10 and 15 m (class 3) accounted for 12.9%, and the last position was occupied by trees exceeding 20 m in height with only 2.4%.

Height of *P. atlantica* boles: The bole heights obtained in the first grove (Oum El Khechab) varied between 0.4 and 3.60 m, with an average of 2.4 m (Fig. 4).

The bole heights of the second class were the most dominant with a relative frequency of 82.8%. Trees with reduced boles (≤ 1.50 m) represent 9.6% of the stand, while trees with bole heights exceeding 3 m accounted for only 7.6%.

For El Khoua grove, the bole height varied from 0.30 to 11.20 m, with an average of 1.9 m. Like the other grove, the second class was the most represented with 584 %, followed by the class of reduced boles (≤ 1.50 m), with 38.3%. Trees with trunks exceeding 3 m in height were the least represented with a proportion of 3.3% (Fig. 4).

Statistical descriptors of dendrometric measurements: The statistical descriptors of the measured dendrometric parameters (total height, bole height and diameter) of the 512 Atlas pistachio trees composing the two studied groves are illustrated in the table below (Table 3).

Table 3. Statistical descriptors of the collected dendrometric measurements of the two groves.

	Oum El Khechab grove	El Khoua grove
Diameter at 1,30 m(m)		
Min	0,01	0,01
Max	1,72	1,53
Mean	0,63	0,39
Σ	0,37	0,31
CV (%)	58,56	79,49
Total height (m)		
Min	1,50	0,80
Max	24,75	24
Mean	11,46	7,90
Σ	5,41	5,91
CV (%)	47,19	74,75
Bole height (m)		
Min	0,40	0,30
Max	3,60	3,9
Mean	2,38	1,88
Σ	0,57	0,92
CV (%)	24,14	38,32

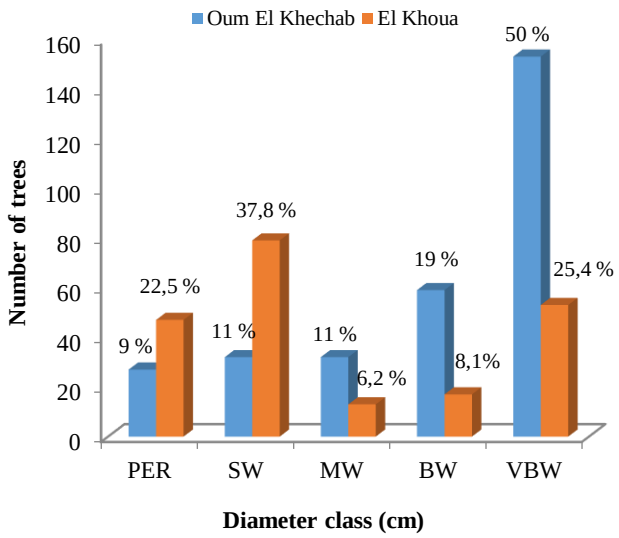

Fig. 2. Distribution of diameters by class of *P. atlantica* in the studied groves.

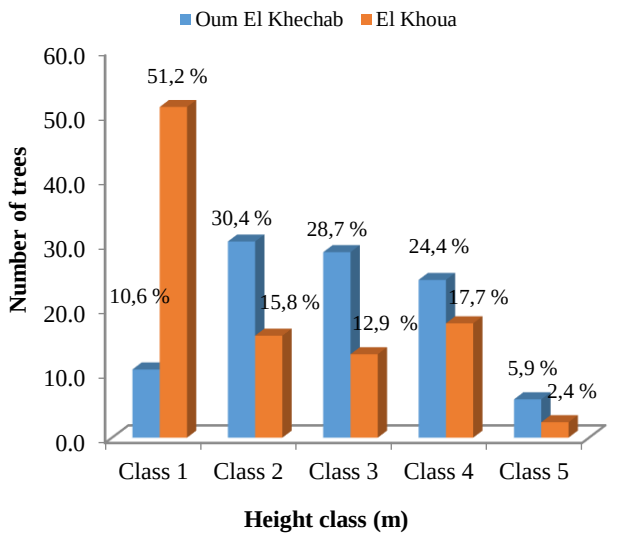

Fig. 3. Distribution of heights by class of *P. atlantica* in the studied groves.

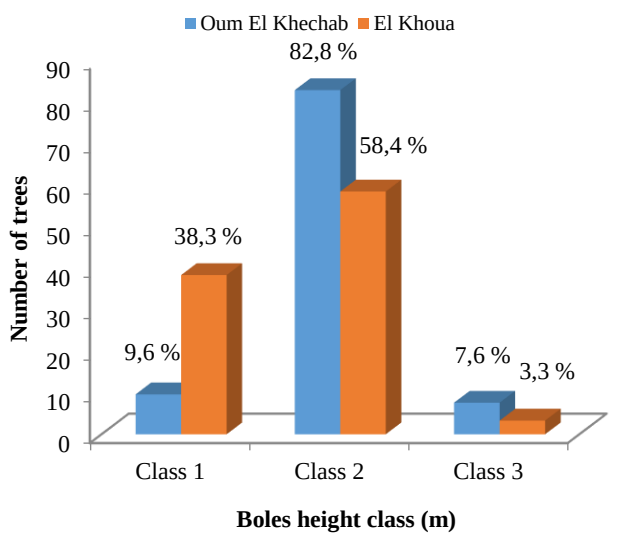

Fig. 4. Distribution of bole heights by class in the studied groves.

Table 4. Descriptive parameters of the Atlas pistachio crown in the studied groves.

Oum El Khechab Grove						
Diameter class		**PER**	**SW**	**MW**	**BW**	**VBW**
Sp (m^2)	Min	0,14	0,09	6,34	7,21	13,64
	Max	18,65	65,70	43,91	104,16	217,92
	Moy	***3,49***	***14,01***	***24,92***	***54,31***	***156,52***
Dho (m)	Min	0,42	0,35	2,84	3,03	4,17
	Max	4,87	9,15	7,48	11,52	16,66
	Moy	***1,97***	***3,89***	***5,51***	***8,13***	***11,18***
h_{h0}/h (%)	Min	22,73	26,32	60,00	44,12	38,82
	Max	78,18	82,22	83,75	86,43	91,35
	Moy	***51,97***	***65,70***	***71,75***	***72,54***	***81,10***
$d_{h0}2/h_{h0}$(m)	Min	0,16	0,24	1,42	1	1,10
	Max	6,75	19,24	12,45	18,69	29,81
	Moy	***2,54***	***4,82***	***5,90***	***9,84***	***10,54***
El Khoua Grove						
Diameter class		**PER**	**SW**	**MW**	**BW**	**VBW**
Sp (m^2)	Min	0,10	0,55	6,58	10,87	12,47
	Max	9,18	96,52	40,48	130,64	183,73
	Moy	***1,70***	***13,97***	***19,77***	***68,08***	***105,69***
Dho (m)	Min	0,36	0,84	2,89	3,72	3,10
	Max	3,42	11,09	7,18	12,90	15,30
	Moy	***1,28***	***3,52***	***4,87***	***9,01***	***10,57***
h_{h0}/h (%)	Min	11,76	46,67	52,50	67,57	38,31
	Max	89,57	78,46	88,57	85,78	88,91
	Moy	***50,28***	***63,67***	***74,77***	***75,27***	***78,78***
$d_{h0}2/h_{h0}$(m)	Min	0,02	0,35	1,53	1,75	0,95
	Max	8,99	58,55	12,28	19,66	15,87
	Moy	***1,83***	***5,89***	***4,62***	***10,51***	***9,57***

The results showed that the crown of the Atlas pistachio tree in the studied groves presented the following quantitative descriptors:
- a projected crown area ranging from 3.49 to 156.52 m^2 in Oum El Khechab and from 1.70 to 105.69 m^2 in El Khoua;
- a crown diameter ranging from 1.97 to 11.18 m in Oum El Khechab and 1.28 to 10.57 m in El Khoua;
- a crown proportion ranging from 51.97 to 81.10% in Oum El Khechab and 50.28 to 78.78% in El Khoua;
- a degree of crown bulge ranging from 2.54 to 10.54 m in Oum El Khechab and 1.83 to 9.57 m in El Khoua

Table 5. Eigenvalues of PCA Axes.

Components	Eigenvalue	Total variance (%)	Cumulative eigenvalue	Cumulative variance (%)
1	5,806348	**72,57935**	5,806348	72,5794
2	0,988419	**12,35524**	6,794768	84,9346
3	0,507536	6,34420	7,302303	91,2788
4	0,365625	4,57031	7,667928	95,8491
5	0,203222	2,54028	7,871150	98,3894
6	0,115797	1,44746	7,986947	99,8368
7	0,013053	0,16317	8,000000	100,0000

In our case, we found that there was significant variability between the diameters of the Atlas pistachio in the examined groves since the obtained coefficients of variation were respectively 58,56% in Oum El Khechab and 79.49% in El Khoua.

This finding is also valid for the total heights of the Atlas pistachio tree in Oum El Khechab (CV ≈ 47.19%) and El Khoua (CV ≈ 74.75%) groves. In addition, there was a mean variability between the tree bole height in that the coefficient of variation was close to a quarter of the mean (CV ≈ 24.14%) in Oum El Khechab and a third (CV ≈ 38.32%) in El Khoua.

Descriptive parameters of the *P. atlantica* tree crown: To describe the quantitative characteristics of the Atlas pistachio tree crown, the previously established diameter classes were used (Table 4).

Principal component analysis (PCA): The eigenvalues of the PCA axes are given in (Table 5).

The principal component analysis performed on the dendrometric parameters collected from the field (total height, bole height, crown height, diameter at 1.30 m) and those calculated (crown diameter, projected crown area, crown proportion, degree of crown bulge) generated a

correlation circle exposing a factorial plane F1-F2 that explained the maximum information, with 72,58% and 12,36% of the variation in the data, respectively (Fig. 5).

This circle revealed a significant positive correlation between crown height, total height and the proportion of the crown whose vectors are overlapped. This positive correlation was also observed between the diameter at 1,30 m and the bole height and between the crown diameter and its projected area. Finally, the degree of crown bulge showed a weak correlation with the other variables.

The strong correlation between total height and crown height and crown diameter and projected area was reported by Grenier *et al*., (2007) in their study of the dendrometric characteristics of sugar maple in Mont-Laurier.

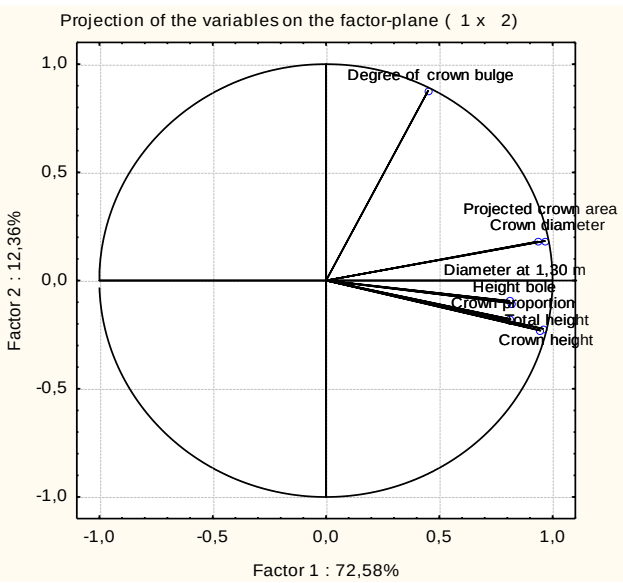

Fig. 5.Correlation Circle Illustrating the Correlations between the Seven Axes.

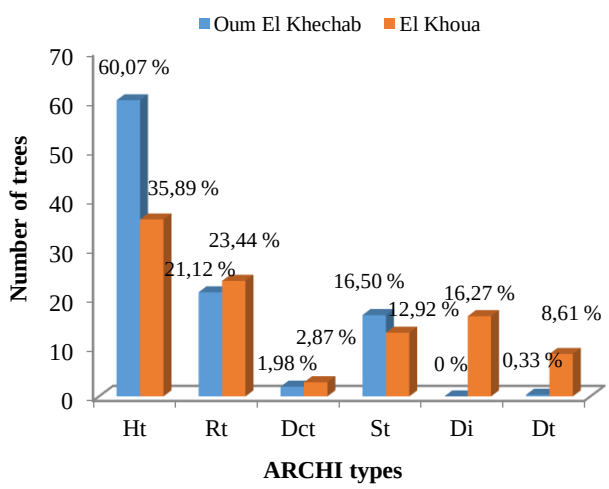

Fig. 6. ARCHI Types Identified at Oum El Khechab and El Khoua groves.

Architecture of *P. atlantica*: ARCHI Types (Photo 2): The architecture is of diagnostic value as it provides information on the developmental sequences of each species as well as on the deviations from normal caused by stress. The ARCHI method takes into account the two components of dieback, namely: the symptoms of crown degradation, i.e. deviations from normal, and the resilience processes, i.e. returns to normal (Drenou, 2009). The method was developed for the first time on pedunculate oak (Drenou *et al*., 2011 and 2012), then on silver fir (Giraud, 2012; Gravier, 2012).

Oum El Khechab Grove: We noted that healthy trees (Ht) constituted a major part of the stand with 182 individuals, i.e., 60.07%. The resilient type (Rt) was represented by 64 trees, i.e., 21.12%, and the stressed type (St) has 50 trees, i.e., 16.50% of the total. These three ARCHI types accounted for 97.69% of the stand. Descending crown tree (Dct) and dead trees (Dt) account for only 2.31% of the stand, with 6 descending crown tree (1.98%) and one dead tree (0.33%). We noted the total absence of trees in irreversible decline (Di) in Oum El Khechab (Fig. 6).

El Khoua Grove: The healthy type (Ht) was still in the majority as in the previous grove but with a lower proportion, i.e., 35.89% (75 trees). The resilient type (Rt) was in second place with 23.44% (49 trees). 34 trees were in a state of irreversible decay (Di) with a rate of 16.27%. Stressed trees (St) represented 12.92% (27 trees). Dead trees (Dt) occupied an important place here, with a rate of 8.61%, i.e., 18 trees, and finally, trees showing the symptom of crown descent (Dct) remained low, with a rate of only 2.87%, i.e., 6 trees (Fig. 6).

Discussion

For structural diagnosis, the diametric structure (D.S) provides information on the stability of the stand (Vincent *et al*., 1988; Favrichon, 1995; Gourlet-Fleury, 1997), and reflects the organisation mode of the forest and pre-forest ecosystem (Hasnaoui, 1992).

The analysis of the current S.D of the *P. atlantica* stands in Messaâd region allowed us to observe a great diversity within the same station and from one station to another. This structure is defined by a homogeneous aspect of the dimensions of the trees in Oum El Khechab grove, dominated by two classes of diameters (big wood, very big wood). This aged stand is characterised by a natural regeneration rate of 9% (subjects with dhp≤ 7.5 cm ⌀). El Khoua grove presents a heterogeneous aspect of tree dimensions, it is characterised by the dominance of three diameter classes (perches, small wood, very big wood). The natural regeneration rate is estimated at 22.5%.

The results obtained in this study were in line with those reported by Guerine & Hadjadj (2019) and Hadjadj *et al*., (2022), who highlighted the state of ageing and insufficient natural regeneration of *P. atlantica* stands in the arid steppe of Gaaloul (Naâma province, Algeria). According to Yahia (2011), 78.5% of the stands of *P. atlantica* in the stations of Batam, Benzouh, Belaroug Zaouia, Botmat in Tamsa and Dayat El Botm in the region of M'sila are dominated by very aged trees.

Another factor that can explain the dynamics of the studied Atlas pistachio stands is the distance of the stands from the town and households. Indeed, natural regeneration is high in El Khoua grove (22.5%) compared to Oum El Khechab grove (9%) which is located right next to the city of Oum El Khechab, which exposes it to anthropogenic factors (grazing, firewood cutting).

In terms of vertical structure, we recorded an average height of 11.46 m at Oum El Khechab station and 7.90 m at El Khoua station. Ifticene-Habani & Messaoudene (2016) reported average heights of 10.92 m at Aïn Oussara (Djelfa), 11.01 m at Messaâd (Djelfa), 8.77 m at Djedida (Bechar) and 7.53 m at Oum Chegag (Bechar). Yahia (2011) reported an average height of 6.1 m of *P. atlantica* stands in M'sila region with a maximum of 17 m and a minimum of 0.4 m. These results lead us to describe the Atlas pistachio tree, in these stations, as a heterogeneous structure.

Concerning the architectural diagnosis, the results of this study confirm the importance of the diagnosis of tree crowns in general and *P. atlantica* stands in particular. The ARCHI diagnostic method developed in this research provides forest managers with a simple and effective decision-making tool that enables them to choose the right silvicultural interventions. The current health status of the Atlas pistachio in Oum El Khechab grove revealed that 60.07% of the trees were healthy and that the resilience capacity was estimated at 21.12%. The dead trees were only 0.33% and those in irreversible decline were absent. However, the results of the ARCHI diagnosis in El Khoua grove were different from the first station. In this case, the healthy trees represented 35,89% and the resilience rate was 23.44%. The rate of irreversible decay was estimated at 16.27% and that of dead trees was 8.61%. From our surveys, we found out that the talwegs feeding this depression had been completely closed, which had exposed the Atlas pistachio to a very high-water deficit. This is probably the most plausible justification for the high rates of irreversible dieback and dead trees.

Photo. 1. Natural regeneration of *P. atlantica* inside Jujube in Oum El Khechab grove (By the authors, June 2022).

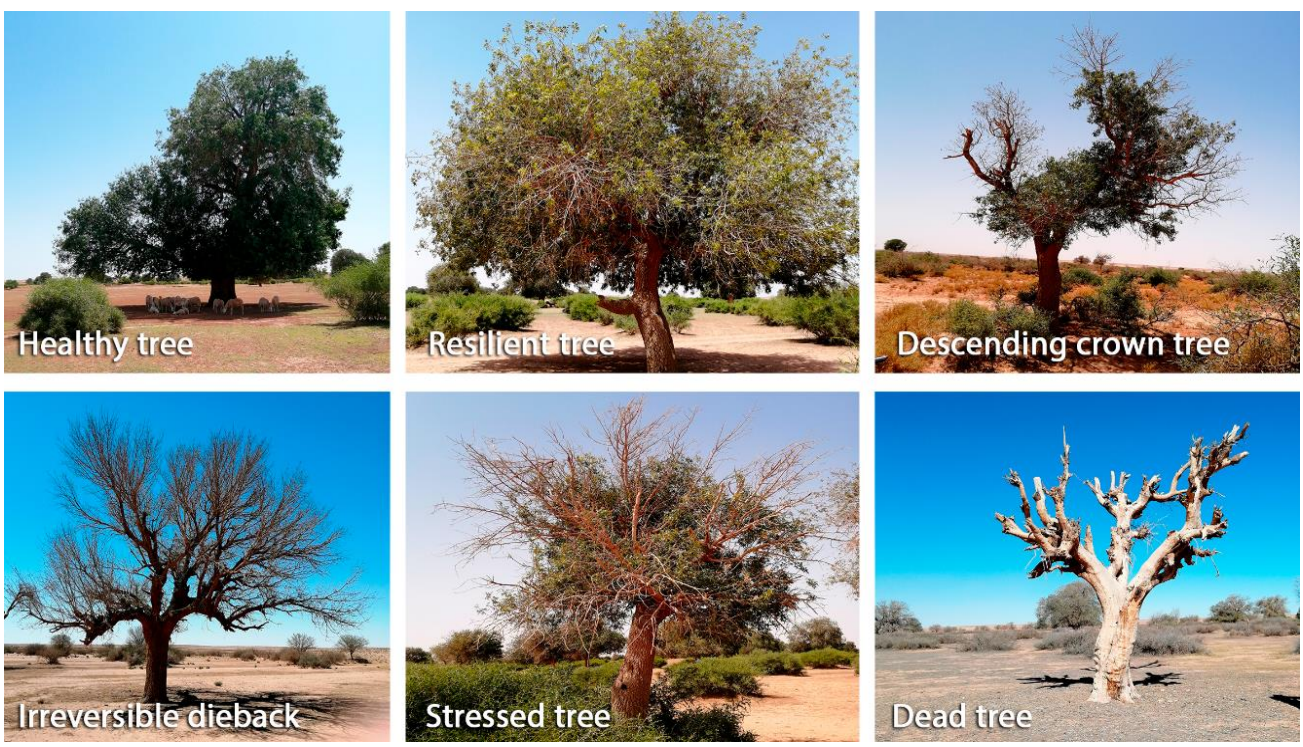

Photo. 2. Photos of ARCHI types identified for *P. atlantica* in Messaâd region (By the authors, June 2022).

Conclusion and Perspectives

The Atlas pistachio tree (*Pistacia atlantica* Desf.) deserves more importance in terms of rehabilitation and extension in biodiversity conservation programmes in Algeria, due to its interest both from an ecological point of view (plasticity, hardiness, drought resistance, soil conservation, etc.) and from an economic point of view (production of essential oils, fodder, wood, beekeeping, recreation, etc.).

This research is essentially focused on the study of structural dynamics (diametric and vertical structure, descriptive parameters of the crown) and resilience capacity (ARCHI diagnosis).

The results made it possible:

- to clarify the different notions related to the structural and architectural dynamics of the species;
- to propose an ARCHI determination key for the Atlas pistachio;
- to provide forest managers with a tool in the form of tables, figures and illustrations to guide them in their rehabilitation work on the species.

It remains very useful to continue monitoring the dynamics of this protected species and to combine the use of the ARCHI method and new technologies such as remote sensing by integrating climatic and soil data.

Acknowledgments

The authors extend their appreciation to Researchers Supporting Project number (RSP2024R390), King Saud University, Riyadh, Saudi Arabia.This research was funded by the Researchers Supporting Project No. (RSP2024R390), King Saud University, Riyadh, Saudi Arabia.

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(Received for publication 28 November 2022)