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Dendrometric study of stands of *Pistacia atlantica* in southwestern Algeria

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Abstract: In the southwestern part of Algeria, the stands of Atlas pistachio (*Pistacia atlantica* Desf.) constitute a special natural heritage. They are usually scattered between the steppe plains and the Saharan Atlas. This study was conducted with the aim of identifying the dendrometric characteristics of Atlas pistachio that could be indicators of good productivity. The aim is to investigate the influence of stationary factors (slope, exposure, geology) on the dendrometric characteristics of *Pistacia atlantica*. The results obtained on the dendrometric parameters of this species are very interesting. From a dendrometric approach, *Pistacia atlantica* is a large tree that can reach impressive dendrometric dimensions: 8 to 10 meters in height and a diameter often exceeding 100 cm. This dendrometric analysis allowed us to make a structural characterization of stands of *Pistacia atlantica*, which is an essential step in the management plan and the valuation in the medium or long term. This species of *Pistacia atlantica* deserves adequate measures of protection, especially in its natural environment. Therefore, a better knowledge of their potentialities, problems, and factors of the decline of this hardy species would contribute to the protection and the preservation to favour their regeneration, which would allow a better extension of this species.

Keywords: stands, *Pistacia atlantica*, southwestern, Algeria, dendrometric

Introduction

The Atlas pistachio tree (*Pistacia atlantica* Desf.) is extremely widespread in the eastern Mediterranean area (Greece, Cyprus, Turkey, Syria, Palestine, Crimea, Iran, Afghanistan, and as far as India) [1]. But it can also be found in the south of North Africa, scattered in the arid and semi-arid regions [2]. It is quite common throughout Algeria; its habitat can extend from the Tell Atlas with a humid soil to the arid and even Saharan regions, where it is scattered (isolated), or in the depressions (*dayas*) on the high steppe plains, the northern Sahara, at the foot of the Saharan Atlas in the best watered parts, and even in the Hoggar in a "relic" state [3–7].

In the southwestern part of Algeria, *Pistacia atlantica* stands have a very extensive botanical area, covering relatively large areas per thousand hectares between the steppe plains and the pre-Saharan region of the Saharan Atlas. These pistachio trees are generally dispersed (rocky outcrops, thalwegs, ravines, and wadi beds) or grouped in the form of a grove, mainly in the alluvial depressions [8–13].

The *Pistacia atlantica* is a sclerophyllous deciduous species, typical of the Mediterranean region. It belongs to the family Anacardiaceae, which once formed dense stands. Due to its poor regeneration, the pistachio tree is becoming increasingly rare because its seeds do not germinate well and are often grazed by both wild and domestic herbivores. *Pistacia atlantica* is one of the endemic (autochthonous) species widespread in the southwestern part of Algeria; it shows a perfect adaptation to extreme conditions.

The aim of the study is to identify the dendrometric characteristics of the *Pistacia atlantica* stands in the southwestern part of Algeria, which could serve as indicators of the potential of a forest management process.

Materials and methods

Study area

On a biogeographic level, the study area belongs to the Mediterranean zone, the highlands sector, and the Saharan Atlas sector, according to Quézel and Santa's subdivisions [14].

A field survey aims to delimit the areas potentially favourable to the development of *Pistacia atlantica*. It was carried out in order to identify and discover the general distribution of *Pistacia atlantica* trees according to the selected criteria (biotope, climate, edaphic, etc.) on 12 well-distributed populations of the study area (*Tab. 1* and *Fig. 1*).

Table 1. Location of study stations

Station no.	Region	Geographic coordinates		
		X	Y	Z (m)
Station 1	El Bayadh	N 32°33'21.6"	E 0°01'29.8"	835
Station 2	El Bayadh	N 33°02'40.3"	E 1°02'20.7"	955
Station 3	El Bayadh	N 33°15'32.9"	E 1°36'57.7"	970
Station 4	El Bayadh	N 33°19'38.7"	E 1°37'27.5"	990
Station 5	Naama	N 32°44'20.0"	W 0°27'14.4"	1,040
Station 6	Naama	N 32°49'06.2"	W 0°13'54.1"	1,145
Station 7	Naama	N 32°59'24.7"	W 0°41'51.6"	1,345
Station 8	Naama	N 33°23'01.0"	W 0°57'46.6"	1,122
Station 9	Bechar	N 31°58'17.06"	W 1°32'17.80"	840
Station 10	Bechar	N 32°00'21.00"	W 1°38'05.13"	780
Station 11	Bechar	N 31°49'03.39"	W 1°45'41.69"	724
Station 12	Bechar	N 32°04'36.16"	W 2°17'45.31"	960

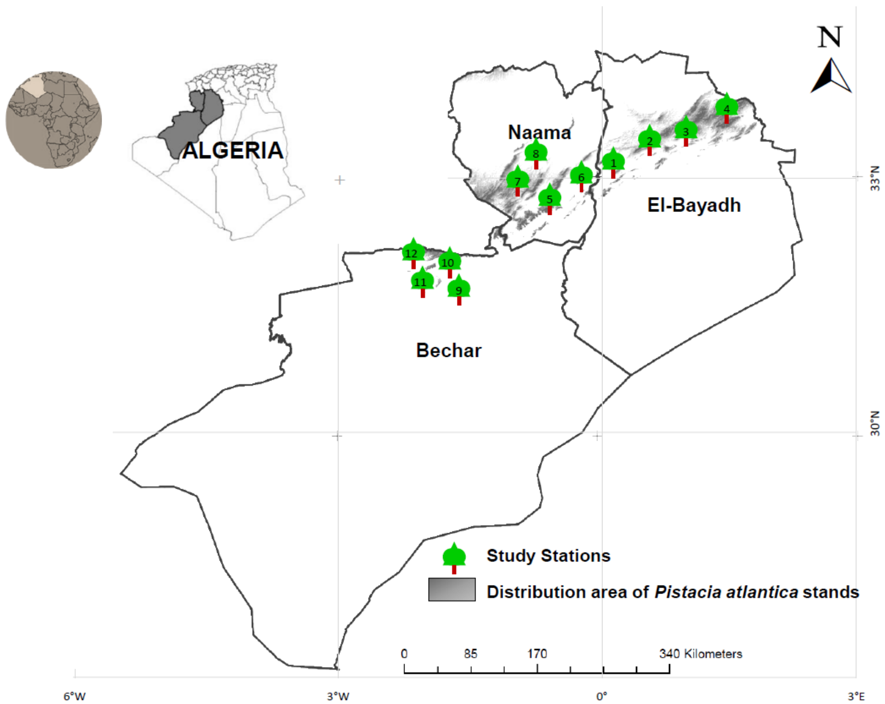

Figure 1. Geographical location of the study area

In terms of climate, the study area is characterized by low and irregular rainfall (between 100 and 250 mm/year) and a fairly long dry period of 6 to 7 months. This explains its belonging to the arid bioclimatic stage [11, 15, 16].

The table below provides the climatic characteristics of the most representative weather stations in the area of *Pistacia atlantica*.

Table 2. Climatic characteristics of study stations (1990–2014)

Region	**Bechar**	**Naama**	**El- Bayadh**
Altitude (m)	807	1166	1341
Rainfall (mm)	112	219	284
Maximum temperature M (°C)	40.7	36.8	34.88
Minimum temperature m (°C)	3.15	0.32	-0.35
Thermal amplitude (M – m (°C)	37.55	36.48	35.23

Materials used (biological and technical)

The study focuses specifically on groups of *Pistacia atlantica* spontaneously occurring in the southwestern part of Algeria.

The following equipment was used:

– Blume-Leiss dendrometer for measuring the heights of trees,
– GPS (Global Positioning System) device for the positioning of trees,
– compass to establish the direction,
– camera to take the pictures,
– tape for the measurement of the circumference at 1.30 m from the ground.

Methodological approach

In the field of forestry, if qualitative criteria are very often used to describe and compare stands, it is sometimes necessary to use numerical data to refine the description and better understand the evolution of a plot [17].

The dendrometric appreciation of a forest stand is based on the study of height, basal area, and density [18].

Various dendrometric measurements were made of the trunk of the trees for *Pistacia atlantica* in the field and to investigate the relationship between the diameter and height of the tree.

The dendrometric analysis included 239 sample trees (individuals) of *Pistacia atlantica* taken at random from the study area. It was based on the determination of the stand dendrometric variables: classes of diameters and classes of heights.

The comparison of the results obtained from the field data was made on the following dendrometric parameters:

Tree height

Table 3. Distribution of trees by height classes

	Class	**Height (m)**
1	Class 1	> 3 m
2	Class 2	3–6 m
3	Class 3	6–9 m
4	Class 4	9–12 m
5	Class 5	12–15 m
6	Class 6	> 15 m

Tree size

The size of a tree is the most commonly used and measured dendrometric characteristic. According to Lombardini et al. [19], the four broad categories of diameter to differentiate trees are defined as shown in the table below.

Table 4. Tree diameter categories

	Trees categories	**Diameter Φ (cm)**
1	Small trees	7.5–22.5
2	Medium-sized trees	22.5–42.5
3	Large trees	42.5–62.5
4	Very large trees	> 62.5

Density of trees

Density refers to the number of trees on a given surface area [17]. This was estimated by counting the number of subjects of *Pistacia atlantica* per hectare.

Results and discussions

Determination of the main dendrometric parameters

a) Height

The results obtained from the distribution of trees by height classes are given in the form of histograms (*Fig. 2*). This figure shows the vertical structure of the woody *Pistacia atlantica* stand in the study area.

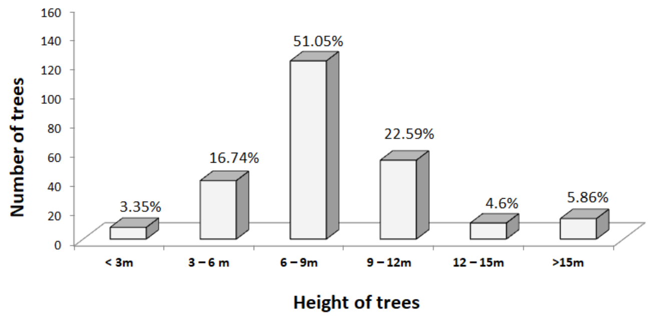

Figure 2. Distribution of *Pistacia atlantica* trees by height class (m)

Results obtained from the distribution of trees by height classes show that the structure is rather heterogeneous because of the high variability of the stems (trunk).

The interpretation of *Figure 2* confirms the following:

– The dominance of heights from 6 to 12 m in the sampling plots at Bechar.
– The first, fifth, and sixth classes are poorly represented in these same plots.
– At the level of the stand sampled at Naâma, there is a dominance of heights of 4 to 10 m and the total absence of trees from 12 to 16 m.
– For the plots studied in the El Bayadh region, we note that the heights mostly range between 6 and 12 m, with the total absence of the subjects in the range of 14–16 m.

The comparison between the results obtained in the different study areas reveals a divergence between the studied Bechar stand and that of Naama and El Bayadh. In fact, the growth in height of *Pistacia atlantica* in Bechar is greater than those of Naâma and Bayadh. This can be justified by the grazing, which is frequent in the areas of El Bayadh and Naama.

Most of the woody species are best represented and grouped in class 6–9 m; this is the class of the most dominant stratum, and it represents 51% of the total number of tree individuals recorded in the study area. The individuals of the classes 9–12 m represent 23%, or 54 subjects of *Pistacia atlantica*. Individuals with a height greater than 12 m are less represented (10%) than the two higher classes (12–15 m and > 15 m) of *Pistacia atlantica* tree. Class 3–6 m individuals take the 3rd place with 17% of total trees measured. The class of < 3 m represents only a small percentage, not exceeding 3.35% of all individuals, which indicates the importance of individuals less than 3 m tall and also testifies to an increased natural regeneration.

All these results and the observations made allow us to deduce that the percentages of height classes differ from one station to another. This is mainly due to several indicators related to the diversity of geomorphological, topographic, climatic, and hydrologic units, biotope, pedo-climatic characteristics, anthropization (logging, overgrazing), etc.

b) Diameter (Φ)

All mean values of the size (circumference or diameter) of a stand are calculated from the frequency distribution of the numbers of trees by size category. *Figure 3* below shows the distribution of the *Pistacia atlantica* trees by diameter classes given in the form of a histogram.

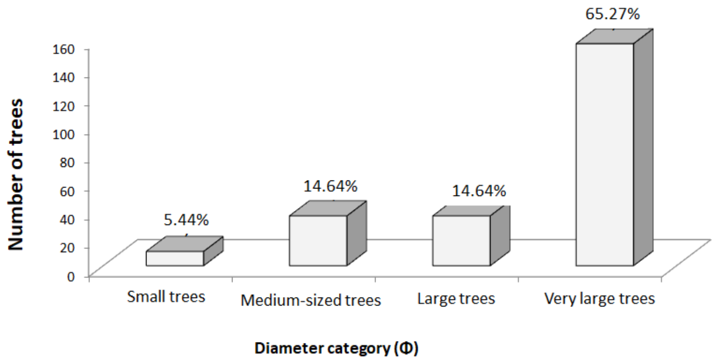

Figure 3. Distribution of trees by diameter classes of *Pistacia atlantica*

The analysis in *Figure 3* shows that the diameter class distribution is quite heterogeneous in the study area. In fact, the majority of the individuals are in the category of very large trees (> 62.5 cm). This category represents 65% of the trees measured in the study area. It is generally characterized by depressions (the case of stations no. 2, 4, 8, and 12); this is explained by favourable humidity and deep soil.

Figure 4. Example of vigorous trees (very large trees) in the study area

For the other categories, individuals of diameters in the ranges of 22.5–42.5 cm and 42.5–62.5 cm represent 14.6% each. Individuals in the small trees category (7.5–22.5 cm) account for only 5.44% of the total trees measured. The latter category of very large trees is somewhat remarkable, especially under the shelter of the clumps of jujube (*Ziziphus lotus*), which is indicative of the regeneration possibilities of the pistachio tree in the study area.

These results are consistent with those obtained by Terras [20], Benaissa [21], and Mansour [22] and suggest the potential of natural regeneration. This regeneration is generally carried out within the clumps of *Ziziphus lotus* (Rhamnaceae), which protect the young shoots of the *Pistacia atlantica* against pasture and promote the germination of their seeds as well as the growth of their young shoots by enriching the soil with organic matter [5, 23, 24, 25]. The regeneration of the *Pistacia atlantica* was also observed inside a tuft of *Retama retam* [10].

When the young regenerated foot reaches a certain height by adapting to the medium, the jujube is found in a lower layer and gradually disappears from its immediate vicinity [24]. In our stations, we have noticed some cases of regeneration of the Atlas pistachio tree at the level of inaccessible mountain cliffs, also acting as a shelter for the animals feeding on it and retaining water precipitation that promotes seed germination.

c) Density

The dendrometric study will allow the estimation of the density and determination of tree structure in the study area.

Density is defined as the total number of stems per unit area [26]. *Figure 5* summarizes the results of the study regarding the tree density of *Pistacia atlantica* stands in southwestern Algeria.

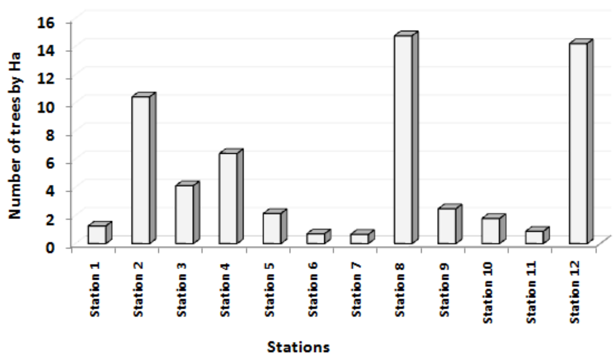

Figure 5. Density of *Pistacia atlantica* trees per hectare

The analysis of the above figure indicates that the highest density of trees is found in the depressions (the case of stations 2, 4, 8, and 12) with 14 subjects, in which case *Pistacia atlantica* is a rather large tree, very massive and spectacular. *Pistacia atlantica* is found in denser stands, i.e. 10 trees/ha in dayas. The regeneration of some young plants has been observed in more or less protected areas. Indeed, this regeneration is always carried out inside the jujube (*Ziziphus lotus*), which would constitute a good protection to the young shoots against winds and herds.

On the other hand, the lowest density is found at Station 7: with only 0.65, it is well dispersed. Density values for stations 1, 5, and 6 are 2.13, 1.25, and 0.70 respectively. The average density in relation to the total area is 8 subjects/ha, where the trees of *Pistacia atlantica* and *Ziziphus lotus* are scattered in isolated spaces because of the drought conditions that afflict this species in the Saharan region. According to Boudy [27], the drier (arid and semi-arid) a forest region, the lower the density of its mature stands because the roots need a considerable living space to draw water from the soil.

Despite this low density, tree growth is relatively good, which may be due to the location of trees in unfavourable sites: the presence of the species in isolation and on riverbanks (depression, wadi beds). A small difference, which is insignificant, is the influence of certain environmental factors.

Pistacia atlantica trees are generally found in well-ventilated and sunny sites, requiring a large spacing between trees to avoid competition. The distance to be applied is more than 20 m, or 10 to 20 trees per hectare in depressions. Often, however, this spacing is not sufficient and must be given more than 100 m, or 1 to 8 trees per hectare.

Correlations between the diameter and height of trees

The study of correlations between the diameter and the height of the trees of a stand makes it possible to highlight the relationships between the dendrometric characteristics of the subjects studied. It also allows learning about the behaviour of *Pistacia atlantica* trees towards the biotic and abiotic factors of the environment.

The linear trend curve and the equations connecting the diameter and the height of the different subjects of *Pistacia atlantica* studied are represented in *Figure 6*. The linear regression lines obtained made it possible to highlight certain correlations.

Results show that the correlation coefficients obtained are all greater than zero ($r > 0.44$) in all the study stations. Almost all established correlations are in close relationship, which translates into the response of *Pistacia atlantica* to the edapho-climatic conditions of the environment. The correlation coefficient characterizing the relationship between the height and the diameter of the Atlas pistachio trees is 0.445 for Naâma, 0.564 for El Bayadh, and 0.681 for Bechar. This confirms that these coefficients are well linked and correlated.

Based on the value of the correlation coefficient, the tree height of *Pistacia atlantica* is closely related to its diameter. Nevertheless, there is a weak correlation between the height and diameter of young *Pistacia atlantica* shoots of a small diameter. This is probably due to the juvenile age of the stand and overgrazing.

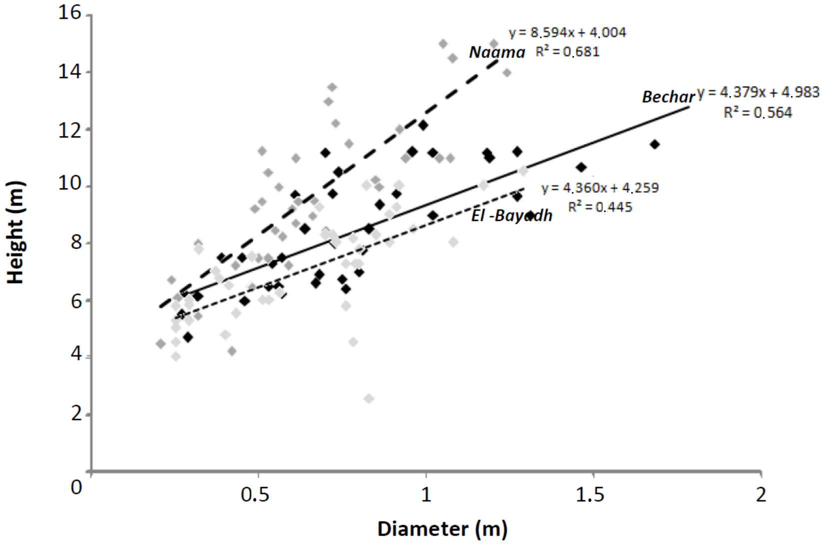

Figure 6. Correlation between the height and diameter of trees

The relationships we found between the measured parameters can be explained by the influence of the stationary, microclimatic, and edaphic factors on the morphology of *Pistacia atlantica* trees.

Diameter growth is generally related to edaphic and climatic conditions and the impact of anthropogenic factors. As an example for low-density stations, the growth of the tree is relatively good; this may be due to the location of the trees in very favourable sites: the presence of the species in an isolated state in the hydrographic network. Therefore, Pistachio trees are generally found in well-ventilated and sunny locations, requiring a large spacing between trees to avoid competition [8, 9, 11, 12, 28].

Pistacia atlantica is one of the tree species inhabiting the arid and semi-arid lands of northern Africa [14]. It is a perennial, hardy, and endemic taxon that can live for several centuries by adapting perfectly to the edaphic and climatic conditions of its habitat [29].

Conclusions

These stands of *Pistacia atlantica* cover vast expanses of the Saharan Atlas and the high steppe plains of Algeria. They constitute an important off-forest heritage of South-West Algeria.

Pistacia atlantica is a large tree that can grow to a large dendrometric size of 8 to 10 meters in height and often more than 100 cm in diameter. Its crown is voluminous and rounded. It is more abundant in the Saharan region (altitude from

700 to 1,400 m). The analysis of the effect of the distribution of *Pistacia atlantica* groups on dendrometric parameters (diameter and tree height) shows a significant difference between the averages of height classes and those of diameters. This indicates that the heterogeneity of the structure of these Atlas pistachio trees between stations depends on the environmental factors of the study environment (geomorphology, lithology, geology, anthropic impacts).

These stands of *Pistacia atlantica* can be an excellent barrier between the high steppe plains and the Saharan space against the advance of the desert. Its rehabilitation and conservation are therefore necessary to safeguard and enhance it so as to contribute to the sustainable development of these fragile arid zones.

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