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CONTRIBUTION TO STUDY OF COMPETITION BETWEEN CORK OAK CROWNS IN THE OULED BECHIH FOREST (ALGERIA)

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Abstract

Touafchia B., Rached-Kanouni M., Zerrouki A.: Contribution to study of competition between cork oak crowns in the Ouled Bechih forest (Algeria). Ekológia (Bratislava), Vol. 43, No. 2, p. 167–174, 2024.

The discipline of silviculture is rapidly developing, based on stand structures or ecosystems, in which stands are managed according to species and structures. The objective of this study is to characterize the growth of cork oak dendrometric variables, and to determine and compare the different crown parameters and their effects on natural regeneration in the Ouled Bechih forest (Algeria). Eight plots of this forest were selected and they underwent a dendrometric study. The results obtained indicated that these plots were moderately dense. The analysis of dendrometric variables by variance analysis showed that there was a significant difference ($p < 0.05$). The distribution of individuals by height and diameter classes indicated a large representation of individuals with heights of 10–15 m and diameters of $27.5 < d \leq 47.5$ cm. The variables selected in the descriptive analysis have a low impact on the heterogeneity of this forest on height and diameter growth. The study of the different crown parameters showed that there was a difference between the plots, and indicated that cork oak trees have a large crown depending on their surface and diameter. These results show that the cork oak in the Ouled Bechih forest is characterized by trees of large diameter with medium heights, due to the predominance of older individuals with more developed crowns. This type of structure leads to strong inter-tree competition in the stand and a low rate of natural regeneration.

Key words: Ouled Bechih forest, *Quercus suber* L., crown structure, natural regeneration

Introduction

Cork oak (*Quercus suber* L.) is a woody species distributed in the Mediterranean climate zones of Western Europe and North Africa, with a narrow geographic range compared to other Mediterranean oak evergreen species such as holm oak (*Q. ilex* L.) These species are of ecological, economic, and social importance, particularly in terms of their biodiversity and sustainable forest production in these areas (Bouazza, 2022).

Cork oak forests are a very important source of income and a sector that is the source of thousands of businesses in Mediterranean countries at various levels of production. Moreover, cork oak is linked to exceptional biodiversity and represents unique ecosystems recognized for their ecological importance (Silva, Catry, 2006). Wood and acorns are precious resources, especially in North Africa. Cork oak is also used for hunting, mushroom gathering, honey production, and tourism (Oliveira, Costa, 2012).

In Algeria, cork oak forests are essentially situated in the north of the country. They stretch between the Tunisian and Moroccan borders, but the largest massifs are located in the east of the country. Between 2001 and 2011, the 230,000 ha of cork oak produced an average of 7000 t/year, compared to 15,000 t/year between 1964 and 1975. The decline in cork oak forest production in Algeria and the Mediterranean basin, in general, has been reported by several authors, who attribute it to fires, overgrazing, and climatic hazards (Aafi et al., 2005; Silva, Catry, 2006; Benabdellah, Amrani, 2014).

Study of stand composition and dynamics by tree size is a good indicator of the state of the forest, both now and in retrospect. In fact, an increased lack in one of the size or height classes is considered a sign of imbalance (McCarthy, Weetman, 2006). In a closed stand with a competitive relation and a social structure, these two variables are obviously biologically linked (Deleuze et al., 1996); height provides an advantage in the competition for light, so that dominant trees have better growth, and particularly, a larger circumference. This competition thus maintains a social structure in the stand, a true relationship of order between trees.

In a forest, the canopy is considered to be the uppermost layer of vegetation. Characterization of the canopy is essential for the management and sustainable use of forest resources, particularly for identifying tree species and monitoring their growth. It helps in monitoring the evolution of biodiversity, cultivation techniques, and the impact of meteorological factors (rainfall patterns, storms, etc.) (Cuesta et al., 2010). In addition, forest cover diversity is an important factor in the variation of understory light environment characteristics. Hence, heterogeneity plays a crucial role in determining tree regeneration patterns and

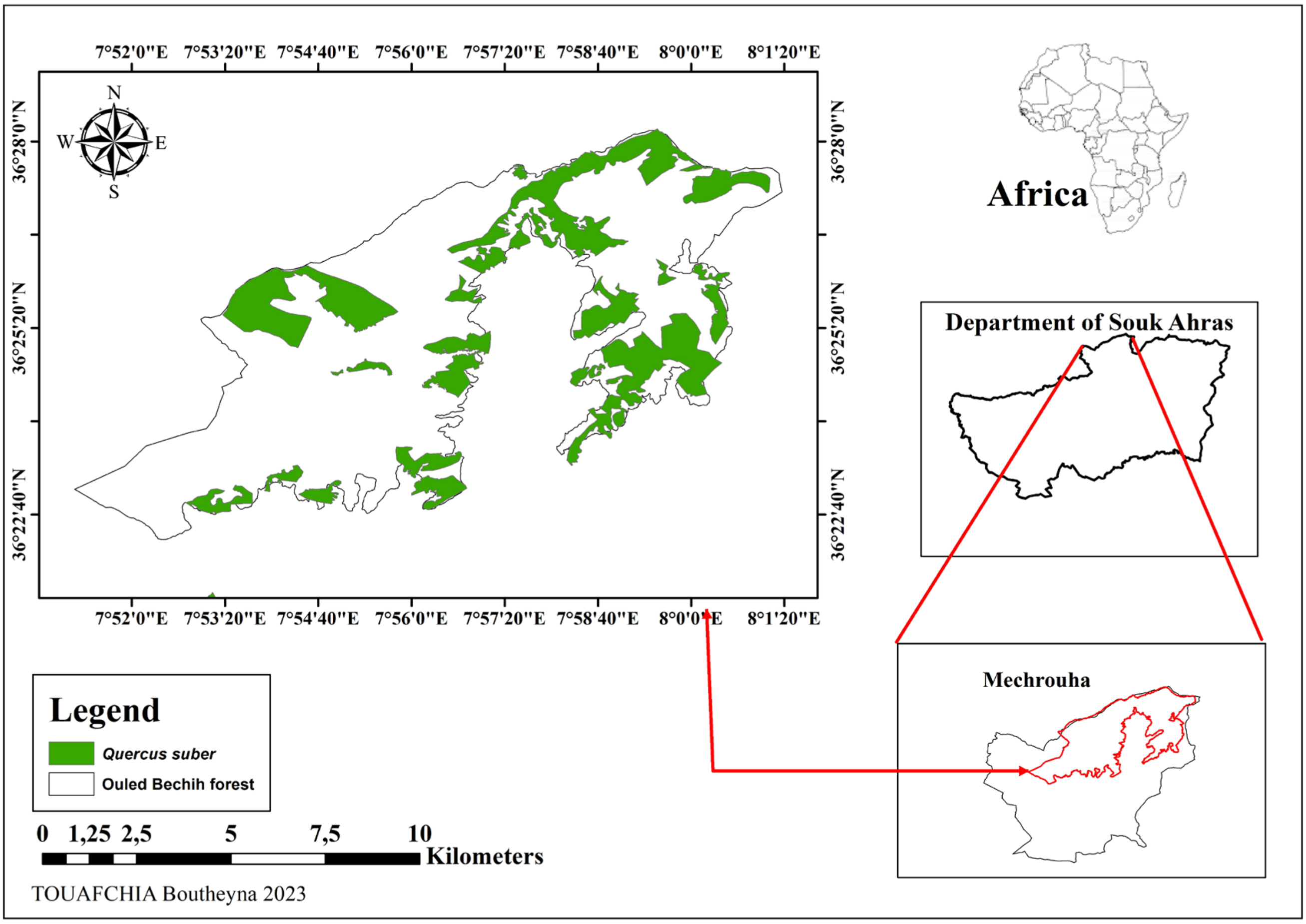

Fig. 1. Presentation of the study area.

the composition and productivity of understory plant communities (Canham et al., 1990, 1994; Frazer et al., 2000).

The structure of the canopy influences processes as important as regulation of the hydrological cycle or the distribution of animal populations (Peters et al., 2006). The tree crown is, therefore, a structural element of the canopy that plays an important role in modeling studies.

The crown of a tree is made up of all branches supporting living leaves (Cannell et al., 1987). As the photosynthetic center of the tree, the crown is responsible for assimilating light energy, absorbing carbon dioxide, releasing oxygen through photosynthesis, and releasing carbon dioxide through respiration (Wang, Jarvis, 1990; Sinoquet et al., 2001). It is an excellent indicator of a tree's growth and the anatomic properties of its wood (Lenz et al., 2012). Size and shape of the crown vary from one species to another, according to the stage of development, the competitive environment, and climate (Sattler, Lemay, 2011; Sattler, Comeau, 2015). Crown length is determined by tree's growth in height and by crown recession, that is, loss of foliage from its base (Power et al., 2012). In this context, other crown variables are added, such as crown base height, crown radius, or crown projected diameter at the soil surface (Power et al., 2012). Crown characteristics refer to morphologic changes (crown length, maximum width, shape, surface area, etc.), while crown architecture refers to the arrangement and distribution of branches and foliage within the tree crown. Properties and structure of the crown play a central role in tree photosynthesis and forest productivity (Power et al., 2012).

Ouled Bechih forest is essentially composed of a stand of *Q. suber* L. and *Q. canariensis* Willd. Due to its ecological position, this forest represents an essential element in the physical, biological, climatic, and socioeconomic balance of Souk Ahras region. It is considered to be not only a cork and fodder production area, but also a place where visitors to the forest can relax. This multifunctional role of Ouled Bechih forest is decisive and deserves to be inventoried and preserved. The objective of this study is to determine the dendrometric characteristics of the cork oak forest stand and to determine and compare various crown parameters and their effects on the natural regeneration of this species, to form a fundamental basis for silviculture and forest management and finally to achieve the exploitation of forest products.

Material and methods

Presentation of the study area

Ouled Bechih forest is situated between 36° 21´ 26˝ N and 7° 50´ 08˝ E in Souk Ahras region of eastern Algeria (Fig. 1). Covering

Table 1. Comparison of height and diameter means (p <0.05).

	Source	DF	SS	MS	F	P
H	**Source**	**DF**	**SS**	**MS**	**F**	**P**
	Plot	7	152,26	21,47	2,84	0,009
	Error	113	853,19	7,55		
	Total	120	1003,45			
D	Source	DF	SS	MS	F	*P*
	Plot	7	4767	681	2,27	0,034
	Error	113	33952	300		
	Total	120	38720			

Notes: H ‒ height; D ‒ diameter; DF ‒ degree of freedom; SS ‒ sum of squares; MS ‒ medium squares; F ‒ Fisher test; *P* ‒ probability.

a total area of 6582 ha, this forest is characterized by a mountainous relief-forming part of Tellienne chain and steep slopes that can sometimes reach 30% (Touafchia et al., 2022). From a climatic point of view, the study area is sub-humid, with an average annual temperature of 16 °C, average annual precipitation of 625 mm, and high atmospheric humidity of 68%. The forest is mainly composed of cork oak and zeen oak. It is characterized by deep brown soil rich in organic matter, with a surface horizon marked in some places by the presence of pebbles and boulders. This forest is characterized by a moderately dense stand with a diversified undergrowth of species such as *Calicotome spinosa* (L.) Link, *Erica arboria* L., *Rubus ulmifolius* L., *Phillyrea angustifolia* L., *Myrtus communis* L., *Crataegus monogyna* Jacq., *Daphne gnidium* L., *Cytisus villosus* Pour, etc.

Data collection

Structure of a stand is defined as the manner in which its dendrometric variables are arranged and follow certain laws. The random sampling method was adopted. Sampling was carried out in eight plots of 900 m^2 area. To characterize the woody vegetation, a forest inventory was conducted in each plot, in which all *Quercus suber* individuals were measured. Individuals with a diameter of less than 5 cm were considered natural regeneration (Abdourhamane et al., 2013). Total height and diameter at 1.3 m from the ground were measured.

Tree crown parameters

Configuration of tree crowns, linked to species and competition between trees, sometimes makes it difficult to estimate their diameter. In practice, crown diameter is measured on its horizontal projection using a decameter. The further the projected surface is from a circle, the greater the number of diameters to be measured (Rondeux, 1999).

Studies have shown that the projected area of tree crowns can be estimated with good accuracy by measuring at least four radii, preferably eight (Cailliez, 1980; Parde, Bouchon, 1988), in directions at equal angles, with the first ray fixed at random. A study by Röhle, Huber (1985) based on measurements of 32, 16, 8, 4, and 2 rays per tree, and considering different assumptions regarding the spatial distribution of trees within stands, showed that four to eight radius measurements per tree were sufficient to estimate crown projection at stand scale, while 8–16 measurements were recommended in the case of trees considered individually.

In the case of n rays, the area of the horizontal projection results from the following root mean square:

$$Sp = \pi * \sum_{i=1}^{n} ri^2/n. \tag{1}$$

From this, the (average) crown diameter is deduced. Thus,

$$Dho = \sqrt{\frac{4}{\pi}} * Sp = 2\sqrt{\sum_{i=1}^{n} ri^2/n}. \tag{2}$$

Diameter and crown height are the two variables generally used to quickly characterize the crown on a dendrometric level. The morphology of the crown can be reflected in different expressions that are useful for modeling the growth of trees subject to competitive effects. The amplitude of the crown is also linked to the photosynthetically active biomass. For a tree characterized by a total height "h," a diameter of 1.3 m "d," a crown diameter "d_{ho}," and a crown length "h_{ho}," the following main parameters can be defined:

- h_{ho}/h = crown proportion,
- h_{ho}/d = crown form index.

Variance analysis was applied to all the variables studied. Significant differences between treatments for each parameter measured were tested using the Fisher test calculated at the 5% threshold. Minitab 16 software was used. To determine inter-variable dependence and proportionality, the correlation significance coefficient (r) was calculated at the 5% level (p = 0.05).

Results

The results from analysis of variance (Fisher test) performed on dendrometric characteristics (height and diameter) of *Q. suber* populations in Ouled Bechih forest showed significant differences (Table 1).

For this stand, 1345 individuals/ha of diameter at breast height ≥5 cm were measured over an area of 0.09 ha (Table 2), with the density of these plots increasing as the altitudinal gradient decreases. Highest value for the latter was obtained in plot 7 (256 individuals/ha) characterized by a low altitude (544 m). But the lowest value was obtained in plot 1 with a high altitude of 1108 m (89 individuals/ha).

In the plots studied, the average total height of *Q. suber* was 12.50 ± 2.79 m (Coefficient of Variation = 23.49%, a flattening

Table 2. Descriptive analysis of the dendrometric parameters of the study plots.

Plot	Alt	N	DP	Ave	σ	σ²	CV %	Skewness	Kurtosis
P1	1108	89	H	14,19[a]	5,1	25,97	35,92	0,12	-1,13
			D	68,71[a]	15,46	238,98	22,5	0,96	1,73
P2	823	189	H	11,21[bc]	2,49	6,21	22,23	0,97	0,97
			D	50,39[b]	14,69	215,8	29,15	0,61	-0,54
P3	607	167	H	11,48[bc]	2,58	6,68	22,52	0,17	-0,22
			D	54,93[ab]	21,81	475,88	39,72	1,07	1,09
P4	613	144	H	12,79[ab]	1,97	3,84	15,32	0,19	-1,49
			D	55,54[ab]	18,5	342,21	33,31	0,12	-1,46
P5	1005	189	H	10,74[c]	2,74	7,5	25,5	0,00	0,1
			D	56,41[ab]	13,48	181,81	23,9	0,33	-0,03
P6	785	122	H	13,66[a]	2,56	6,55	18,73	-0,77	-0,23
			D	67,2[a]	12,17	148,1	18,11	1,25	1,85
P7	544	256	H	12,33[abc]	2,88	8,31	23,37	-0,58	0,35
			D	49,04[b]	20,15	406,08	41,09	1,21	1,56
P8	576	189	H	13,56[a]	2	4,01	14,78	-1,3	1,39
			D	50,04[b]	17,2	295,88	34,38	1,8	3,84

Notes: Alt – altitude; N – density; DP – dendrometric parameters; Ave – average; σ – standard deviation; σ² – variance; CV % – coefficient of variation

coefficient and a positive asymmetry coefficient of 0.11 and 0.21, respectively) and the average diameter was 56.84 ± 16.68 cm (CV = 32.79%, a flattening coefficient of 0.68 and an asymmetry coefficient of 0.23 for the overall stand). Table 2 shows that there were variations in height and diameter between plots. Plot 1 is the most varied (H = 14.19 m, σ = 5.10, and CV = 35.92%), with a skewness index = 0.12 indicating straight asymmetry and a kurtosis index = -1.13 meaning that the distribution is flattened; in contrast, plot 5 is characterized by a low height compared to the other plots (H = 10.74 m, σ = 2.74, and CV = 25.5%), with a skewness index = 0 and a kurtosis index = 0.1.

As for average diameters, trees with maximum size are located in plot 1 (D = 68.71 cm, σ = 15.46, and CV = 22.5%) with a skewness index = 0.96 and a kurtosis index = 1.73, while plot 7 is characterized by a low average diameter compared to the other plots (D = 49.04 cm, σ = 20.15, and CV = 41.09%), with a skewness index = 1.21 and a kurtosis index = 1.56.

Distribution of individuals by diameter classes of *Q. suber* in Ouled Bechih forest is shown in Fig. 2. Analysis of stand's diameter structure shows a large representation of individuals in two diameter classes 27.5 < d ≤ 47.5 cm and 47.5 < d ≤ 67.5 cm, or 38.86% and 38.03%, respectively. These are generally medium- and very large-diameter trees. Small-diameter trees (poles 7.5 < d ≤ 17.5 cm), indicative of natural regeneration, are absent from the study area.

Distribution of height classes reveals a predominance of individuals of varying heights (Fig. 3). Trees in the 10-15 m height class are the most represented (52.91%), while trees in the 20-25 and 1–5 m are poorly represented (1.65 and 3.31%, respectively). From these observations, it would appear that height distribution structure is close to regular trend.

Table 3 shows that tree crown indices studied are differently varied, average crown area (Sp) is 126.52 ± 31.38 m², and average crown diameter (D_{h0}) is 12.22 ± 1.58 m. Thus, highest values of these indices are recorded on plot 6 (170.39 ± 73.27 m² and 14.44

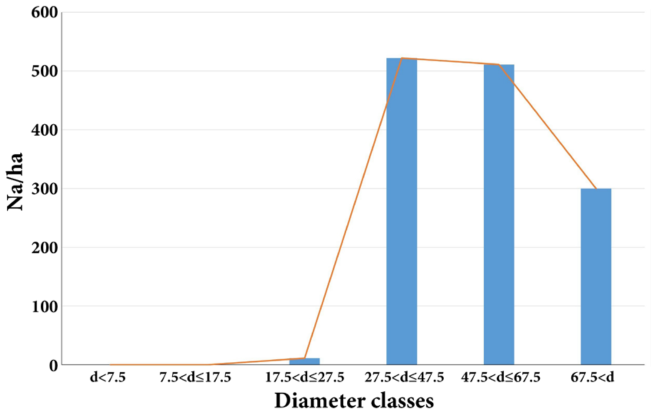

Fig. 2. Diameter distribution of the 8 plots.

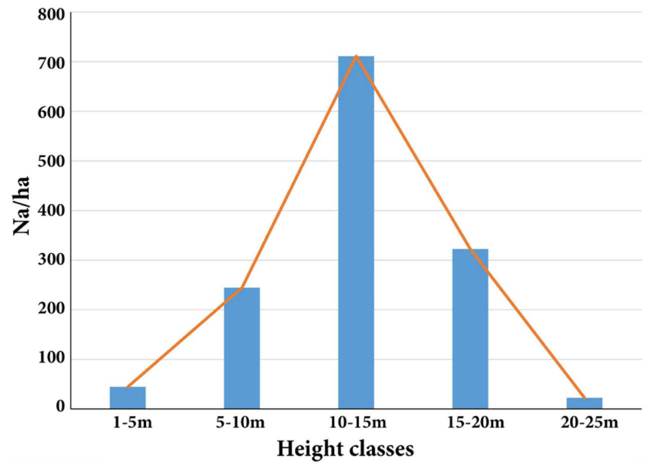

Fig. 3. Height distribution of the 8 plots.

Table 3. *Qurecus suber* crown indices.

Plot	Sp (m^2)	D_{ho} (m)	h_{h0}/h	h_{h0}/d
P1	127,82±71,61	12,24±3,87	0,76±0,11	15,66±5,53
P2	135,13±76,71	12,67±3,53	0,74±0,07	17,11±3,57
P3	136,53±87,49	12,56±4,15	0,62±0,12	13,52±3,62
P4	163,68±60,45	14,21±2,69	0,70±0,07	17,42±5,12
P5	89,74±38,12	10,44±2,38	0,67±0,11	12,69±3,19
P6	170,39±73,27	14,44±3,05	0,74±0,09	15,19±3,34
P7	95,09±49,75	10,60±3,03	0,73±0,11	20,10±6,36
P8	93,77±46,68	10,63±2,62	0,73±0,11	21,13±5,96

Notes: Sp – average crown area; D_{h0} – average; h_{h0}/h – crown proportion index; h_{h0}/d – crown shape index.

Table 4. Correlation matrix.

	Alt	N	H	D	Sp	D_{h0}	h_{h0}/h	h_{h0}/d
Alt	1							
N	-0.553	1						
H	0.032	-0.555	1					
D	0.652	-0.876	0.548	1				
Sp	-0.024	-0.634	0.280	0.500	1			
D_{h0}	-0.021	-0.633	0.284	0.500	0.999	1		
h_{h0}/h	0.242	-0.185	0.630	0.255	0.055	0.074	1	
h_{h0}/d	-0.572	0.445	0.392	-0.522	-0.287	-0.271	0.533	1

± 3.05 m, respectively) and lowest values are recorded for plot 5 (89.74 ± 38.12 m^2 and 10.44 ± 3.05 m, respectively).

With regard to crown proportion index (h_{h0}/h) and crown shape index (h_{h0}/d), results obtained show that they vary between plots; average of these indices is 0.71 ± 0.05 and 16.63 ± 2.91, respectively. Highest values are found in plot 1 (0.76 ± 0.11 and 29.97 ± 7.17), while lowest values are found in plot 3 (0.62 ± 0.12 and 9.26 ± 7.73). This difference in crown indices may be due to competition between crowns for solar energy and other factors such as water resources and mineral salts.

The correlation coefficients between different variables studied (Alt, N, H, D, Sp, D_{h0}, h_{h0}/h, and h_{h0}/d) are shown in Table 4. Analysis of the latter shows that there is a negative correlation between the variables: Alt with N (-0.553), and Alt with h_{h0}/d (-0.572). This negative correlation shows that as altitude increases, density (N) and crown form index (h_{h0}/h) decrease. Thus, there is a positive correlation between altitude (Alt) and diameter (D) r = 0.652, meaning that diameter increases with altitude. A significant negative correlation was found between density (N) and all variables: height (H), diameter (D), crown area (Sp), and crown diameter (D_{h0}) (-0.555, -0.876, -0.634, and -0.633, respectively); this correlation indicates that these variables reduce with lower density. A positive correlation between height (H) and diameter (D) r = 0.548 and the crown proportion index (h_{h0}/h) r = 0.630 indicates an increase in these variables with height growth. The variable D (diameter) has a positive correlation with crown area (Sp) and crown diameter (D_{h0}) r = 0.500 and a negative correlation with crown form index (h_{h0}/d) r = -0.522. A strong positive correlation between the variable crown area (Sp) and crown diameter (D_{h0}) r = 0.999 is explained by the strong relationship between the growth of these two variables in parallel. The crown proportion index (h_{h0}/h) correlates positively only with the crown shape index (h_{h0}/d) r = 0.533.

Discussion

Analysis of dendrometric parameters of *Q. suber* in Ouled Bechih forest shows that tree density increases with decreasing altitude. The average density of cork oak in the Ouled Bechih forest is 1345 trees/ha, not far from the threshold accepted by Saccardy (1937).

Analysis carried through on cork oak of Ouled Bechih forest shows a variability in the level of significance between height and diameter. This variability reflects the effect of altitude and density on the distribution of individuals between plots. In addition, the relation between tree diameter and height varies not only according to forest structure, but also according to the growing environment. Consequently, for a given height, trees growing in high-density stands will be smaller in size than those growing in less-dense stands, with the smaller sizes being due to competition between trees. The high number of large average diameters and average heights trees in this forest can be explained by the predominance of older individuals. These observations could be associated with climatic conditions (reduced rainfall, concentration of rainfall over a short period of the year) and anthropogenic factors, which are the main obstacles to regeneration. Small-diameter individuals are less represented due to a recruitment deficit (Rabiou et al., 2015).

The analysis of kurtosis and asymmetry coefficients shows that there is inter-plot heterogeneity in distribution of heights and diameters. The mean kurtosis values observed for these two parameters (H and D) in eight plots were 0.21 and 0.23, respectively. These values indicate a distribution with a less flat peak and thicker ends than normal distribution (leptokurtic distribution). For coefficient of asymmetry, distribution of observations around the mean shows positive values greater than 0 (0.11–0.68); these values indicate that distributions are unilateral and spread to right of the mean, so peak is found in large trees (Messaoudene, 1989; Rabhi, Messaoudene, 2013).

Distribution by diameter and height classes is used to understand tree dynamics. It is also used to assess the impact of anthropogenic pressure on the tree population (Cunningham, 2001). For cork oak in Ouled Bechih forest, individuals have an average diameter of 56.53 cm and an average total height of 12.50 m. The large average diameters and higher average heights of the trees can be explained by the predominance of older individuals. This distribution of trees shows the predominance of the medium wood and large wood categories. According to Oswald (1980), this type of structure indicates strong inter-tree competition within stands, which explains the low rate of natural regeneration in these cork oak stands. According to Catry et al. (2009) and Moreira et al. (2009), large-diameter trees, represented by older individuals, are more resistant to fire damage than smaller-diameter trees. The perch category represents a very low rate, which also confirms the poor natural regeneration in this forest. These observations are higher than those recorded by Chouahda (2016), for the El Kala cork oak forests, and by Letreuch-Belarouci et al. (2013), for the Tlemcen cork oak forests. Growth in size is favored where water input is abundant and soils are deep (Piqué et al., 2008); these factors influence the diametral growth of cork oak. In addition, air temperature and soil moisture have a significant influence on cork oak trunk diameter growth (Piqué et al., 2007). These parameters are still linked to cork growth and quality. Diameter and height structures of cork oak stands in Ouled Bechih forest show that the future of their populations may not be assured, when in natural stands, the frequency of small-diameter stems (young individuals) is lower than that of large-diameter individuals (old individuals) (Feeley et al., 2007; Ajbilou et al., 2008; Hounkpèvi et al., 2011). Overall, the diameter structure of these natural stands reveals a high proportion of large-diameter old trees.

In a forest stand, each individual maximizes its photosynthetic capacity through the shape of its crown, and the optimal shape depends on the tree's light environment (Canham et al., 2006; Pretzsch, 2014). In this context, cork oak trees in the Ouled Bechih forest are characterized by large crowns, with an average crown area (Sp) of 126.52 ± 31.38 m^2 and an average crown diameter (D_{h0}) of 12.22 ± 1.58 m. With regard to the proportion index (h_{h0}/h) and the crown shape index (h_{h0}/d), the results obtained show that they vary between plots; the averages of these indices are 0.71 ± 0.05 and 16.63 ± 2.91, respectively.

Rondeux (1999) points out that the diameter of a tree›s crown is an interesting dendrometric characteristic, mainly for quantifying the effects of silvicultural treatment. Individual tree growth for a given species and type of environment depends on many factors. Several empirical competition indices have been developed (Houllie et al., 1991), but their effectiveness is limited at the tree level. Competition between trees is, in fact, expressed through competition for an environmental resource: light, water, mineral elements, and, possibly, space. In practice, these environmental factors act together, but it is essential to prioritize them.

Canopy cover is generally defined as the percentage coverage of the vertical projection of tree crowns (Walker, Hopkins, 1990). Despite its simplicity of calculation compared to projected tree cover, tree cover is less important as a biological measure. Distinct changes in canopy cover have been observed during stand growth. Taking even-aged stands as an example, the canopy cover usually increases from a low level at the start of stand, peaking shortly after canopy closure at the start of stem exclusion stage, then decreases again as overstory elements decompose and gaps form in the canopy during the old growth stage. A number of studies have focused on the use of elements related to tree size, such as diameter, height, and volume. In part, this reflects the association between stem size and other structural characteristics such as foliage distribution and crown dimensions (Spies, 1998). Stem size information is also easy to collect and has been used as the basis for many permanent plot measurements (Acker et al., 1998).

Cork oak, grown in dense stands, is forced to grow taller. The competition for light will cause trees to stretch and branches to be inserted at tighter angles. This leads to interception of radiation (Espirito et al., 2014). In addition, most trees have deformed crowns. Such deformation influences the average diameter and horizontal projection of the canopy. In fact, cork production capacity is linked to the volume of the crown and consequently to the tree's photosynthetic potential.

Conclusion

Social, economic, and ecological factors, combined with management objectives, determine on the one hand, the suitability of a silvicultural system for a stand or group of forest stands and on the other hand, the desirable combination of systems within a landscape unit. One of the key issues in creating new silvicultural systems is how the distribution of harvested and retained trees influences the composition, growth, and development of future stands.

The present study investigated the relationship between two dendrometric parameters (diameter and height) and crown indices for cork oak stand in Ouled Bechih forest (Algeria). Results show that this species is characterized by trees of large diameter and medium height. Older trees with more developed crowns predominate. This type of structure indicates strong inter-tree competition within the stand, which explains the low rate of natural regeneration.

Establishing a structural model for cork oak is an important tool that complements studies on the species' silviculture and productivity. Such a tool can help foresters to gain an accurate idea of the woody material in a climatic–ecological context requiring precaution in silvicultural practices to maintain the balance and durability of cork oak stands in the Ouled Bechih forest. These results are also useful for establishing a yield table by diameter class, which can be used as a management tool for cork oak forests, whose importance is both ecological and economic.

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