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## **SITE VARIABILITY AND DIEBACK OF ATLAS CEDAR IN THE CEDARFOREST OF THENIET EL HAD (WEST OF ALGERIA)**

### **SUMMARY**

Main goal of the paper was to investigate the wasting of the Atlas cedar (*Cedrus atlantica* (Endl.) Manetti ex Carrière) in the national park of Théniet El Had (west of Algeria). We have installed 59 temporary plots of circular shape and a surface of 10 acres each to study this effect. At the level of each plot, we have performed measurements (density, basal area, dominant circumference and dominant height), analyze of soil (pH, organic matter, humidity, rate of limestone, texture and nitrogen content) and noted some site parameters (exposure, altitude, slope and micro relief). The results show that the total basal area and density of trees are very important in the plots of the altitudinal floor 1400-1600 m, oriented toward the north and steep slope ( $>20^\circ$ ) where there is a positive relations on soils basaltic and texture of sandy-loam soils. The soil has an average depth at low varies from one canton to another. It is sandy-loam type with a pH of 5.92 to 7.8, not salty rich in organic matter, poor in nitrogen and non-limestone. The decline of the Atlas cedar is frequent through the northeastern, sunniest and driest exposures, along the altitudinal range between 1400 and 1600 m, where water losses are greater than the contributions on slopes  $> 20^\circ$ .

**Key words:** Atlas cedar, decline, Theniet El Had, physic - chemical properties of soil, site factors.

### **INTRODUCTION**

The cedar of the Atlas is a noble species, majestic and endemic in the North Africa, existing for millennia. It presents the bioecological and socio-economic value giving him a universal importance (M'Hirit, 1994). In North Africa, *Cedrus atlantica* covers an area of 145,000 ha in Morocco (Demarteau et al., 2007; Zine El Abidine et al., 2013) and 16000 ha in Algeria (FAO, 2000). It's the first national park established during the colonial period in 1923 year and proclaimed once again as a national park after the independence in 1983 year. In Algeria, since the year 1999 to 2002 (the beginning of drought), the cedar forest

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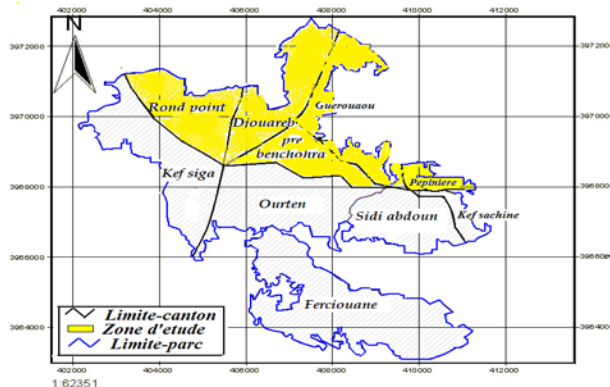
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dieback symptoms affecting all age classes were observed (Bentouati, 2008). This situation has only worsened from Djebels Boumerzoug and Tuggurt to Batna (national Park of Belezma) in an area of 300 ha (Meftah, 2001). As well as the study of Kherchouche *et al* (2013) showed that the drought is responsible for triggering dieback in this forest. In contrast, Talbi and Bouhraoua (2015) reported that the *Buprestidae* and *Scolytinae* beetles are responsible for the majority of the damage observed on Cedar. In 1984, the forest service revealed that hundreds of stems of cedar are affected by dieback in the Cedar Forest of Theniet El Had. The number of dead cedar on foot is lifted up to 2891 stems (PNTH, 2006). They were divided into small bouquets or isolated among the healthy stands. In July 1992, the cedars declining stands were 3/4 of the canton Rond-point, 1/4 of the canton Kef Siga and 1/4 of the canton Djouareb. In 2008, the work of Sarmoum (2008) was shown that among the probable causes of this phenomenon is the drought. According to the results of Naggar (2010), the local over density and the spatial arrangement inappropriate contribute to the decline of the cedar of the Atlas of Theniet El Had. Concerning the settings measurements and essentially the density and basal area of the cedar to Teniet was found that the density is slightly decreased after 30 years of growth because of the absence of the natural regeneration, dieback and illegal logging (Mairif, 2014). It is mainly due to illegal logging while the basal area is strongly reduced. In contrast, Taleb *et al.* (2016) has reported that there is no relationship between the rate of decline and topographic features and other edaphic factors. The hypothesis raised assumes the effect of factors site on the measured parameters and on the rate of decline of cedar. The main objective of this study is to search for possible relationships existing between the environmental parameters, soil and indexes with dieback of the Atlas cedar in the various cantons of the National park of Theniet El Had.

## MATERIAL AND METHODS

The study area is located in the National park of Theniet El Had (Tissemssilt, west of Algeria) (Fig. 1).



**Figure 1.** Delimitation of the study area (Gueraouaou, Djouareb, Pre-Benchohra, Pepiniere et Rond-point) within the National park of Theniet El Had.

This park is part of the prolongation of the massif of the Ouarsenis and occupies the two slopes of Djebel El Meddad. It is located in the sub-humid bioclimatic floor in cold winter. 2,968 ha is covered by forest stands (PNTH, 2006). This study is based on the percentage of needle desiccation and branch mortality.

Four classes of cedar dieback based on the Nageleisen (1994) and Benhalima (2006) were defined in Table 1.

Table 1. Dieback classes of the Cedar

Cantons	Number of deserted trees	Classes	Lost hands	Health Categories
Pepiniere	0	C0	0 –5%	Healthy tree
	3	C1	10 – 25%	Tree weakened
	0	C2	30 –45%	Trees weakly depleted
	2		50 - 60%	Tree moderately depleted
	2		65 – 90%	Tree heavily depleted
27	C3	>95%	Dead tree	
Guerouaou	0	C0	0 –5%	Healthy tree
	10	C1	10 – 25%	Tree weakened
	0	C2	30 –45%	Trees weakly depleted
	11		50 - 60%	Tree moderately depleted
	10		65 – 90%	Tree heavily depleted
71	C3	>95%	Dead tree	
Rond-point	0	C0	0 –5%	Healthy tree
	9	C1	10 – 25%	Tree weakened
	1	C2	30 –45%	Trees weakly depleted
	1		50 - 60%	Tree moderately depleted
	4		65 – 90%	Tree heavily depleted
49	C3	>95%	Dead tree	
Djouareb	0	C0	0 –5%	Healthy tree
	1	C1	10 – 25%	Tree weakened
	0	C2	30 –45%	Trees weakly depleted
	4		50 - 60%	Tree moderately depleted
	0		65 – 90%	Tree heavily depleted
27	C3	>95%	Dead tree	
Pre-Benchohra	0	C0	0 –5%	Healthy tree
	21	C1	10 – 25%	Tree weakened
	3	C2	30 –45%	Trees weakly depleted
	13		50 - 60%	Tree moderately depleted
	12		65 – 90%	Tree heavily depleted
109	C3	>95%	Dead tree	

The dendrometric characterization of stand is defined for an irregular forest. The dendrometric data characterized with dominant circumference, height,

total basal area and density. They correspond to the measures carried out on 1456 trees. In particular, 390 trees have got worsening indexes.

In addition, the topographic data collected at each plot were as following: exposure, altitude, slope of the terrain and type of microrelief. The microrelief qualitative criterion is classified among the most complex stationary factors (Masson, 2005). It is evaluated on the basis of input and loss of water. *TOPO 1*: the side losses of water are superior to inputs; *TOPO 2*: the inputs are zero or equal to the losses of water by drainage; *TOPO 3*: water flows more slowly at this level, which is a favorable situation; *TOPO 4*: the water situation is exceptionally favorable. "TOPO" meaning is the topography peculiarity. According to the homogeneity of the stations, 21 samples of the soil in the A1 horizon were collected. The determination of the total limestone was measured using the volumetric method using the Bernard calcimeter; pH (water) and pH (KCl) are measured using a pH meter with a soil / water ratio of 1:5. The soil organic matter was based on the determination of organic carbon multiplier 1.72 was used to change from carbon to total organic matter. The total soil nitrogen content was measured follow the Kjeldahl method. Particle size analysis has four different stages (Mathieu and Pieltain, 2007);

## RESULTS AND DISCUSSION

The statistical characteristics of dominant circumference and height, density and total basal area are recorded in Table 2.

Table 2. Descriptive statistics of the various dendrometric variables.

Dendrometric variables	Descriptive statistics				
	Min	Max	Moy	Standard deviation	CV (%)
C dom (m)	1.23	3.45	2.04	0.53	25.78
H dom (m)	6.37	30.25	17.23	4.35	25.24
G (m <sup>2</sup> /ha)	14.7	83.6	39.87	17.51	43.92
Density (feet/ha)	100	700	175	98.64	56.50

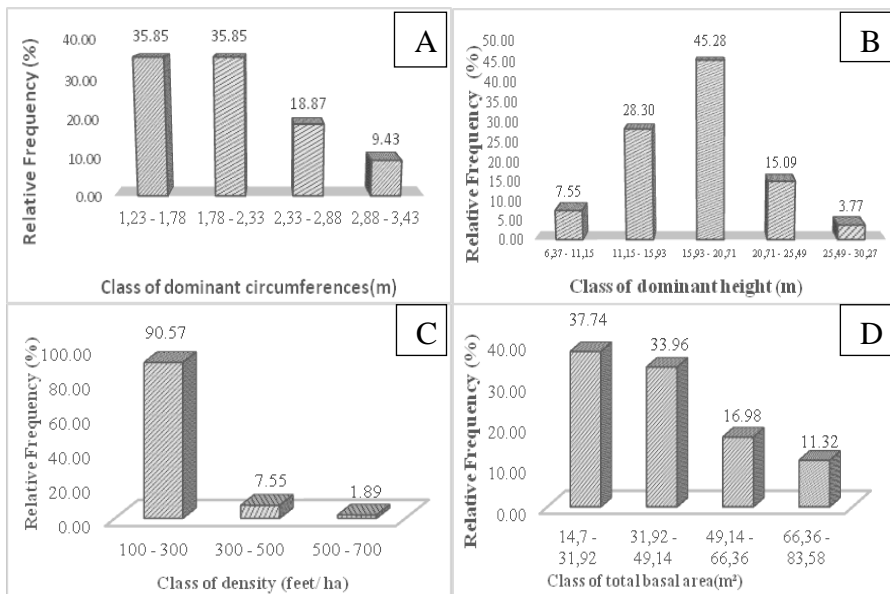
Symbol: *Min* : Minimum ; *Max* :Maximum ; *Moy* : means ; *CV* : Coefficient of variation ; *Cdom* : Dominant circumference ; *H dom* : dominant height ; *G* : total basal area.

The distribution of the dominant circumference classes of the stands (Fig.2 A) is decreasing. The class of 1.23 to 1.78m has a relative frequency of about 36%.

Nevertheless, the largest stands (from 2 to 3 m) are more represented with a relative frequency of 64.15%. It was established that approximately 36% of the stand has dominant height (Fig. 2B), while stands with dominant height from 15.93 to 20.71 m (the most productive class) show the highest frequency (45.28%). If we refer to the study of Bentouati (2006) carried out at the Belezma

cedar, the differences in height and circumference reveal much more variations of the state and of the stands age.

The distribution of the relative frequencies of the classes of the total density of the Atlas cedar can be better visualized in Figure 2C. Through this figure, 90.57% of stands have a total density less than 300 feet/ha. On the other hand, about 2% of the stands have a very high density (500-700 feet/ha). These results allow us to say that there is no great competition between individuals. It is therefore a moderately dense forest at different stages of development. Throughout Figure 2 D, the total basal area shows a decreasing pattern where about 38% of stands have basal areas less than 32 m<sup>2</sup>/ha. On the other hand, 11.32% of stands (the most fertile class) have land areas more than 66.36 m<sup>2</sup>/ha.



**Figure 2.** Distribution of dominant circumference (A), dominant heights (B), density (C) and total basal area (D) of Atlas cedar stands.

For all the plots, three variants of exposition are retained (North, East and West). Due to the diversity of the topographic sites of the study plots the topographic stratification selected reveals four types of topography observed in the field.

*TOPO1* : presenting 37.29% of all observations ; *TOPO2* : presenting 20.34% of all observations ; *TOPO3* : presenting 27.12% of all observations ; *TOPO4* : presenting 15.25% of all observations.

On the basis of a staging of 200m of altitude, three altitudinal classes are retained. The slope values recorded in the study plots are from 0 to > 20°. Thus, on the basis of a difference of 10° of slope, three classes of slope are retained.

At the level of the study plots, it should be noted that the depth of the soil varies greatly from one canton to another. For example in Canton Guerouaou, it is moderately weak (30 cm) with an increase in stony load and rock outcroppings every time we climb up. These outcrops constitute a constraint for the growth of trees. On the other hand, in Pepiniere, Rond-point and Pres-Benchohra township, the coarse-grained load is moderately present and the soil is deep (more than 50 cm deep), allowing good root exploitation. The observation of the charge in coarse elements is moderately present. Two layers of texture characterize all soil samples: sandy and sandy loam. Since it is a gardened stand, where the notion of age makes no sense, the total density and the total basal area are chosen as dendrometric variables that explain the rate of this type of stand. The choice of these two variables allows us to explain the evolution of stand structure and to identify stationary fertility regardless of age. Based on total density stratification, the analysis of the variance showed no significant difference in Cedar dieback. Dewatering is very common (90.63%) in plots where density classes are less than 300 feet/ha. Indeed, the high density of the stand causes strong competition between the trees and consequently a difficulty of growth of the stems and a weakening of the trees.

If we refer to the total recorded basal area values, the 14 to 32 m<sup>2</sup>/ha class has the highest dieback rate (44.30%). This descriptive situation, which is subject to analysis of one-factor variance, does not reveal any significant difference in the Cedar dieback rate across the total basal area values recorded is shown in Table 3.

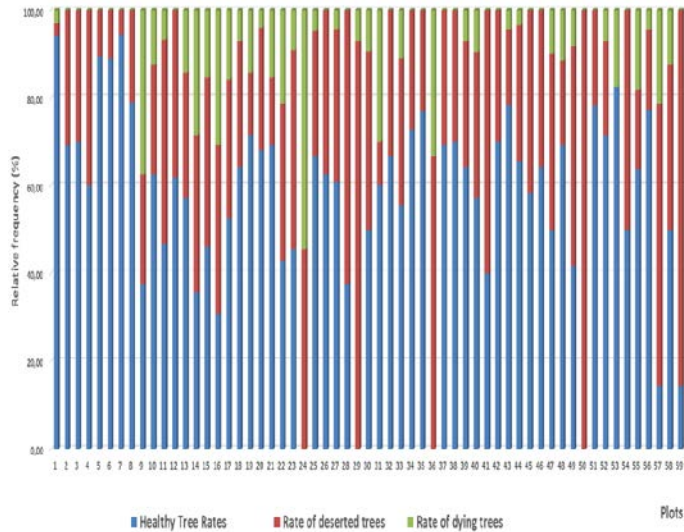
Table 3. Results of the variance analysis at the 95% significance level between cedar dieback and dendrometric variables (total basal area and density).

<b>Dendrometric variables</b>		<b>Dewatering rate (%)</b>	<b>F observed</b>	<b>F theoretical</b>
<b>Density</b> <b>(Feet / ha)</b>	100 - 300	90.63	0.47	3.16
	300 - 500	8.35		
	500 - 700	1.01		
<b>Total basal area</b> <b>(m<sup>2</sup>)</b>	14.7 – 31.92	44.30	0.33	2.77
	31.92 – 49.14	29.87		
	49.14 – 66.36	17.22		
	66.36 – 83.58	8.61		

The rate of decline per plot is evaluated against all cedar stems identified, whether healthy, deserted or declining. This evaluation translates into the following formulation :

$$\text{Rate of decline per plot in (\%)} = \frac{\text{Number of subjects (healthy, declining or declining)}}{\text{Total number of plot subjects}} \times 100$$

As shown in Figure 3, plot (50) is in Pre-Benschohra Township where the rate of dieback is 100% (there is no healthy subject), this plot is characterized by an east orientation, an altitude of 1555m, a slope of 24° and a *TOPO 1*. This situation, clearly evident on land, shows a singular peculiarity relative to this canton. This one, shaded and moist, reveals the most cedar deadwood. The plot (7) in the Pepiniere canton, on the contrary, remains the one where the decline is least noticeable (5.71%), and this, since the Cedar initiation until today. This plot is located in the lower elevations, on a flat terrain of 7 ° slope and an exposure of NNE. In addition to this peculiar tendency of the Pepiniere to be the one where the dieback is relatively weak, it is also the one where the cedar is almost in the pure state.



**Figure 3.** Rate of dieback per plot

Observations of the different exposures across the plots recorded in Table 4 show that there is a significant relationship between exposure and decline, despite it being encountered across all exposures, remains very common (52.66%).

The dieback is found to be very frequent, 75.44%, through the altitudinal stratum "1400 to 1600 m". On the contrary, it is less important at altitudes less than 1200 m. This low rate of decline seems to be related to the forest stand structure since the presence of Atlas Cedars remains low at this altitude (Zedek, 1993). We note that 57.21% of deserted trees are located on highly rugged terrain where gradient values are > 20. On the other hand, the decline is less frequent across slope classes "0 - 10°" and "10 - 20°", resulting in rates of 17.47 and 25.32% respectively.

Table 4. Analysis of variance at 95% significance level between decline rate and stationary factors

Stationary Factors	Site specificity	Dewatering rate (%)	Analysis of the variance (F obs)
Exposure	E – EE	26.84	<b>3.17*</b>
	N – NE	52.66	
	NW - WW	20.1	
Altitude	1000-1200m	6.33	1.78
	1200-1400m	18.23	
	1400-1600m	75.44	
Slope	0°- 10°	17.47	0.31
	10° - 20°	25.32	
	>20°	57.21	
Microrelief	TOPO 1	34.68	1.98
	TOPO 2	15.44	
	TOPO 3	28.61	
	TOPO 4	21.27	

\*: meaning at 5%.

Due to the diversity of the topographic sites of the study plots, the rate of decline is relatively high (34.68%) on "TOPO 1" type land, which results in water losses greater than the inputs. However, the type "TOPO 4", where the water situation is exceptionally favorable, has a rate of dieback of 21.27%. The results of Bonneau *et al.* (1969) show that the dieback is more intense in the more hydromorphic soils, that is to say in the soils where the water table is closer to the surface. Also, the topographic position affects the depth of the soil and its ability to retain water. Nevertheless, we do not record any significant difference in the rate of dieback through the topographic formations and the different altitudinal classes.

Through the texture strata, the frequency of the dieback phenomenon is low about 31% in the sand stratum (Table 5).

On the other hand, it is very common in the sandy loam stratum (69%). According to Oueld Safi (2014), the sandy texture is characterized by a low water and nutrient retention capacity. The phenomenon of dieback is very common in the classes where the humidity is low, a rate of 66.37% of the total population, whereas it is less frequent (33.63%) in the classes with very high humidity. The first limestone level stratum comprises a dieback of the order of 85%, whereas the second stratum comprises only a dieback of 15%. The phenomenon of dieback is very common (48%) in samples with high nitrogen content, whereas it is less frequent in the 11.93 to 22.06 % classes where a 21% rate of deserted trees is noted.

On the whole of the physicochemical parameters of the soil taken into account in our work, only the pH seems to have an effect on the dieback of the



Cedar of the Atlas. Indeed, the results obtained on the acidity of the soil show that the decline is less frequent (35%) in the soils where the pH is slightly acid (5.92 to 6.86), very favorable values for the vegetation, and it is very frequent (65%) in soils with low pH (7.8).

Table 5. Analysis of variance at the 95% significance level between the rate of dieback and soil factors

Edaphic Factors	Variants	Dewatering rate (%)	F observed	F theoretical
Soil texture	Sandy loam	69.03	1.67	4.38
	Sandblaster	30.97		
Humidity (%)	9.78 - 25.60	66.37	0.08	4.38
	25.60 - 41.00	33.63		
Organic material (%)	0.92 - 3.42	30.97	1.27	3.55
	3.42 - 5.92	37.17		
	5.92 - 8.42	31.86		
Limestone content (%)	0 - 0.67	84.96	0.60	4.38
	0.67 - 1.35	15.04		
pH	5.92 - 6.86	35.0	5.99*	4.38
	6.86 - 7.80	65.0		
Nitrogen content (%)	1.8 - 11.93	31.0	1.15	3.55
	11.93 - 22.06	21.0		
	22.06 - 32.19	48.0		

\*: meaning at 5%.

## CONCLUSION

In order to better elucidate the problem of dieback, we were able to statistically investigate the possible relationships between the rate of decline and the ecological descriptors from the one hand and the soil parameters on the other hand. The decline of the Atlas Cedar is frequent through the most sunny and dry-oriented exposures to the north-east, where about 53% of the trees in the Atlas mountains are depleted.

Along the altitudinal stretch between 1400 and 1600 m, the rate of decline is about 75.44% of the total number of Cedars inventoried. On *TOPO 1* type sites where water losses are greater than contributions, the decline is estimated at 34.68% of the total population. On slopes > 20°, we have a decline rate of 57.21%. The data obtained from this work certainly allow us to better understanding the biological, ecological factors that govern the functioning, dynamics and evolution of cedar trees. They will be used in the implementation an adequate management plan and objective and rational silvicultural interventions.

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