ASSESSING THE SEVERITY OF GREEN CYPRESS (*CUPRESSUS SEMPERVIRENS* L.) DIEBACK IN THE WESTERN TRARAS MOUNTAINS (NORTH-WEST ALGERIA)

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Abstract. In recent years, the green cypress has experienced many problems in the Western Traras Mountains, among which are the dieback which results in browing and ultimately the death of the tree. The objective of our study is to emphasize the main causes of the decline of the green Cypress in the western mountains of Traras. The experimental approach is based on installation of the units of sampling through all tasks of the Cypress decayed (abnormal leaf coloring) being of the region of Bab El Assa and Marsa Ben M'hidi. These units of sampling among 25 are of surface concentric respectively 4, 6, 8 and 10 are. The global sanitary indication is estimated at 2.6564, showing that the sampled populations are at the beginning of decay. An analysis of the variance shows that health status is better than the stems present a maximal extension of their crowns. A high density and unfavorable social positions contribute to the decline of the green Cypress in the western mountains of Traras. The problem of decay does not stop with stationary and dendrometric factors as cause, because we have other aggravating factors, are insects. Each plot was the subject of a specific technical sheet bringing together all the data collected in the field. The data to be collected are dendrometric, symptomatological of dieback and stationary factors. In order to highlight the different correlations that may exist between dieback and stationary and dendrometric parameters, we interpreted our data based on one-way analysis of variance at the 95% significance level, using SPSS software. It appears that: The health state of the stands presents a significant variability in relation to the different microreliefs studied, to the extent that we note that this state is better in situations favoring the accumulation of water and on moderately inclined terrain. The health status of stands shows significant variability in relation to altitude to the extent that the “F value” is greater than the “Critical F value”. The health status of the Cypress improves as the altitude increases. The rate and index of dieback show great variability in relation to exposure. The same goes for the degree of inclination of the terrain, where we record a high rate in uneven terrain, having a slope greater than 20°. Likewise, we are recording a loss of vigor of the Cypress to the extent that the health index reaches a value of 2.71 relating to Cypresses that are weakened or beginning to die back. The health status of the stands varies significantly in relation to the average size. We observe that the dieback rate is low among small stems (less than 0.85 m), not exceeding 10%. The health status of the stands improves among the stems at maximum size (more than 1.5 m), with much better growth. The health index presents significant variability in relation to height classes. In fact, the least vigorous stands are those with low dominant heights, less than 11 m. The health status remains better in stands of 11 to 19 m, either that with average dominant heights.
Keywords: *decline, health assessment, characterization, symptomatology, green Cypress, Northwest, Algeria*

Introduction

Mediterranean forests cover approximately 81 million hectares (9.4% of global forest area) and are made up of a mosaic of deciduous and coniferous forest species (Mugnossa et al., 2000; Badeau et al., 2007). These forests provide ecological, social, economic and aesthetic services necessary for life and human well-being (Luyssaert et al., 2010; FAO, 2010). They are characterized by great heterogeneity which favors the adaptation of multiple plant formations, however they remain subject to an irregular climate and frequent disturbances which lead to a certain fragility of their ecosystems. This situation is further complicated by the extension of human activities in forests such as agriculture, livestock breeding, urbanization which inevitably leads to the decline of forest cover and the reduction of its biodiversity (Adjami, 2008).

In Algeria, forests and maquis cover 4.1 million hectares, representing an afforestation rate of 16.4% for the north and only 1.7% if the arid Saharan regions are also taken into consideration. These afforestation rates are obviously very insufficient to ensure physical and biological balance. The Aleppo pine occupies an area of more than one million ha followed by the cork oak and the holm oak. Among the secondary endemic species, are the cupressaceae, especially the Thuya *Tetraclinis articulata* and the Junipers which constitute the majority of forest and pre-forest formations in dry mountainous areas. These formations are of great ecological importance, through their role in protection against the processes of desertification and erosion, which are very dynamic in these regions.

In Algeria, the genus *Cupressus* is found, except for a few rare small formations, as an isolated tree or used as a windbreak or ornamental or street tree. The endemic or naturalized species of this genus are: the Tassili cypress (*Cupressus dupreziana* A. Camus), the Atlas cypress (*Cupressus atlantica* Gaussen), the evergreen cypress (*Cupressus sempervirens* L.). The Arizona cypress (*Cupressus arizonica* Greene) is an introduced species and not widely used.

The Green Cypress *Cupressus sempervirens* L. is mainly used as a windbreak in regions at risk of violent winds. During the colonial period, in the plains of Mitidja and that of Mohammedia where vast fields of citrus fruits were planted, this species massively in order to border and delimit these fields serving as shelter and to create a microclimate favorable to the cultivation of citrus fruits.

Currently this species is widespread and used by the local population as a species to demarcate their fields (market gardening, arboriculture, others, etc.) especially after the problem of fragmentation (sharing and subdivision of agricultural land by inheritance between the same family). In mountainous areas, this species is rarely used in soil conservation work at risk of water and wind erosion. It is present everywhere in Muslim, Christian and Jewish cemeteries (Larbi and Belhgherbi, 2007).

The problem of health degradation of forest ecosystems has been known since the end of the 19th century. It increased in many countries at the beginning of the last century, in Europe in particular, but also in America. The appearance of a spectacular phenomenon known as “decline” or dieback only took on a truly worrying character in the early 1980s (Bonneau, 1987; Allain et al., 2015). This degradation, characterized by various anomalies, was reported for the first time by numerous authors such as (Sousa and Ayat Kadiri, 2005; Adams et al., 2009; Bottero et al., 2021). Several adverse factors have been involved in this process which often has two phases; a weakening phase followed by a phase of decline itself (Bouhraoua, 2003). This phenomenon can be divided into two interrelated groups. The first, difficulty to control, encompasses problems linked to the

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physiology and ecology of the tree, such as aging (Allgaier Leuch et al., 2017) and the second concerns certain constraints, abiotic such as the consequences of drought, the absence of silviculture, fires, overgrazing, as well as the action of man and biotics preventing natural regeneration, in particular the predation exerted on each part of the tree (the trunk, the branches, the leaves, the twigs and cones) by fungi and insects (Bigler and Vitasse, 2021; Blondet, 2021).

Insects are very often involved in the dieback process, either as a primary factor triggering the phenomenon, or as a secondary factor accentuating and amplifying the process over time (Battisti and Jactel, 2010). The subcorticolous and xylophagous species in particular which cause the most significant damage are found among ten families belonging to the orders Coleoptera, Hymenoptera and Lepidoptera. Coleoptera are by far the richest in wood-eating species, notably the *Scolytidae*. This family is placed by many authors at the forefront of natural enemies of coniferous forests, and which are responsible for more than 70% of damage (Cailleret et al., 2017).

The health problems of Algerian Cyprires date back to the beginning of the last century following the appearance of the phenomenon of dieback, especially in the center and even in the west, on young plants and adult trees (Anonymous, 2016). By the middle of the last century, many stands were already showing serious symptoms of weakening (Delatour, 1983; Choat et al., 2018). This situation, which lasted until 1990, led to a reduction in the surface area of Cypress, almost half of which was transformed into scrubland. Currently, the majority of Cyprières are in a deplorable state and a large part is still doomed to disappear. To this end, a series of hypotheses was put forward to try to explain the main probable causes of mortality of this tree.

The dieback of forest trees is a complex phenomenon (Badraoui and Assali, 2007; Cailleret, 2011) whose responsible factors can be very diverse and not easily identifiable and prioritized (Mouna, 1994; Benjamâa and Khaldi, 1998), and they lead to general deterioration, which often ends with the death of the trees (Landmann, 1994; Zine El Abidine, 2003). The Green Cypress of the Western Traras Mountains is a typical example of this phenomenon.

The insufficiency of studies and works in this fragile environment on this precious species, their environmental importance as well as the worsening of this risk of degradation have caused the extent of this degradation both qualitatively and quantitatively.

With this in mind, our work focused on the assessing the severity of Green Cypress *Cupressus sempervirens* L. in Western Traras Mountains.

This study takes place in 25 plots installed in the region of Bab El Assa and Marsa Ben M’hidi, or 450 stems sampled.

Materials and methods

Presentation of the study area

The Western Traras or M'Sirda region, that is to say the region which was recognized by the delimitation operations undertaken between 1905-1923 (Nichane, 2011).

Administratively, this space extends over an area of 338 km2, and concerns four communes: the commune of Bab El Assa, the commune of Souk Tleta, the commune of M'Sirda Fouaga and the commune of Marsa Ben M'hidi.

The region is located at the northwestern extremity of Algeria, touching both the Mediterranean Sea and the Kingdom of Morocco with the following limits: To the north,

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the Mediterranean Sea, to the east, the commune of Souahlia, to the south, the commune of Maghnia and to the west, the Algerian-Moroccan border *(Fig. 1)*.

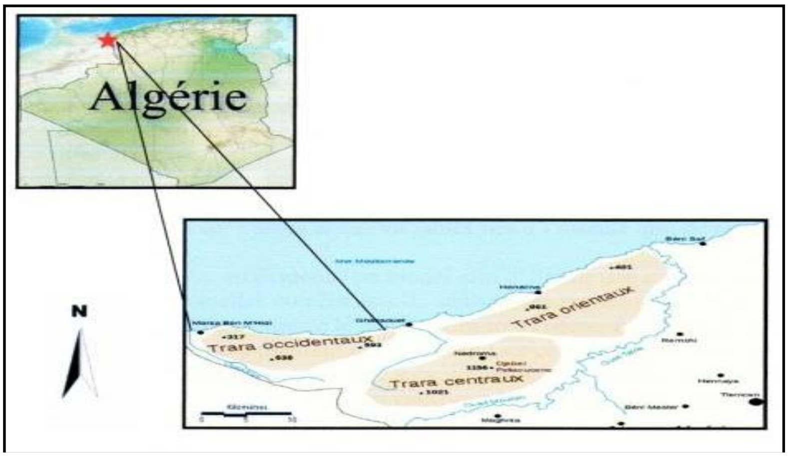

Figure 1. *Location of study area (Nichane, 2015)*

The region is characterized by a semi-arid Mediterranean climate with a warm winter with an average annual precipitation of 300 mm and an average temperature of 18°C. We also note that the region has undergone a remarkable bioclimatic change compared to the ancient period. Precipitation decreased by 10% and temperatures increased. This change, already reported by numerous authors (Benabadji and Bouzza, 2000; Quezel, 2000) for the western region, has clearly accentuated the dominant "arid" character of this region. The main groups constituting the bedrock are carbonate formations, non-carbonate formations, volcanic formations and Quaternary formations (Medjahdi, 2001; Nichane, 2011).

The forest area occupied by the Western Traras Mountains is estimated at 6453 ha distributed between Aleppo pine, eucalyptus, thuja, cypress and other formations (Nichane, 2011).

Forest dieback has been a major environmental issue since the 1980 (Landmann, 1994). Many examples of dieback of forest species are cited by different researchers. In Morocco, Bakry and Abourouh (1996) cite the decline of the cork oak. The phenomenon of dieback on Quercus cerris was also described in Italy by Vannini (1990). In France, the decline of maritime pine is reported by Guyon (1991). On pedunculate oak, Sessile oak, spruce and beech, dieback is studied by Laurent and Lecomte (2006). In France, the study of this phenomenon of degradation on cork oak is carried out by Rigolot (2008), Garrigue et al. (2008), on beech and fir the work is recommended by Rigolot (2008), Garrigue et al. (2008), Le Meignen and Micas (2008) and Dentand (2008). Likewise in Spain, Portugal and Morocco by Varela (2008).

In recent decades, the main forest species in the Mediterranean regions have been affected by this phenomenon, such as the Atlas cedar in North Africa (Benabid, 1994; Badraoui and Assali, 2007; Bentouati, 2008). Various pine species in Morocco are affected by declines (Zine El Abidine, 2003).

The health problems of the Algerian cypress, of which the cypress of the Western Traras Mountains is a typical example of this phenomenon, date back to the beginning of the last century following the appearance of the phenomenon of dieback, especially in the center and even in the west, on young subjects and adult trees (Anonymous, 2016). By

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the middle of the last century, many stands were already showing serious symptoms of weakening (Boudy, 1955; Natividade, 1956). This situation, which lasted until the 1990s, led to a reduction in the surface area of Cypress, almost half of which was transformed into scrubland. Currently, the majority of cypress is in a deplorable state and a large part is still doomed to disappear. To this end, a series of hypotheses was put forward to try to explain the main probable causes of mortality of this tree.

The insufficiency of studies and work in this fragile environment on this precious species, their environmental importance as well as the worsening of this risk of degradation have caused the extent of this degradation both qualitatively and quantitatively.

With this in mind, our work focused on the assessing the severity of green cypress (*Cupressus sempervirens* L.) Dieback in the western traras mountains (North Western Algeria). This study takes place in 25 plots installed in the region of Bab El Assa and Marsa Ben M'hidi, 450 stems (trees) sampled.

Selection/allocation, shape and size of plots

Given the irregularity of the distribution of dieback spots across the forest, we considered it necessary to distribute the sampling plots within the islets of dieback Cypress trees following an experimental protocol developed in Canada concerning the dieback of maples (Benjamâa, 2004; Zemirli, 2006). The distribution is envisaged so that it covers all Cypress trees affected by dieback. A total of 25 circular plots are installed in the region of Bab El Assa and Marsa Ben M'hidi (*Fig. 2*).

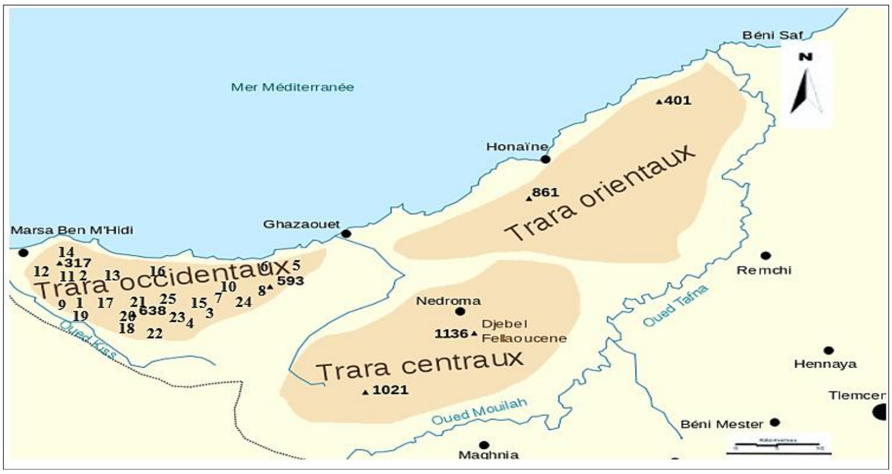

Figure 2. *Location of study plots (Medjahdi et al., 2008) modified. 1 to 25: Study plots*

At the level of each patch of dying cypress, we install a plot made up of four concentric sampling units with surfaces of 4, 6, 8 and 10 areas (*Fig. 3*).

The choice of these plots was made after a survey and a broader observation of the dieback problem, taking into account the following points: the accessibility of the plots, the intensity of the dieback tasks, the exposure, the altitude and topography. During the installation of these plots, we were equipped with certain measurement and observation equipment (GPS, bleume-leiss, magnifying glass, etc.) and documentation (Staff guide: Cap Milonia n° 237, scale 1/50,000).

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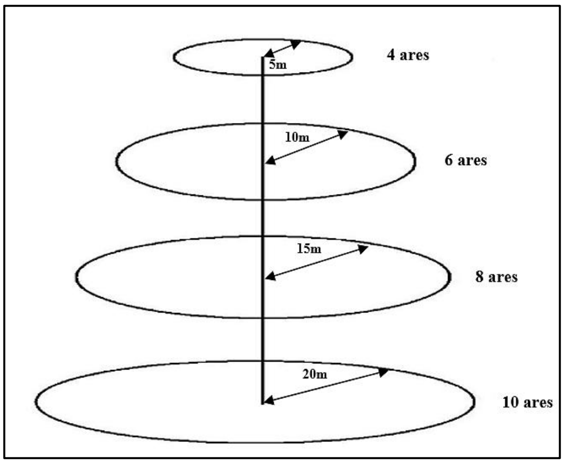

Figure 3. *Schematic presentation of concentric plots*

Data collection

Each plot was the subject of a specific technical sheet bringing together all the data collected in the field. The data to be collected are dendrometric, symptomatological of dieback and stationary factors.

Dendrometric data

The dendrometric measurements taken for each dying and dying tree are the *total height* and the *circumference at 1.30 m*.

Total height

Height is the most important characteristic to measure or estimate in order to determine volume or various shape parameters.

The total height of a tree is the distance separating the base of the tree and its terminal bud (Rondeux, 1999). To measure the height of trees, we used devices called dendrometers. The most used are Blume-Leiss, of German origin.

Circumference at 1.30 m

The circumference is a very important dendrometric parameter, it is measured at 1.30 m (human height) using a tape measure (Rondeux, 1993; Massenet, 2006).

Stationary data

Altitude, slope, exposure and microrelief are the main factors taken into account. The aim is to research the interaction between the population and the ecological conditions in which it develops, by referring to Lecomte and Rondeux (2002).

- Altitude is the vertical distance that exists on earth from mean sea level, it is measured using GPS.
- The slope is expressed in degrees and measured using the Blum-Leiss.
- The exposure allows you to indicate the North, West, East or South orientation and measured using a compass.
- The microrelief identified with the naked eye: concave, cunvex or intermediate.

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Symptomatic data of dieback

Dieback is a process involving multiple causes that act in synergy. For the tree, it results in symptoms that can be observed in a loss of vitality and mortality of perennial organs, then a thinning of the crown or other consequence of a reduction in leaf mass. Other more specific symptoms may appear depending on the factors involved (Nageleisen, 2005). *Table 1* shows Qualitative notes of intensity of symptomatological criteria observed on trees (Nageleisen, 2012).

Table 1. *Qualitative notes of intensity of the symptomatological criteria observed on the trees (Nageleisen, 2012)*

Note	Intensity	Frequency	Number	indicative %	Health Category/Class
0	Absence	Zero	0	0	healthy tree
0+ (0.5)	Very weak	Very weak	A few rare	1 to 5	C0 C0
1	Light	Weak	Few to few	6 to 25	C1
2	Quite strong	Moderate	Quite numerous	26 to 50	weakened tree
3	Forte	Important	Many	51 to 75	C2
3+ (3.5)	Very strong	Very important	Very numerous	76 to 95	dying tree C3
4	Total	All the noted part concerned	Total	96 to 100	dead tree C4

The dieback rate presents the proportion of dying trees in relation to the proportion of healthy trees. It reflects the general condition of the stands and is calculated as follows:

$$\text{Dieback rate (\%)} = \frac{\text{Number of trees withred and affected}}{\text{Total number of trees in the plot}} \times 100 \qquad \text{(Eq.1)}$$

The dieback index (ID) allows the general state of the stand to be expressed directly from all the trees taken individually (Bouhraoua, 2003).

The dieback index is based on the density of leaves and the mortality rate of perennial organs (twig, branch). It is calculated by the following formula (Bouvarel, 1984; Nageleisen et al., 2017):

$$\text{ID} = \frac{(n1.p1) + n2.p2) + (n3.p3) + (n4.p4)}{N} \qquad \text{(Eq.2)}$$

where,

n_i: number of trees of class i

P_i: weight of class i (1 if i = 1, 2 if i = 2, …)

N: total number of trees observed in the plot

Table 2 shows the values of the health index are located at four levels of decline ranging from healthy to severely declining stands.

Data analysis

In order to highlight the different correlations that may exist between dieback and site and dendrometric parameters, we considered it essential to interpret the data on the basis of one-way analysis of variance at the 95% significance level.

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Table 2. *Main categories of dieback of the green cypress stand taken into account according to the "ID" (Nichane, 2015)*

Dieback Index "ID"	Health status
ID < 2.30	healthy stand
2.30 < ID < 2.80	stand at the beginning of decline
2.80 < ID < 3.4	fairly serious decline
ID > 3.4	severe or severely wasting disease

This choice of study is based on the fact that we can only consider the possibility of a significant correlation on the basis of a statistical study. The analysis of variance makes it possible to acquire this possibility, especially since it is the subject of numerous research works (Dagneli, 1977).

On the basis of the **F** test, the results are subject to correlation analysis which may or may not be significant at the 95% threshold. This is the most well-known test and plays an important role ANOVA analysis of variance. The analysis is done by SPSS software.

Results

Symptomatic description of the stems

The dieback symptoms observed along the crowns were similar for all the trees sampled. The end of the crown is therefore the starting point of dieback which gradually degrades the crown down to its basal part.

The evolution of dieback along the inventoried stems of the Green Cypress can be located at different stages which follow one another over time.

Stage 0: Healthy trees or reference trees

These trees represent 23% of the trees sampled with less than 10% needle discoloration and leaf deficit. The crowns expand and duplicate the architecture of the branches. The latter are more or less connected from the top to the base. The transparency of the crowns is less than 5% (*Fig. 4*).

Figure 4. *Healthy green cypress (Stage 0)*

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Stage 1: Weakened trees

12% of the total stems inventoried show an apparent reduction in growth due to the reduction in annual shoots. This is reflected by a reduction in the branches.

We then observed a thinning of the crown, following a reduction in branching (*Fig. 5*). These weakened trees can be subject to insect attack.

Figure 5. *Weakened green cypress (Stage 1)*

Stage 2: Tree beginning to die back

The dieback first attacks the end of the crown. 15% of the stems inventoried show signs of dieback at the ends of their crowns, while their lower parts still remain healthy (*Fig. 6*).

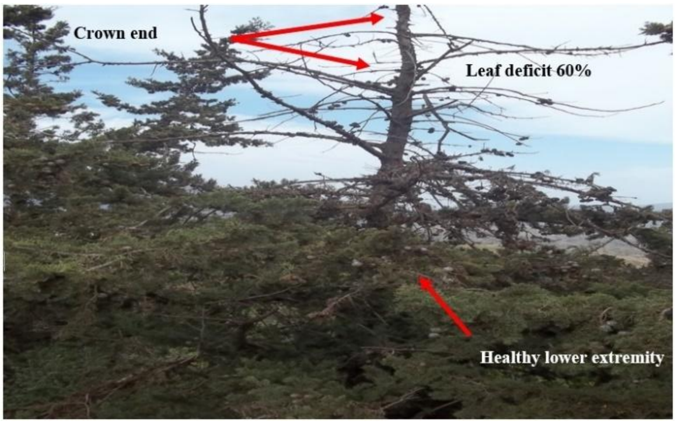

Figure 6. *Green cypress at the beginning of dieback (Stage 2)*

Stage 3: Slightly dying tree

6% of the stems inventoried have a leaf deficit of almost 100% at the ends of their crowns. The upper 1/3 of the crown is characterized by a foliar deficit of 60%. It evolves from the tips of the branches to their base. It is followed by a loss of short branches which

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carry the missing needles. Finally, the twigs fall. At the level of the middle 1/3 of the crown, the latter remains green and has a foliage deficit of 25%. The lower 1/3 of the crown remains green and the leaf deficit does not exceed 20% (*Fig. 7*).

Figure 7. *Slightly decayed green cypress (Stage 3)*

Stage 4: Moderately withered tree

At this stage, there are 8% of the stems inventoried where we observe dieback at the level of the average 1/3 of the crowns. The foliar deficit varies between 40 and 60%, therefore it affects more than half of the crown. The end of the crown is clearly individualized. The lowest parts of the crown are still healthy (*Fig. 8*).

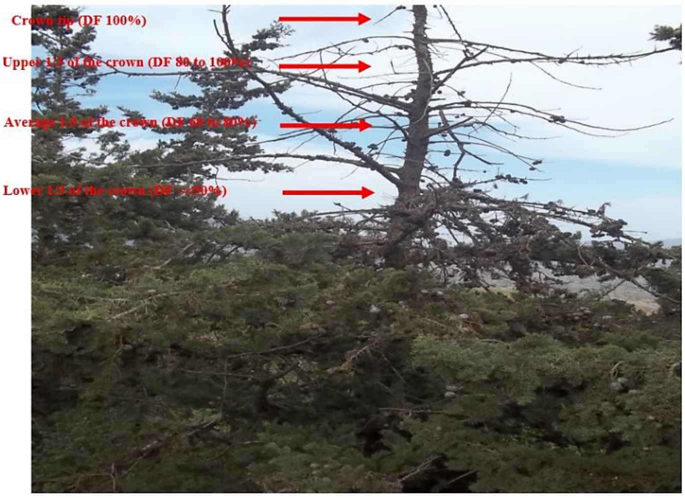

Figure 8. *Moderately withered green cypress (Stage 4)*

Stage 5: Severely dieback tree

The dieback reaches the lower 1/3 of the crown. 17% of the stems inventoried have a leaf deficit which exceeds 75%. The dieback becomes irreversible at this stage (*Fig. 9*).

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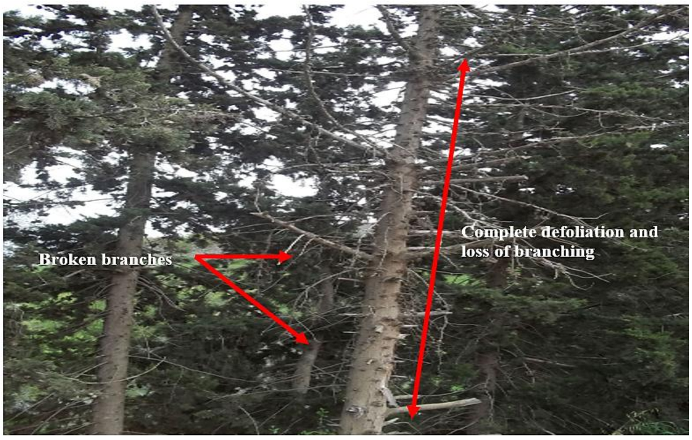

Figure 9. *Severely withered green cypress (Stage 5)*

Stage 6: Tree withers or dead standing

At this stage, there are 9% of the stems inventoried, from which we note a total absence of the crown. Deterioration begins from the end of the crown to the lower 1/3 (*Fig. 10*).

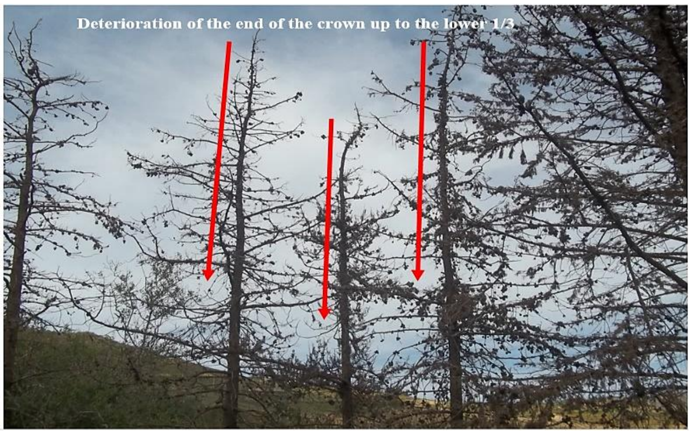

Figure 10. *Standing dead green cypress (Stage 6)*

Stage 7: Previously withered tree

10% of all stems sampled are considered to be formerly withered trees. These trees are characterized by strong weathering and loss of vitality. They are exposed to numerous weak parasites such as subcortical insects and wood-eating fungi (*Fig. 11*).

Overall distribution of stems by leaf deficit classes

According to the European approach (DSF, 1991), the different estimates of Cypress stems are grouped into five large classes.

C 0: corresponds to stands with an opaque crown, presenting a leaf deficit of less than 10%.

C 1: defoliation is of the order of 15 to 25%, corresponding to stands showing apparent signs of dieback.

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Figure 11. *Formerly withered green cypress (Stage 7)*

C 2: corresponds to defoliation of 30 to 60%, the stands are considered moderately or moderately withered.

C 3: corresponds to defoliation oscillating between 65 to 95%, the stands are considered to be seriously declining.

C 4: corresponds to defoliation greater than 95% (100%), the stands at this stage are completely withered and their state is irreversible (dead).

Estimates of green cypress leaf deficit are presented as follows:

C 0: 23% of stands have defoliation less than 10%.

C 1: 27% of stands show defoliation of 15 to 25%.

C 2: 14% of stands show defoliation of 30 to 60%.

C 3: 17% of stands show defoliation of 65 to 95%.

C 4: 19% of stands show defoliation more than 95%.

Reading these results shows that 1/4 of the stand has healthy trees belonging to class C0. The rest, or 77% of the trees are affected (having lost more than 15% of the needles belonging to classes C1 to C4). Thus, moderately defoliated C2 or moderately withered trees have a relative frequency of 14%. Furthermore, dying trees, whose health status is irreversible C3, have a relative frequency of around 17%, as for completely dying or dead trees C4, they have a relative frequency of 19% (*Fig. 12*).

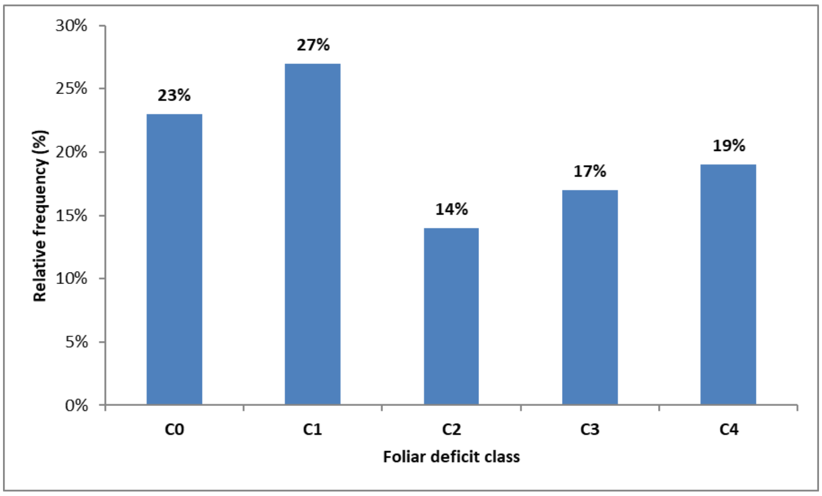

Figure 12. *Overall distribution of green cypress trees by leaf deficit classes*

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Overall distribution of study plots by leaf deficit classes

The defoliation classes show great variability across the 25 study plots. Indeed, the distribution of plots by defoliation classes allows us to draw the following conclusions (*Fig. 13*).

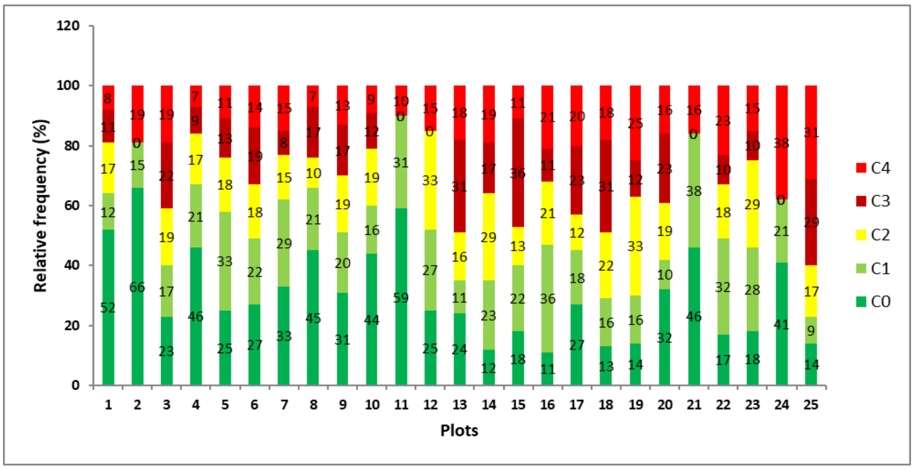

Figure 13. *Distribution by plot of leaf deficit classes*

Plots 1, 5, 7, 8, 10 are those where more than 70% of the stands have defoliation less than 25% (classes C0 and C1).

Plot 25 has 30 to 40% of stands in the dieback stage (class C4).

Plots 15, 18 have the highest proportions of heavily dying Cypress trees (class C3), including significant dieback.

Plots 11, 2, 21 and 24 are essentially composed of healthy stands (classes C0 and C1) and completely withered stands.

Plot 12 is made up of healthy, moderately and severely impaired stands (classes C0, C1, C2 and C4). The intermediate class C3 is absent.

Overall distribution of plots according to health index

The health index calculated for each of the study plots determines the overall health status of the stands and reflects the extent of the physiological degradation of the tree.

Fig. 14 illustrates the results of calculating the health indices for the 25 study plots. We notice a certain variability in the health index at the level of the study plots. It appears that the green cypress *Cupressus sempervirens* is generally weakened or at the beginning of decline to the extent that the overall health index is around 2.6564.

In light of these results, we can conclude that the inventoried Cypress stands are considered as follows (*Fig. 15*).

24% of stands are healthy.

36% of stands are beginning to die back.

24% of stands are dying.

16% of stands are seriously declining.

Although the stands in serious decline do not exceed 16% of all cypress trees inventoried, the health status remains in an alarming and critical situation to the extent that the stands at the beginning of decline present a high relative frequency of around 36%.

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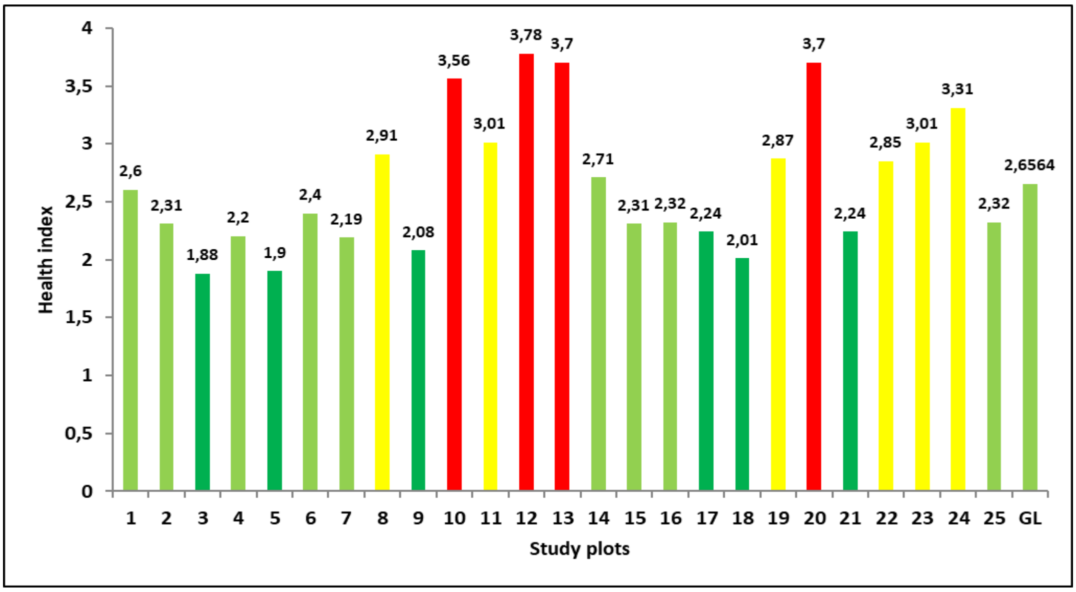

Figure 14. *Fluctuation of the health index at the level of the 25 study plots*

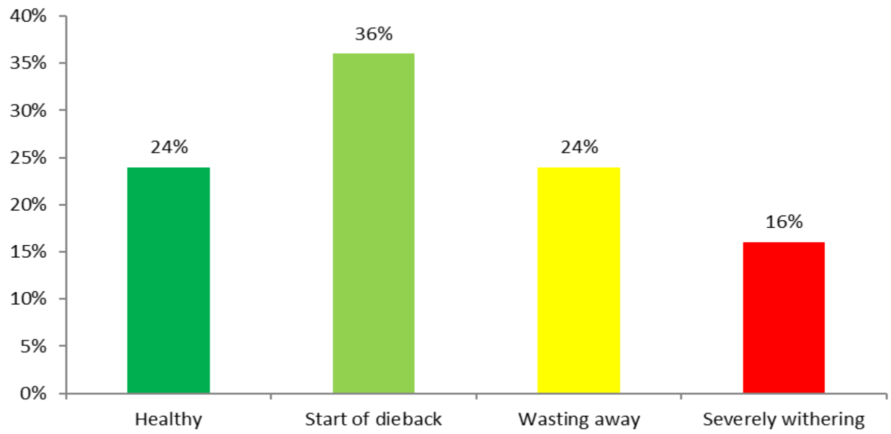

Figure 15. *Health status of the green cypress cupressus sempervirens*

Variability of dieback in relation to dendrpmetric parameters

Variability of dieback in relation to total height

Table 3 presents the results of the one-way analysis of variance at the 95% significance level of dieback in relation to total height. It indicates not significant variability for the dieback rate (value of F is less than critical F). The dieback rate is low (17%) in the 11 to 15 m category, i.e. that of average heights.

Table 3. *Analysis of the variance of Cypress dieback in relation to total height at the 95% significance level*

	F	F critical	Meaning
Dieback rate	2. 3400198	3. 90127864	Not significant
Dieback index	3. 10367530	3. 03261209	Significant

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Likewise, we record significant variability between the health index between dieback and height classes. In fact, the least vigorous stands are those at low heights, i.e. those less than 11 m. On the other hand, the health status is better in stands of 11 to 19 m, i.e. those of average height.

Variability of dieback in relation to circumference at 1.30 m

Through a one-way analysis of variance at the 95% significance level, we record that the wasting rate and dieback index exhibit significant variability in relation to circumference to the extent that the value of F is greater than F" critical (*Table 4*).

Table 4. *Analysis of variance of Cypress dieback in relation to circumference at the 95% significance level*

	F	F critical	Meaning
Dieback rate	4. 02654980	2. 19846750	Significant
Dieback index	6. 58900137	4. 01798532	Significant

Variability of dieback in relation to site parameters

Variability of dieback in relation to altitude

A possible dieback/altitude relationship is highlighted through one-way analysis of variance at the 95% significance level (*Table 5*). It appears that the dieback index and the dieback rate show significant variability in relation to altitude to the extent that the value of F is greater than the critical value of F. The health status of the Cypress improves as the altitude increases. The work of Sarmoum (2008) and Naggar (2011) confirms this result on the Cedar at Theniet El Had where dieback affects cedar groves at lower altitudes much more.

Table 5. *Analysis of the variance of Cypress dieback in relation to altitude at the 95% significance level*

	F	F critical	Meaning
Dieback rate	2. 19456200	0.98325002	Significant
Dieback index	5. 002136578	2. 92187651	Significant

High altitude vegetation takes advantage of the intense radiation which promotes their chlorophyll activity (Masson, 2005).

Variability of dieback in relation to slope

The degree of inclination of the land determines the stability of the soil and water retention (Khanfouci, 2005).

The decline shows an increasing rate in relation to the slope of the land. In fact, the dieback rate is high in hilly terrain with a slope greater than 20°. Likewise, there is a loss of vigor of the Cypress to the extent that the health index reaches a value of 2.71 relating to Cypresses that are weakened or beginning to dieback. Through a one-way analysis of variance at the 95% threshold, it appears that the dieback index presents significant variability in relation to the slope of the land (*Table 6*).

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Table 6. *Analysis of the variance of Cypress dieback in relation to the slope at the 95% significance level*

	F	F critical	Meaning
Dieback rate	1. 34987041	2. 00231567	Not significant
Dieback index	3. 34598072	1. 99854600	Significant

Variability of dieback in relation to exposure

The installation of the 25 study plots according to their exposures mainly to the north and south, led us to deduce that the dieback rate, as well as the dieback index, present great variability across the cantons. This is evident if we refer to the one-way analysis of variance at the 95% significance level (*Table 7*).

Table 7. *Analysis of the variance of Cypress dieback in relation to exposure at the 95% significance level*

	F	F critical	Meaning
Dieback rate	3. 57483910	2. 01589723	Significant
Dieback index	5. 21897603	1. 87993421	Significant

The dieback rate is higher in the Acherrab canton located on the southern slope, 33%. This is the canton in the rainy month. It appears that precipitation influences not by its quantity but its distribution in relation to the phenology of the tree.

On the other hand, dieback is low in the cantons of El Mahsar (15%) and Sebabna (19%) located on the northern slope.

As for the effect of the exposure of the plots, Houamel (2012) reported serious dieback on the Cedar located on the southern slopes in the Batna region. On the other hand, Naggar (2011), on the same species recorded a very high dieback rate in the cantons located on the northern slope in the Tissemsilt region. Furthermore, in the same region, Zemirli (2006) noticed a significant decline in cedar located on an east-northeast exposure. In the Middle Atlas (Morocco), Ghaioule and Lieutier (2006) found that mortality of cedar crowns is more evident on plots located in the south than in the north.

Variability of dieback in relation to topography

In forest stands, water stress is the cause of 90% of the annual variation in the width of conifer rings in semi-arid regions (Fritts, 1966).

Water supply is influenced by topographical conditions. Through one way analysis of variance at the 95% significance level, we seek a relationship between dieback and the different topographical situations favoring or not water retention. We note that the dieback rate and the topographical index show significant variability with respect to the different topographical situations studied (*Table 8*).

Table 8. *Analysis of the variance of Cypress dieback in relation to topography at the 95% significance level*

	F	F critical	Meaning
Dieback rate	5. 10072530	3. 19063542	Significant
Dieback index	3. 44805619	2. 20087621	Significant

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Discussion

According to the various works carried out on the dieback of different species (Arfaoui, 2002; Belahbib, 2004; Benjamaa and Roques, 1999; Benjamaa, 2004, 2005; El Alaoui El Fels, 1999; El Hassani, 1984; Adjami, 2008; Bakry et al., 2001; Beghami, 2010; Benhalima, 2004; Benjamaa and Khaldi, 1998; Bouhraoua, 2003; Cailleret, 2011; Delatour, 1983; Derak et al., 2008; Drenou, 2012; El Yousfi, 1994; Fiot et al., 2007; Garrec et al., 1991; Giraud, 2012; Gravier, 2012; Guyon, 1991; Houamel, 2012; Laflamme, 1992; Landmann and Bonneau, 1994; Nageleisen, 2007; Naggar, 2011; Sarmoun, 2008; Soussa and Ayat Kadiri, 2005; Talbi, 2010; Zemirli, 2006; Zine El Abidine, 2003; Saighi, 2013), several factors are likely to cause the symptoms and damage observed in our sampled Cypress trees. It is generally accepted that this dieback results from a general and gradual deterioration of different types of tissues caused by the interaction of biotic and abiotic stress and which involves several factors implicated to explain this phenomenon.

Faced with the complexity of Cypress dieback, scientists evoke the combined scenario of three series of responsible factors: the predisposing factors, act in a sustainable and long-term manner on the population, the abiotic or biotic triggering factors, act over a short period of time, and aggravating factors intervene on previously weakened trees and often lead to a fatal outcome (Delatour, 1983, 1990).

Predisposing factors: These are factors which exert their action permanently for a good part of the life of the tree, during which its sensitivity to the action of other factors increases. These factors operate continuously without interruption for long periods and lead to the gradual weakening of trees without causing the appearance of symptoms. These factors are essentially edaphic, climatic and silvicultural factors (Maugard, 1992; Soussa and Ayat Kadiri, 2005).

Edaphic factors: the consequences of soil degradation on cypress are a reduction in production and a limitation of regeneration of these populations, a reduction in biodiversity and an increase in phytopathogenic risks (DGRF, 2006).

Climatic factors: are ecological factors most often involved throughout the world in the destabilization of forest ecosystems and the triggering of phenomena of deterioration of their health status. Precipitation which plays a vital role in the water supply of trees (Bouhraoua, 2003).

Silvicultural factors: are age, overgrazing, density and competition with other species. The age of trees “aging” leads to a reduction in the physiological defense capacities which facilitate the establishment of harmful insects and various diseases, thereby limiting the natural regeneration of this species (Saighi, 2013).

Overgrazing; leads to a reduction in natural regeneration, compaction of the land and a reduction in its permeability. In addition, the disappearance of the shrub layer promotes an increase in sunlight at ground level (Ruiu, 2005).

Triggering factors: These are unfavorable factors which act in a short time on the physiology of trees and intervene independently of their apparent state of health and thus create favorable conditions for the action of accelerating factors (attacks by certain species of fungi or insects). They are abiotic and biotic in nature (Maugard, 1992).

Drought; is a main triggering factor where there is a relationship between leaf loss and spring rainfall deficits (Bouhouara, 2003), but in general the Cypress resists drought quite well, but when the site and silvicultural conditions are unfavorable (exposure to excessive winds and strong sunshine, superficial and poorly permeable soils, close-packed

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populations, soil depleted by agricultural activities, total elimination of undergrowth, excessive grazing), it is more easily exposed to water stress.

Underbrush or the presence of abundant undergrowth seems to have a negative effect on the vigor of stands; it competes with trees for water and mineral elements. Our study plots are affected by this factor.

Fires are considered a triggering factor, it is indeed a significant dieback factor which causes the physiological weakening of the tree, the most serious of which coincided with years of drought where water stress was particularly strong. At the European level, the major fires of the summer of 2003 covered more than 865,000 ha in Portugal, Spain, Italy and France, including 7% (i.e. 59,000 ha) of cork grove (Peyre, 2004). In Tunisia the risk of fire is linked to climatic conditions which is usually greatest during the months of May to October (Benjamâa, 2004). Our study plots are little affected by this factor.

Aggravating factors: are factors which lead to their action in the terminal phase of dieback, on deeply stressed trees, the action of which most often results in the death of the trees. These factors are essentially of biotic origin (secondary xylophage, weak pathogen) (Landmann, 1994).

The biotic agents associated with the decline of the Green Cypress are mainly insect pests (Nichane, 2015). A fairly rich procession of xylophages settles in deeply stressed trees; these xylophages can either weaken the tree or accelerate its death (Saighi, 2013).

Conclusion

The green cypress *Cupressus sempervirens* L., despite its limited surface area in the mountains of the Western Traras, undergoes very intense degradation due to the phenomenon of dieback which becomes more and more important with the years and the hypotheses, as to the origin of this scourge which remains not yet identified in a precise and sufficient manner.

The diagnosis established during this study shows that the causes of this decline are varied, but the most obvious reasons are the absence of adequate silvicultural management of these cypress trees, aggravated by unfavorable climatic changes, anthropogenic pressure, pests. and diseases. All these factors combined have weakened the population and favored the phenomenon of dieback.

The experimental approach prevails the installation of sampling units across all the tasks of the Withered Cypresses, falling within the region of Bab El Assa and Marsa Ben M'hidi. These units number 25 with a surface area of 4, 6, 8 and 10 are. A total of 450 Cypress stems (trees) were inventoried.

Across all the stems sampled, 23% of them are healthy, 12% weakened, 15% at the beginning of dieback, 6% slightly withered, 8% moderately withered, 17% seriously withered, 9% dead on the stand and 10 % formerly withered.

The 450 stems sampled are grouped into five large classes, 23% represent C0 with defoliation less than 5%. 27% represent stems with 6 to 25% defoliation and represent C1. 14% characterize C2, these stems having a defoliation of 26 to 50%. Class C3 is characterized by stems having a defoliation of 51 to 95%, they represent a rate of 17%. Finally, C4 with 19% represents completely defoliated stems.

The defoliation classes show great variability across the 25 study plots.

The defoliation classes show great variability across the 25 study plots. Indeed, plots 1, 5, 7, 8, 10 are those where more than 70% of the stands are healthy (classes C0 and C1). Plot 25 has 30 to 40% of stands in the dieback stage (class C4). Plots 15, 18 have

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the highest proportions of severely dying Cypress (class C3). Plots 11, 2, 21 and 24 are essentially composed of healthy stands (classes C0 and C1) and completely withered stands. Plot 12 is made up of healthy, moderately and severely withered stands (classes C0, C1, C2 and C4).

The overall dieback index estimated at 2.6564 shows that the sampled stands are at the beginning of dieback.

The results obtained show that 36% of the stands are at the beginning of decline.

24% of stands are dying. 16% of stands are seriously declining.

Although the stands in serious decline do not exceed 16% of all cypress trees inventoried, the health status remains in an alarming and critical situation to the extent that the stands at the beginning of decline present a high relative frequency of around 36%.

By means of one way analysis of variance, at the 95% significance level, we sought to assess the rate of dieback and consequently the health status of the stands in relation to the various qualitative and quantitative. It appears that:

- The health state of the stands presents a significant variability in relation to the different microreliefs studied, and this to the extent that we note that this state is better in situations favoring the accumulation of water and on moderately inclined terrain.
- The health status of stands shows significant variability in relation to altitude to the extent that the "F value" is greater than the "Critical F value". The health status of the Cypress improves as the altitude increases.
- The rate and index of dieback show great variability in relation to exposure. The same goes for the degree of inclination of the terrain, where we record a high rate in uneven terrain, having a slope greater than 20°. Likewise, we record a loss of vigor of the Cypress to the extent that the health index reaches a value of 2.71 relating to Cypresses that are weakened or beginning to die back.
- The health status of the stands varies significantly in relation to the average size. We observe that the dieback rate is low among small stems (less than 0.85 m), not exceeding 10%. The health status of the stands improves among the stems at maximum size (more than 1.5 m), with much better growth.
- The health index presents significant variability in relation to height classes. In fact, the least vigorous stands are those with low dominant heights, less than 11 m. The health status remains better in stands of 11 to 19 m, i.e. those with average dominant heights.

Some ideas for good management can be proposed:

- Cutting down trees infested with pests to limit their spread.
- Maintaining a reasonable density represents a solution to limit water competition in the stand and ensure its vigor.
- Management adapted to local conditions must be essential for the conservation of Cypress trees.
- A determination of the impact of abiotic stresses on the eco-physiological functioning of Cypress trees in reforestation programs.
- An analysis of drought resistance mechanisms, for a better site/genotype match.
- A determination of the appropriate types of soil development, making it possible to improve the water balance of soils in different situations and their effectiveness over time.

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- An impact study of different silvicultural treatments that can promote soil water balance.

Overall, monitoring and precautions are necessary to maintain the health of Cypress trees.

To implement a strategy to protect these fragile ecosystems, and in order to counteract this scourge, it would be interesting for this theme to be supplemented by other in-depth studies carried out on other factors and in other regions by involving biology, pedology, silviculture, planning and ecology.

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