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Biodiversity of the oak groves of the Tlemcen Mountains, Algeria. Phytoecological aspects

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ABSTRACT: The objective of this study is to know the influence of environmental conditions on the distribution of oak species in the Tlemcen Mountains. We made a bioclimatic and floristic study on four stations located on the mountain ranges of the Tlemcen Mountains. This study was carried out, taking into account the ecological aspect oriented towards the presence of oak species within the four study stations. The main ecological gradients governing the ecological trends of oak forests in this area have been characterized. The ecological dynamics of oak taxa within the local floristic procession for each station was analyzed by Mintab 16 software according to factorial discrimination of correspondences (A.FC), which led us to highlight the most influential ecological gradients.

Keywords: Tlemcen Mountains; Climate; Oak forest; Factorial analysis; Algeria.

1. INTRODUCTION

The Mediterranean forest covers nearly 81 million hectares, or 1.5% of all wooded areas on the planet. The particular character of these forests is related to their great biogeographical, historical, climatic and physiognomic heterogeneity on the one hand. And on the other hand with their instability and vulnerability linked to both the Mediterranean environment and human activity [1].

The Tlemcen Mountains offer a very interesting model for studying the evolution of flora and vegetation. The variety of landscapes, but also their differences remain very remarkable ;their distribution is conditioned by a large number of ecological factors [2]. In Algeria, the oak area is evaluated at 400,000 ha including the zeen oak which covered 66,000 ha in 1950 [3], and 65,000 ha in 1990 [4]. Most of its populations are located in the east of the country, on the other hand, it is less widespread in the west; in particular in the Monts de Tlemcen. Although the region has known and knows repeated fires, the coexistence of species, and endemism, indicates that we are indeed in the 48th hot spot of the circum-Mediterranean [5].

This endemism is expressed especially at the level of the zeen oak, which is represented by two subspecies, according to Quezel and Santa [6], clearly different; *Quercus faginea* subsp. baetica, and *Quercus faginea* subsp. tlemcenensis, the latter is the most frequent and dominant in the Tlemcen Mountains and begins to invade the wettest areas of the Hafir and Zarifet forests where it appears as a natural succession to the grouping of cork oak as well as holm oak in the forest of Moutas. *Quercus faginea* subsp. tlemcenensis endemic species in the Tlemcen Mountains and in eastern Morocco [3-6]. This species is related to *Quercus faginea*. It has been long considered a hybrid. Currently, phytogeographers give it the status of a subspecies of *Quercus faginea* [7]. The presence of oaks in the Tlemcen Mountains obeys an altitudinal scale in relation to the biolimaic stages (ombrotypes, thermotypes) which begins with the positioning of *Quercus coccifera* between 1000 and 1200 m (Figure 1). A little higher (1200-1400 m) are interspersed *Quecus faginea* sub-tlemceniensis and *Quercus ilex rotentifolia*. It is at this level that the hybridization of this species manifests itself in favor of four sub-species *Quercus baetica* (Webb) Maire, *Quercus faginea* Lamk, *Quercus tlemceniensis* (A.D.C) Maire and Weiller and *Quercus alpestris* [8]. This work proposes an analysis of the vascular flora centered on the oak grove of the region and located on the mountain ranges of Tlemcen. Four study stations where the oak seems to be performing well have been chosen. They are Hafir, Zarifet, Moutas and Beni-Snous. Although limited to these stations, this analysis could bring out the main ecological gradients, which govern the distribution of oak forests. As well as the identification of the historical and current factors at the origin of the fluctuations of this resource, providing a database for any management action and conservation of the biodiversity of oaks in the area [5].

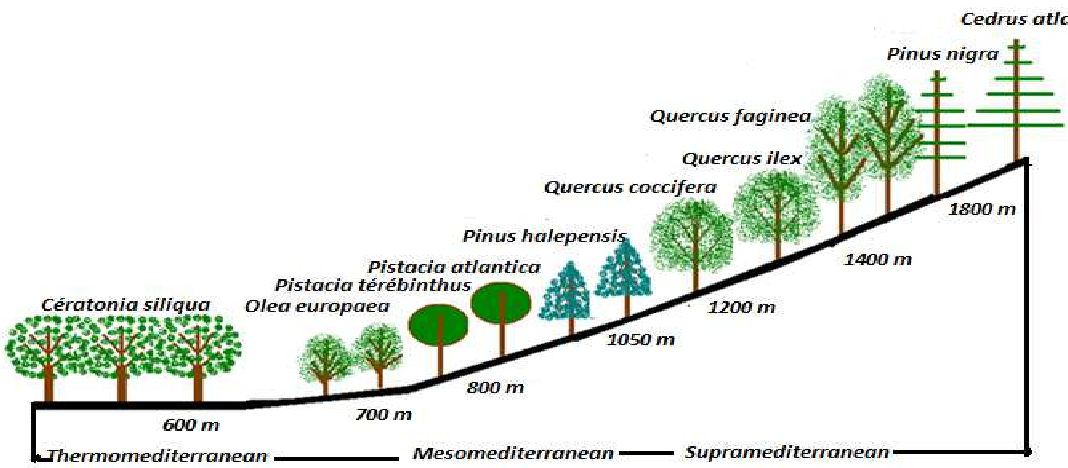

Figure 1. Altitudinal profile of the vegetation stages of the sylvatic species of the Tlemcen Mountains.

2. MATERIALS AND METHODS

2.1. Study area

The study stations are located at the level of the mountains of Tlemcen which administratively belong to the Wilaya of Tlemcen in the western end of Algeria , it is located around the intersection of the parallel latitudes north of 34° 30' and 35° and west longitudes of 0° 30' and 2°. It is a mountain range with an altitude of between 600 m and which culminates at certain points at more than 1800 m and they extend over an area of 178,000 ha. The Tlemcen Mountains are limited by the Algerian-Moroccan border to the west, Oued Mekerra to the east, the Plain of Maghnia to the north and the steppe of Aricha and El Gor to the south. Four stations were chosen to examine the distribution of the different oaks according to the type of climate and the altitude:

1. Hafir station: at the level of the Hafir forest at an altitude of 1325 m and with a recovery rate of 60% to 70%.
2. Zarifet station: located west of the city of Tlemcen, at an altitude of 1050 m and an overlap of 55 to 65%.
3. Moutas station: at the Moutas reserve, at an altitude of 1215 m, and a recovery rate of 60%.
4. Beni-Snous station: the station rises to an altitude of 733 m and its rate is 50%.

2.2. Bioclimatic synthesis

Climate plays an essential role in determining the distribution of plants. Emberger [9, 10] particularly emphasized this role with regard to Mediterranean vegetation. The western region of Algeria is characterized by low rainfall with great inter-monthly and inter-annual variability [11]. All the forests subject to the Mediterranean bioclimate are subdivided into several bioclimatic groups according to: the value of annual precipitation, the pluviothermal coefficient of Emberger [9, 10, 12] and the duration of the summer drought [13]. The climate was defined using climate data recorded by 4 weather stations, and to have more reliable results, it took an observation period of about 20 years between 1999 and 2019 on all stations (Table 1 & 2).

Table 1. Geographic data of the meteorological station (Source: O.N.M. 2019).

Station	Longitude	Longitude	Altitude (m)
Hafir	34°47’ N	01°26’ O	1270
Maghnia	34°52‘ N	01°47‘ O	426
Safsaf	34°57’ N	01°17’ O	592
Sebdou	34°38’ N	01°20’ O	720

Table 2. Average precipitation (P in mm) and temperature (T in °C) from meteorological stations.

Month/ Station		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Hafir	T	5,71	6,91	10,23	13,4	17,45	22,24	25,75	25,8	21,06	16,73	10,11	6,91
	P	63,71	47,1	42,48	35,24	36,38	12	3,29	7,52	32,29	43,43	77,95	55,52
Maghnia	T	10,07	10,71	13,54	15,78	19,28	23,81	27,61	27,73	23,32	19,81	13,95	11,34
	P	49,1	41,62	36,05	40,38	24,43	5,57	1,48	3,86	20,38	37,43	55,76	46,19
Safsaf	T	5,48	6,63	9,91	13,12	17,28	22,56	26,65	25,73	20,7	16,38	9,74	6,58
	P	67,43	49,14	43,62	35,81	38,71	13,43	3,95	7,24	33,29	47,33	79,38	57,62
Sebdou	T	6,35	7,44	10,63	13,77	17,52	22,1	25,67	25,58	21,13	16,94	10,5	7,4
	P	69,67	52,86	43,9	38,24	35,38	10,57	2,38	6,05	28,76	44,95	80,43	62,33

2.3. Geomorphological synthesis

The geological overview allows us to state that most of the regions of the Tlemcen Mountains are formed mainly of limestones and dolomites. These two more or less hard sedimentary rocks are easily eroded by rainwater, which by dissolution gives a karstified appearance to the dolomite and the cliff. Bouazza [14] gave a geological overview of the Tlemcen region. The same author specifies that the substratum is characterized by carbonate rocks of an Upper Jurassic age and sandstone marls of Tertiary age. The lithology is heterogeneous, it is formed mainly by layered marly formations and well-individualized lacustrine limestone [15].

The Dolomies of the Tlemcen mountains characterize the large dolomitic escarpments which dominate the cliffs of El-Ourit (eastern part of the study area) and the slopes south of Sebdou and Hafir and Beni-snous. These formations constitute the first group of dolomites of the Upper Jurassic [15].

2.4. Floristic analysis

The method used for sampling the vegetation is that of Braun-Blanquet [16] and Guinochet [17] known as sigmatist. The sampling of the vegetation in the Tlemcen Mountains, carried out from 200 phytoecological surveys, allowed us to inventory part of the flora richness from the presence of the various oak trees, which inhabit the stations. The study area has a total of 349 taxa divided into 56 families. The stations chosen are: Hafir, Maghnia, Sebdou and Safasaf (Appendix 1).

The surveys were made on floristically homogeneous surfaces [17], and carried out in the spring, and they were done according to the minimum area method [18]. 120 phytoecological surveys were carried out, distributed over the four stations which made it possible to highlight the main phytoecological gradients involved in the distribution of the different species [19].

Each surface floristic survey was produced according to the Braun-Blanquet [18] method. Each sheet shows the abundance, dominance and sociability of the inventoried plant species. The basic work used for the identification of the taxa collected in the field is from the studies carried out by Quezel and Santa [6], Battandier [20], Vella [21], Blanca et al. [22] and Dobignard [23]. We gave each species an exp code: *Pistacia lentiscus* P11, *Quercus ilex rodentifoliae* or *ballota* Q2.

A statistical treatment by factorial analysis of the correspondences (F.a.c.) was carried out to better study the distribution of the different species in the 4 stations. Statistical processing was done with Minitab19 software. To facilitate the work, the species have been coded according to a first letter code and a number. The first letter for the genus, and the species number in an alphabetical order [7].

3. RESULTS

3.1. Bioclimatic results

Examination of the ombrothermal diagrams (Figure 2) shows that the dry period extends from April to October for the 3 stations Maghnia, Saf-saf, Sebdou, which represents a period, which lasts approximately 6 months. For the Hafir station, the dry period extends over a period that lasts 5 months between the month of May and the month of September.

According to Emberger pluviothermal climagramme, (Figure 3), we see that the 3 stations: Hafir, Safsaf and Sebdou are located at the level of the sub-humid level in temperate winter. The Maghnia station lies between the lower sub-humid and upper semi-arid stage with a warm winter (Table 3).

Table 3. Bioclimatic data of stations.

Station	**P** (mm)	**M** (°C)	**m** (°C)	**Q_2**	**I.C**	**Climat Type**	**Dry periode Month**	**Bioclimatic stage**	**Thermotype**	**Ombro-type**
Hafir	475,52	25,80	5,71	81,97	18,87	Semi-arid	05	Sub-humid to temperate winter	Meso-mediterraneen	Semi-arid superior
Maghnia	362,24	27,73	10,07	70,27	12,9	Semi-arid	06	The lower sub-humid with warm winter.	Thermo-mediterraneen	Semi-arid inferior
Saf-saf	476,95	26,65	5,48	77,94	19,03	Semi-arid	06	The sub-humid in temperate winter	Meso-mediterraneen	Semi-arid superior
Sebdou	456,9	25,67	6,35	81,83	17,97	Semi-arid	06	The sub-humid in temperate winter	Thermo-mediterraneen	Semi-arid superior

P – precipitations; M – maximal temperature; m – minimal temperature; Q_2 – Emborotermic quotient of emberger; I.C – Index of continentality.

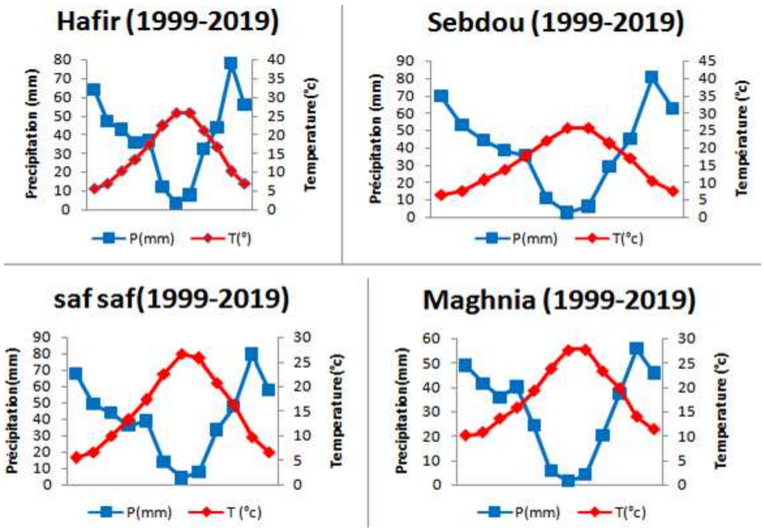

Figure 2. Ombrothermal diagrams of Bagnouls and Gaussen.

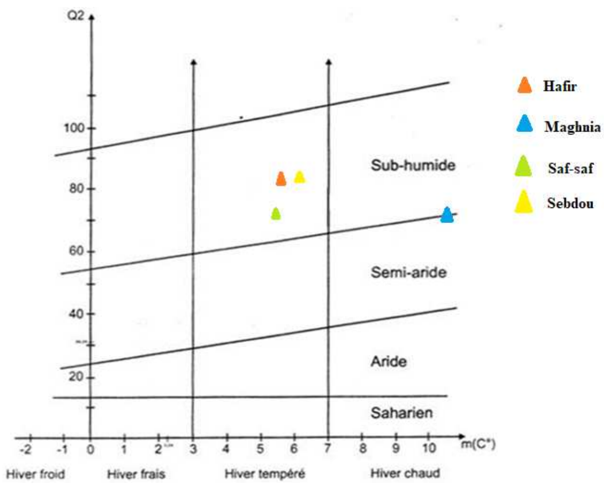

Figure 3. Emberger pluviothermal climagram (Q).

3.2. Biological diversity

The classification of the biological, morphological and biogeographical types with the taxa recorded at the level of the four stations, out of the 200 inventoried records. Allowed to notice the domination of the Ateraceaes and Fabaceaes families at the level of the majority of the surveys. For the biological types, we also record the dominance of the therophyte type followed by chamephytes following the decreasing line Therophytes > Chamephytes > Geophytes > Hemicryptophytes > Phanerophytes. The morphological types that accompany the different oak formations in the four stations are marked by heterogeneity between woody and perennial and annual herbaceous species [24]. Annual grasses dominate, reaching a percentage of 50%. Finally, the biogeographical types which are characterized are the Mediterranean and Western Mediterranean elements [25].

3.3. Vegetation analysis

Discrimination by factorial analysis of correspondences F.a.c. was performed by factorial correspondence analysis using the Minitab 16 software. The variables were introduced in the form of codes for each species in order to facilitate the reading of the factorial designs (Appendix 1). These codes are represented by lowercase letters taken from the vernacular name of the taxa present and identified from the flora of Quezel and Santa [6], for example *Quercus suber* Qs, *Quercus ilex rodentifolia*e or *ballota* Qi [8]. The presence and absence indices were retained in the statistical processing by factorial correspondence analysis (F.a.c) [8]. The search for the ecological significance of the factor axes will be based on the confrontation of species with strong relative contributions and their distribution on the one hand on the positive side and on the other hand on the negative side of each of the axes [7]. We will thus attempt to specify the major ecological factors which are highlighted in the form of ecological gradients [7]. These have a major influence on the active and evolutionary dynamics of the taxa inventoried [26]. A particular interest is directed towards the trainings with oak groves at the level of all the stations selected. We have chosen to interpret axes 1 and 2 because they represent the values of the variances and the rates of inertia, the highest. The examination of the factorial maps illustrating the 2/1 projection plans makes it possible to characterize the ecological gradients which gravitate among the different species of oak.

3.3.1. Station 1, HAFIR

Station 1 (Fig. 4) has axis 1-2: variance = 77.61, and rate of inertia = 38.9%. On the positive side of the plane is positioned the species *Quercus coccifera* which has the highest contribution. The species *Quercus faginea* sub *tlemceniensis* is positioned on the positive side of axis 1 and at the same time on the negative side of axis 2. It isolates itself perfectly concretizing the endemism it indicates. On the positive side of axis 1 and 2 at the extreme right, the species *Quercus ilex* and *Quercus suber* are similar, sharing the affinity for the siliceous substrate. In the negative side of the plan, we find chamephytic and pahnerophytic species of mediterranean lawns and matrorals. *Cistus albidus*, *Prasium majus*, *Erica arborea*. The ecological gradients that stand out the most are altitude, anthropization by fire and humidity.

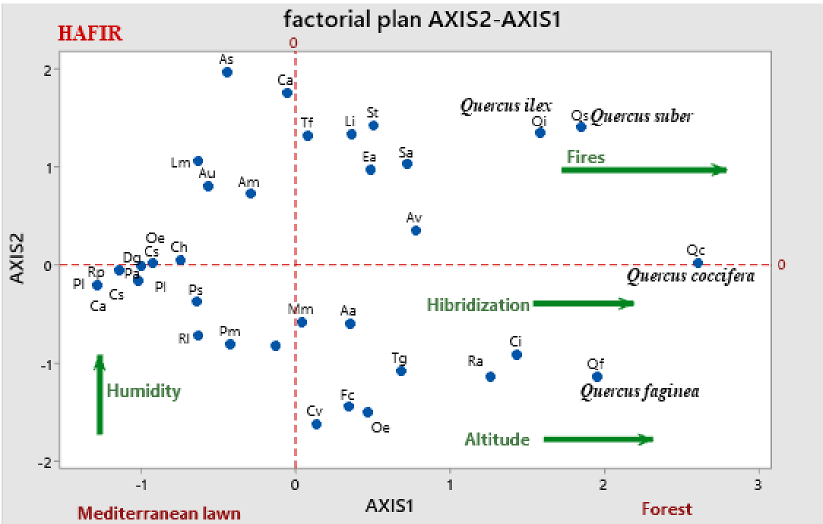

Figure 4. Factorial map of the ecological gradients of the HAFIR station.

3.3.2. Station 2, ZARIFET

Station 2 (Fig. 5) has axis 1-2 : variance = 74,625 and rate of inertia = 37,3%. All the oak species have a strong contribution and are grouped together on the positive side of axis 1. The presence of *Cedrus atlantica* argues for the altitude gradient which goes in the positive direction of axis 1. At the end of the plane *Quercus ilex* is illustrated on the positive sides of two axes. The *Quercus coccifera* seems more stable tolerating limestone better than the others, does not change position in the middle of the plane opting slightly towards the negative side of axis 2. *Quercus faginea* at this station take the direction of the altitude gradient to project towards *Quercus ilex*. It is at this interval, which corresponds to this Euclidean distance on the plane that the hybridization of *Quercus faginea* interferes. *Quercus faginea* appears to have less hybridization at high altitudes [27], where *Quercus ilex* Sub *roduntifoli*a predominates [14]. The most prominent ecological gradients are altitude, anthropization, hybridization and endemism. As in the previous station on the negative side of the plan we find the chamephytic and phanerophytic species of Mediterranean lawns and matrorals. *Phyleria anguistifolia, Lobularia maritima, Cistus villosus.*

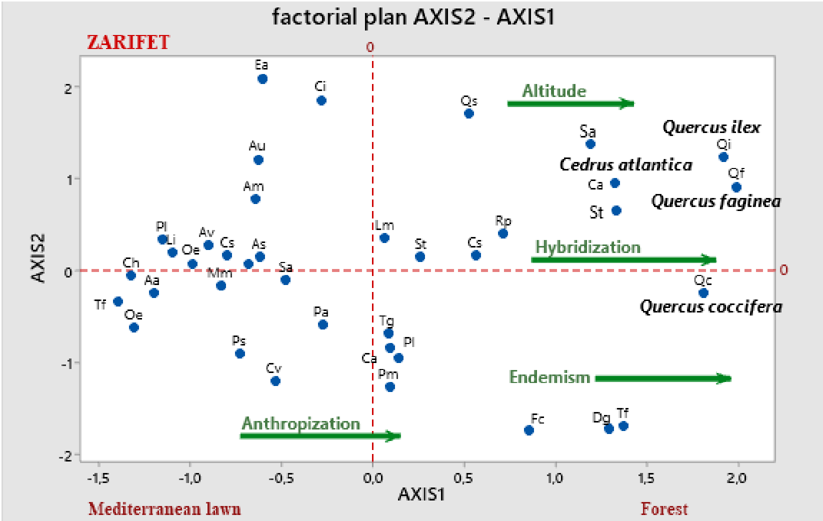

Figure 5. Factorial map of the ecological gradients of the ZARIFET station.

3.3.3. Station 3, MOUTAS

Station 3 (Fig. 6) has axis 1-2: variance = 75,60 and rate of inertia = 37,8%. At the level of the Moutas station, the species which have the highest contribution are the endemic species represented by the oaks. These taxa are projected in the line of the plane illustrating the altitude gradient. On the positive side of axis 1, and negative of axis 2 are positioned *Quercus coccifera, Cedrus atla*ntica and *Quercus suber*. Cork oak is closer to cedar because of their preference for silicultural substrate [24].

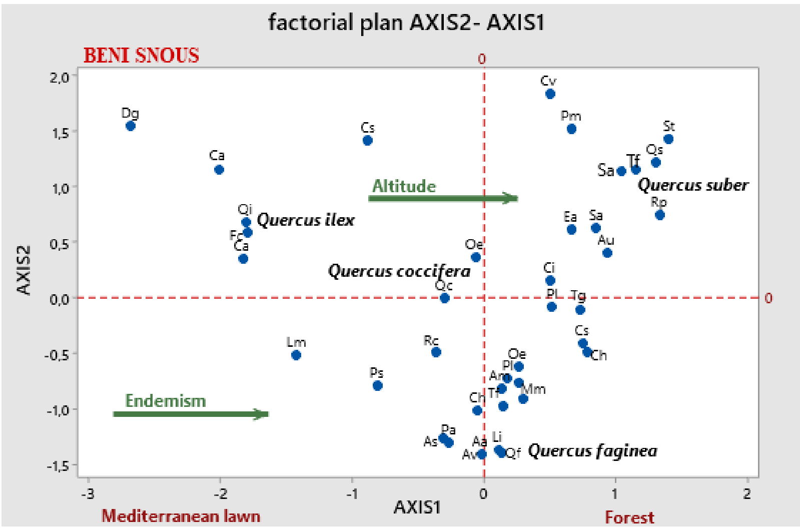

Figure 6. Factorial map of the ecological gradients of the MOUTAS station.

The presence of *Quercus fagin*ea near *Quercus ilex* projects these two taxa into the supra-Mediterranean stage, leaving the hybridization interval for *Quercus faginea* between positioning *Quercus* *coccifera* as the lower limit and *Quercus ilex* as the upper limit. On the negative side of the plan we persist, the chamephytic and pahnerophytic species of Mediterranean lawns and matororals. *Rhamnus lycioides, Rosmarinus officinalis, Ruta chalepensis.*

3.3.4. Station 4, BENI- SNOUS

Station 4 (Fig. 7) has axis 1-2 : Variance = 75,55 and rate of inertia = 37,8%. At the level of the Beni-Snous station, *Quercus faginea* seems to be well positioned in its refugee at the negative end of axis 2. It is accompanied by certain species, in particular *Lobularia maritima, Phagna lonsaxatile*. The *Quercus suber* seems to be well shared its affinity to the silicole substrate with the *Arbutus unedo* which are both positioned at the positive ends of the axis 1 and 2. The *Quercus coccifera* always seems to preserve its position in the middle of the plane tilting a little towards the negative side of the axis 1. Marking its territory as the lower limit of the supra-mediterranean level. The *Quercus ilex* in this station marks its contribution on the negative side of axis 1 in the middle of the positive part of axis 2. Marking a forest stand accompanied by *Cistus* species, *Cistus monspeliensis*, *Cistus albidus*. The endemism and altitude gradients are the most significant in this station. The hybridization gradient seems to be expressed the least because the different oak stands seem to congregate uniformly in forest stands in ecological refugiums [14].

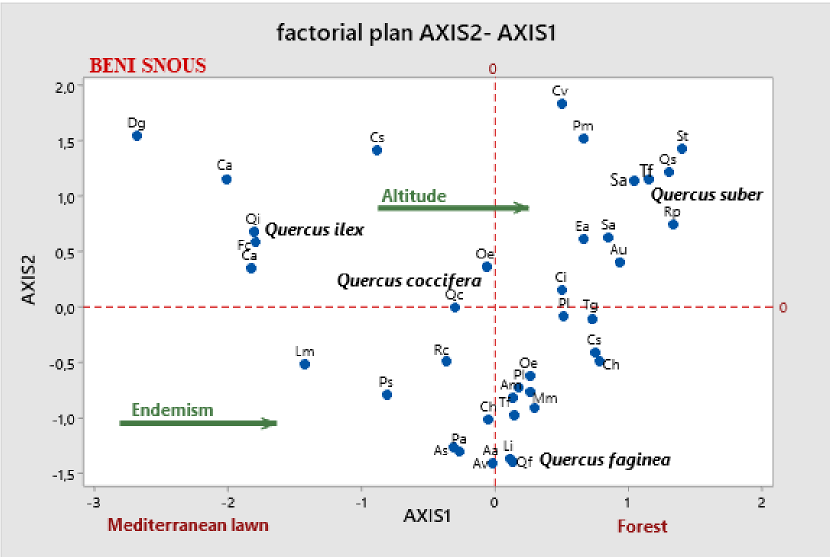

Figure 7. Factorial map of the ecological gradients of the BENI-SNOUS station.

3.4. Atropism and fires

The forest potential of the study area is not immune to the fires of the summer period of each year, given that it is subjected to intense multiple pressures which continually threaten its degradation. The annual average of burnt areas is around 122 ha for the period from 2004 to 2019.The area was the scene of major fires during 1994 and 1996 and 2015 (Figure 8) when the burnt area exceeded the 1000 ha, more exactly 1304.30 ha.

Statistics show that the forest fire situation continues to worsen from year to year, thus jeopardizing an already severely degraded vegetation cover [7]. The alteration of the vegetation cover is accompanied by a loss of soil. The succession of these events can lead to apparently degraded facies with significant rock outcrops. This situation constitutes a plateau in the general dynamics of the vegetation, but it is in no way irreversible. The consequences of fires on the ground were pointed out by Aubert [28] namely the change of the structure of the humus horizon, the reduction of the water retention capacity, the increase of the pH, the increase of rate of limestone by shattering of the parent rock and the decrease in the total cation exchange capacity [28]. The striking characteristic of Mediterranean vegetation is its ability to adapt to the repeated action of fires. The plants of the Mediterranean regions which are subjected to fire periodically present adaptations which ensure their survival or their rapid recolonization of the environment [29].

Figure 8. Photos of a stand of Kermes oak (Zarifet forest, Tlemcen mountains) ravaged by the August 2015 fire (Photos Ghezlaoui 2015).

3.5. Pathogens

It is also important to point out that the *Quercus phaginea* at the level of the four stations including that of Moutas which shelters a very large number of species of galls of very varied size, shape and color (Figure 9). Including the famous cherry scab "*Cynips quercusfolii*", which is a *Cecidia* or an outgrowth appearing on a plant tissue, caused by a pathogen (animal). Indeed, this gall is caused by the laying of a small insect "wasp" *Cynips quercusfolii* and the oak does not seem to suffer from it [8]. When we walk in autumn in the forest, we notice very round galls, a little rough, of pale green, yellow or/and red and brown color, fixed on the fallen leaves (underside, on the vein). They are called "cherry galls", they are very common. These are oak-specific galls [30].

Figure 9. Forest of *Quercus faginea* sub *tlemceniencis* affected by *Cynips quercusfolii* (Beni-Snous) (Photos Ghezlaoui 2015).

6. DISCUSSION

The forests of the Tlemcen Mountains offer an eccentric and very diverse botanical landscape, linked to the circumstances of the climate, soil and relief from the coast to the steppe. They are characterized by mixed groups of Holm oak and Zeen oak in the forest of Hafir and Zarifet [31]. The study of the ecological gradients that influence the distribution of oaks leads to characterize the factors that play a key role in their plant stratification and distribution. These gradients stand out at all stations: altitude, endemism, anthropogenic effect and hybridization gradient for *Quercus faginea* [24]. This has a hybridization interval, between the stage of positioning of *Quercus coccifera* as the lower limit and the stage of *Quercus ilex* as the upper limit [8].

It is probable that the current forest dynamics in the zone considered, are rather favorable to the Holm Oak, following an increasing altitudinal gradient [32]. And to oak kermes in lower altitudes, because of their strong resilience after fire [24, 33]. Cork oak and Zeen oak deserve to be privileged in these landscapes, where the soils are favorable to them, in particular in reforestation programs in areas sensitive to fires [7]. The cork groves ensure the sustainability of forest cover in the Mediterranean area at high risk of fire, for the benefit of the landscape and its biodiversity, especially animal biodiversity [34]. This model emphasizes the critical importance of these areas for regional planning conservation biogeography [35]. Therefore, refugia are crucial areas in the current climate change context and future research will lead to a modeling and conservatory management approach [36].

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