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Post-fire regeneration of cork Oak and holm Oak at Tlemcen National Park (Western Algeria)

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ABSTRACT The most worrying factor in forest degradation is fire, whose outbreak and spread is favored by physical and natural conditions. Algeria, like other Mediterranean countries, is paying a high cost. It must be recognized that forest fires have become disastrous in the last decades. An average of 30,000 hectares is destroyed every year, threatening the country's ecological balance. This study aims to identify the post-fire dynamics of forest structuring species in Tlemcen National Park (Western Algeria). This article is written in this context. This work is based on observations as well as a monitoring of burned sites. The aim is to show concretely the resilience of cork Oak (*Quercus suber* L.) and holm Oak (*Q. ilex* L.), the flagship species of Tlemcen National Park, in order to develop a conservation strategy and identify a succession model after a fire. An experimental protocol has been put in place to assess vegetation regeneration. Post-fire morphometric measurements were performed three years in a row (T1, T2 and T3) during the adequate phenological period. The observed elongations range from 22.6 cm to 17.9 cm in the first year; 46.16 cm to 36.5 cm in the second year and 95.2 cm to 67.3 cm in the third year in favour of holm Oak. Monthly and inter-year comparative analyses reveal that, under the same site conditions, holm Oak shows a better adaptability to fires than cork Oak. The various measures recorded show an elongation of 20.95% in favour of holm Oak in the first year, 20.92% in the second year and 29.30% in the third year in favour of the holm Oak. A competition for the recapture of the burnt space takes place after the fires. As for the other species, there is a self-succession where chamephytic species are the most favoured.

KEY WORDS Cork Oak; holm Oak; fire; Regeneration; Tlemcen National Park.

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INTRODUCTION

Forests in the Mediterranean region offer significant systemic services; however, they are heavily impacted. Lavorel et al. (2006) note that forest fires are a major threat to Mediterranean forests as they have an impact on plants, animals and forest managers' activities.

In hot periods, mainly in summer and early autumn, forest managers are often called upon to manage fires that outbreak here and there and to predict reliable models for risk assessing. Today these risks increase with climate change.

Pinal et al. (1998) find that in the Mediterranean region, summer and early autumn are rather dry and thus, forests become potentially more vulnerable to fires. Le Houerou (1980) finds that over time, the Mediterranean forest goes on burning. He estimates that an average of more than 200,000 hectares of forest burn each year in the Mediterranean basin; while Valez (1990) estimates that 700,000 to 100,000 hectares are devastated each year.

Algeria, a country in the southern Mediterranean, has not been spared by this scourge. In 2002 Madaoui gave the history and the toll of forest fires in Algeria. Missoumi et al. (2004) argue that the forest area in Algeria does not exceed 1790000 ha or 1% of the country's total area. These same authors state that by adding regressive forest formations whose evolution is uncertain such as scrub, brush and alfa-grass formations, the vegetation cover would be 3879000 ha or 2%.

These plant formations are hit hard by fires. An average of 30,000 hectares is lost every year. According to the work of Benderradji et al. (2004), the area that is burned per fire varies in accordance with its situation: the Northeast (N.E), the Central North (C.N.) and the Northwest (N.W.) of the country. The statistical report is 51 ha in the N.O., 37 ha in the N.E. and only 18 ha in the C.N. When we read these figures we find that the N.O. part is more exposed to fires than other parts of the country. This difference is probably due to the nature of the substrate, the geomorphology of the terrain, the floristic composition and the slow response of fire managers.

Many works on western Algerian forests have been devoted to the development of forest plant structures (Bouhraoua, 2003; D.G.F., 2004; C.F.T., 2008; Letreuch-Belarouci, 2009; Bouhraoua et al., 2014; Belgherbi & Benabdelli, 2015).

Tlemcen National Park, which is an integral part of northwestern Algeria, is experiencing a worrying problem in the evolution of plant stands as a result of repetitive fires, overgrazing and forest clearing. These formations essentially consist of *Quercus suber, Q. ilex, Q. faginea, Arbutus unedo, Pinus halepensis, Acer monspeliensis, Calycotome spinosa, Rhamnus alatemus, Cistus monspeliensis, C. salvifolius, Clematis flammula, Chamaerops humilis, Daphne gnidium, Erica arborea, E. scoparia, Helichrysum stoechas, Lavandula stoechas, Lonicera implexa, Osyris alba, Viburnum tinus, Phyllyrea angustifolia, Ruscus aculeatus, Sarothamnus scoparius, Smilax aspera.*

The aim of this work is a contribution to find out the post-fire reactions of the flagship species of the forest formations of Tlemcen National Park, after the October 2016 fire which caused great damage to the plant structures in place. More specifically, the aim is firstly to understand the regenerative variation over time, of two key species of these formations: cork Oak (*Quercus suber* L.) and holm Oak (*Q. ilex* L.); and secondly to determine the model of plant succession.

MATERIAL AND METHODS

Study area

The Zariffet Natural Forest is located 5 km southwest of the town of Tlemcen. It covers an area of 926 hectares, divided into 4 cantons (Boudy, 1952). It is a mountain Oak forest developing on a very rugged terrain whose altitude oscillates between 1000 and 1217 m. In administrative terms , the Zariffet forest massif falls under the forestry district of Tlemcen. It is limited to the north by the municipality of Mansourah, to the south by the ridges of Beni Bahdel, to the east by Terny and to the west by the municipalities of Zelboun and Béni Master.

A part of Tlemcen National Park was hit by a fire in 2016 (1°38'1''W; 34°83'55'' N) which devastated dozens of hectares, changing the landscape (Fig. 1). This disaster was followed by a plant response that led to a succession which was based on the nature of the burned taxa, the soil, the topography, the violence of fire and the climate.

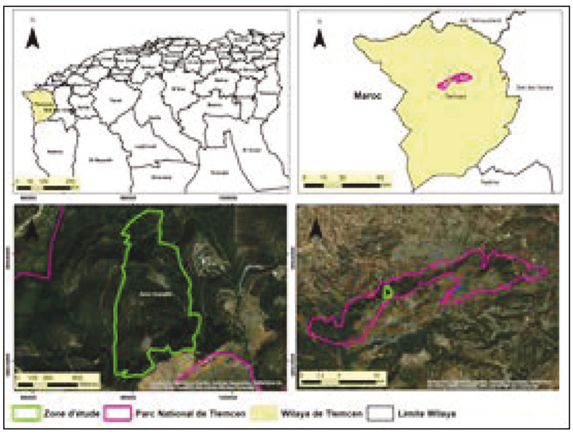

Figure 1. Location of the study area
(Zariffet State Forest, Tlemcen National Park).

Methods

In this context we have selected two of the most abundant species of the forest, the cork Oak and the holm Oak. These two taxa dominate the forest formation of the national park. In terms of ecological requirements, these species tend to be heliophile, thermophile, xerophile to mesoxerophile (sometimes mesophile), acidiphile with large trophic amplitude (Rameau et al., 1989) and rustic. According to the same authors, the holm Oak has a taproot system, well developed from the first year, which gives it the ability to thrive in inhospitable environments (arid, rocky, limestone).

In the park, both species grow well in their biotope. It should be noted that the cork of the cork Oak is used for commercial purposes.

The fire that occurred on 24.X.2016 caused a loss of 80 ha or almost 9% of the forest area. To better understand the responses to the trauma caused by the fire we carried out a post-fire follow-up. This operation lasted three years in a row (2017 [T1]-2018 [T2]-2019 [T3]). An experimental protocol was developed to achieve our expectations. We placed fixed and geo-referenced milestones on a 500 m long transect. On the route we randomly selected five squares of 100 m^2 each.

Inside each square we spotted the trees on which the follow-up would be done. Twenty trees for each species (four trees per square) were retained, and on each tree, 5 measurements were performed each year in April, May and June. During our follow-up we considered the elongation of twigs and/or stump shoots. The various measurements were treated statistically.

RESULTS AND DISCUSSION

Basing our work on indirect visual cues such as the degree of vegetation burnt, the appearance of the burnt soil surface and the vegetation residues, we were able to identify the degree of alteration caused by the fire. According to the evidence left on the ground where we noted a cleaned soil and charred trees on the one hand and by using Amandier's work (2004) as a support on the other hand, we deduced that the fire that devastated the forest of Zariffet was a third-degree fire. In addition, Amandier (2004) showed the degree of fire sensitivity of the different parts of the cork Oak (Fig. 2). In this work it was shown that the upper parts of this species indicate the intensity of the fire and that the damage is related to the age of the tree and therefore the thickness of the cork.

In our case, the fire reduced the density of stands by destroying smaller trees and preferentially reducing the average and large trees on the one hand and devouring the chamaephytes and therophytes on the other hand (Fig. 3). It should be noted that the structure of the cork O. consists of: very large wood, large wood, medium wood, small wood, poles and saplings; and thus the impacts are different depending on the parts affected by the fire.

Morpho-metric regeneration of cork Oak

In Mediterranean ecosystems, the species existing before the fire are found again immediately after, but in different proportions: we then speak of self succession (Hanes, 1971). The regeneration

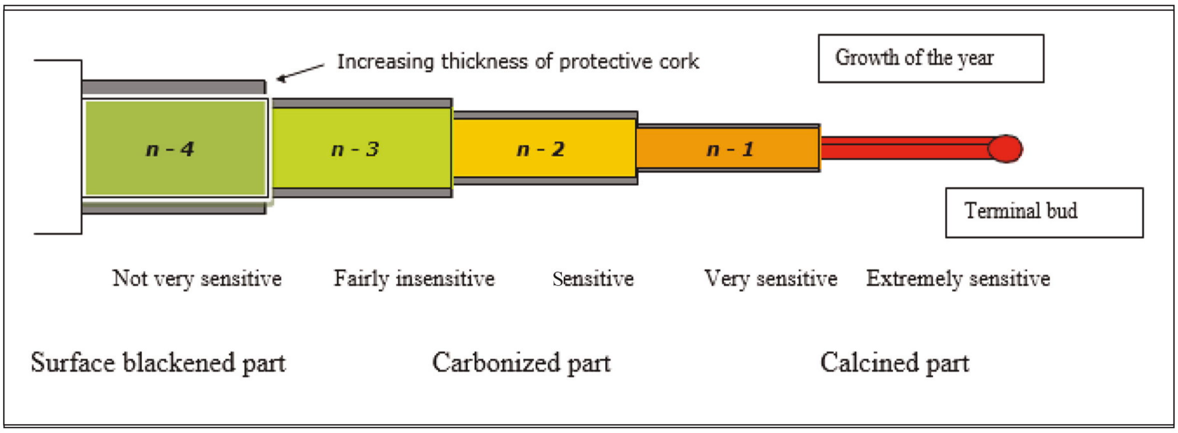

Figure 2. Sensitivity to burning of cork Oak (Amandier, 2004).

Figure 3. Damage caused by forest fire at Zariffet (Tlemcen National Park:
rest of the fire (24.X.2016) (to the left) and intervention of forest managers (to the right).

Year	Nature of species	April	May	June	Average
		Lengths of twigs and / or shoots (cm)			
T1- (2017)	holm Oak	9.1	14.7	22.7	22.7
	cork Oak	6.5	10.9	17.9	17.9
T2- (2018)	holm Oak	27.8	34.3	46.2	46.2
	cork Oak	20.3	25.7	36.5	36.5
T3- (2019)	holm Oak	51.1	68.5	95.9	95.2
	cork Oak	40.3	49.6	67.3	67. 3

Table 1. Extended oak regeneration cork and holm Oak.

time varies depending on the biological type and the nature of the plant as well as the frequency of the fires. The obtained results were treated statistically. The average of these measurements represents the length of regeneration of the species at the moment T1, T2 and T3 (Table 1). It should be noted that in each times T1, T2 and T3 three one month-spaced measurements were carried out (end of April, end of May and end of June).

On the site we found that cork Oak had twig and stump shoots regenerations, while holm Oak had stump shoots only. The stump shoots occurred at the base of the burned tree trunk.

The analysis of the elongations of the two species shows that the responses of the two taxa follow a model of direct regeneration or self-succession. Nevertheless, the upper part of the cork Oak is protected by cork, which explains its adaptation to fires.

At T1 time (i.e. 08 months after the fire) cork Oak regeneration records an average of 17.9 cm with a standard deviation of ±5.31; in T2 (20 months later) an average of 36.5cm was recorded with a standard deviation of ±10.35 and in T3 (32 months later), the average length of new twigs is 67.3cm with a standard deviation of ±13.41 (Fig. 4). The response is important in T3 and the appearance of the forest gradually recovers its original state.

It should be noted that forest managers have faced the problem of cork Oak regeneration since the beginning of the 20th century; the rarity and difficulty of natural regeneration and the uncertain results of regeneration operations by stem shoots or artificial seedlings were then recognized (Marion, 1956).

Morphometric regeneration of holm Oak

Holm Oak is also very well represented in our study area from a dominance-abundance point of view. The shoots are reconstructed by stem shoots and the obtained measurements after 32 months show the taxon's ability to recover the environment. The results are as follows: the average is 22.7 cm in T1 with a standard deviation of ±9.99; 46.2 cm in T2 with a standard deviation of ±20.10 and 95.2 cm with a standard deviation of ±38.77 in T3 (Fig. 5).

Comparative analysis of post-fire responses

The distribution of the 18 taxa at the seven stations in the study area is heterogeneous according to environmental variables (including rugged terrain and a mixture of various plant species) (Fig. 6).

Both oak species are fire resistant, and are highly stable according to Connell & Statyer (1977); they are characterized by a very wide elasticity associated with high persistence and good regeneration.

Inter-monthly analysis of the responses of the two Oaks species

Overall, the inter-monthly elongations in the space time (2017–2019) is more appreciable for holm Oak, in other words, there is faster regeneration for holm Oak than for cork Oak (Table 2). The first works on forest successions date back to Clements (1963). However, it was Gleason (1917)

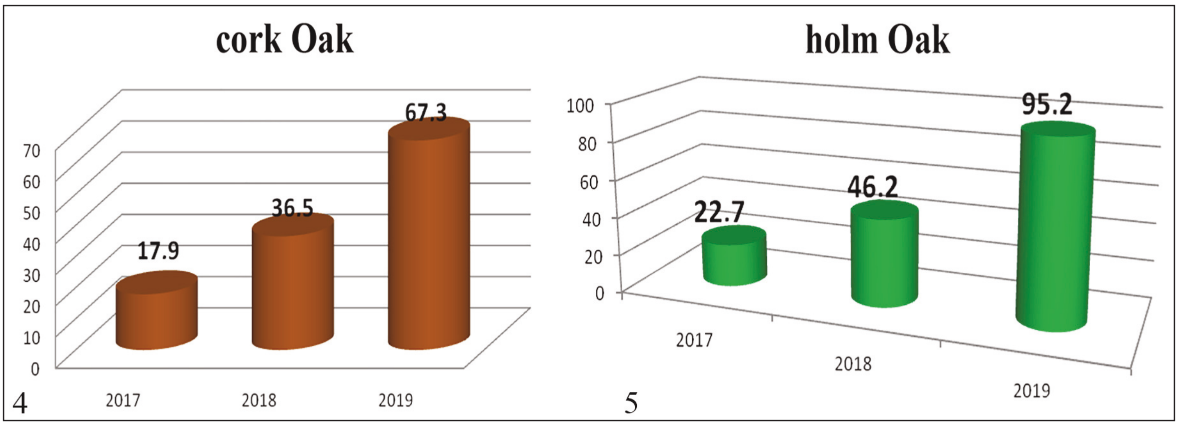

Figure 4. Functional response of the cork Oak (cm). Figure 5. Functional response of the holm Oak (cm).

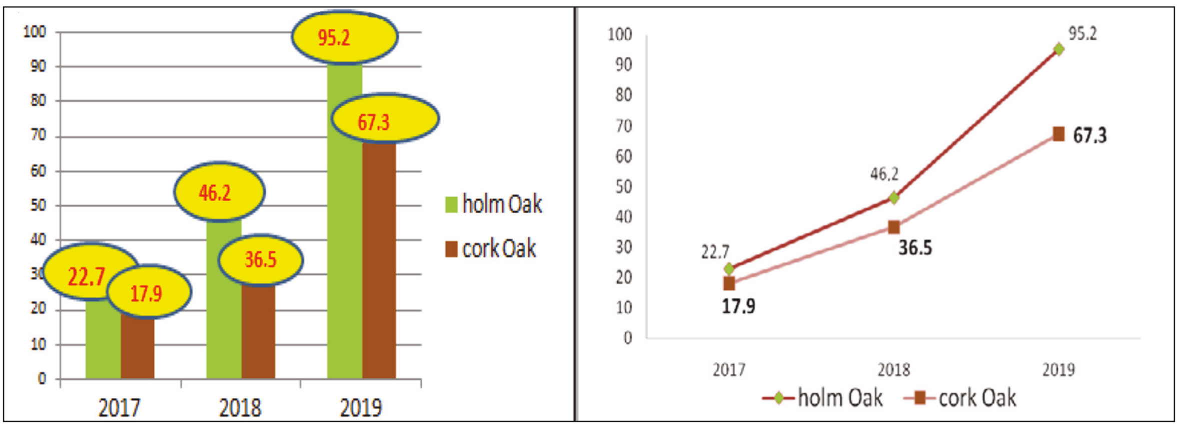

Figure 6. Average functional response of both types of Oaks.

Figure 7. Regeneration of cork Oak after 1 year. Figure 8. Regeneration of cork Oak after 3 years.

Figure 9. Holm Oak stump rejection after 20 months of fire passage.

	Species	2017	2018	2019
T2 may – T1 april	holm Oak	5.6	6.5	15.4
	cork Oak	2.4	5.4	11.1
T3 june- T2 april	holm Oak	7.9	13.9	27.4
	cork Oak	8.0	8.8	17.7

Table 2. Comparative elongation of the two Oaks over time.

who developed a stochastic theory based on the individual. Studies on successions have helped to provide a cluster of sometimes convergent, sometimes divergent or even contradictory conceptions according to Lepart & Escarre (1983).

We notice that, overall, the vegetation has recovered and that the chamaephytes tend to occupy the ground. This recovery is rather timid in the first year. However, in the third year the vegetation recovers its splendour and vivacity (Figs. 7, 8).

The results of this study appear to be consistent with the concept of Egler's initial floristic composition (1954) and Connell & Slatyer's tolerance model (1977). The majority of herbaceous and shrub species are able to regenerate vegetatively after fire or to quickly invade the devastated site by seed (Alghren. 1960; Carleton & Maycock. 1980; Flinn & Pringle, 1983). It is noted that after a disturbance, the recolonization of a site occurs quickly, as the majority of the species that were present before the fire regenerate. Our results agree with those of Hasnaoui (2008) and Medjati et al. (2013) on the regeneration of *Chamaerops humilis* and Chamaephytes in the matorrals in the region of Tlemcen.

After fire, soil fertility plays a major role in the dynamics of an ecosystem's plant species. In the succession process of fire-restricted ecosystems, the optimal use of nutrients promotes the resilience of plant formations (Ouadah et al., 2016). Indeed, vegetation recovery in the first years after the fire has a decisive ecological role in the mobilization of nutrients and their storage in biomass. This recovery depends on the regeneration success.

CONCLUSIONS

To sum it up, the results obtained show that the evolution of vegetation after fire follows Egler's model (1954) which is called the model of the "*initial floristic composition*"; that is, all species are present in stands short after fire, even though the subsequent relative abundance of individuals and the recovery rate of each species changes somewhat. In the case of self-succession in the sense of Hanes (1971) the perennial and annual species respond better and a competition of vegetative elongation is observed on the ground. In this context cork Oak has a significant recovery power after the fire; however the holm Oak is more efficient than the cork oak in terms of regenerative capacity.

We noted that the shoot regeneration of stumps from both Oak species is easily adaptable to fires. In addition, fire is considered a valuable supplement for their construction of moribund stands. Although cork Oaks shoot until old age, some older subjects no longer normally bear this property under marginal site conditions. A coppicing is recommended on all subjects that are stunted and likely to wilt because the stump and roots very often keep their vitality and their ability to shoot or sucker.

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