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The Occurrence of Creeping Plants in Plantations: A Dilemma of Cork Oak Forest Regeneration in Tunisia

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Abstract: As natural regeneration and direct sowing have been considered difficult, planting was adopted as a solution to attenuate the decline of cork oak forest. However, Tunisian planted cork oaks showed a troublesome phenomenon characterized by the presence of creeping plants which has a negative influence on height growth and cork production. This study aimed to estimate, for the first time in Tunisia, the percent of creeping cork oaks among those planted between 1995 and 2008 and to make a diagnosis in order to propose solutions to this problem. The percentage of creeping plants was determined in 2014 within 35 plots installed in 13 perimeters, situated in northern Tunisia. Crown diameter and total height were measured for the whole plants. Moreover, the creeping plants were were distinghished and inventoried in categories according to shoot ramification. The average survival rate, estimated at 55±30%, varied between 0% and 100% depending on perimeter. The average percentage of creeping plants reached 82% ranging between 0 and 100%, which reflects the extent of this phenomenon. Furthermore, 64.3% of creeping plants were classified in category I (1 main stem) where as 12.41% and 23.29% were classified in categories II (2 ramifications) and III (3 or more ramifications), respectively. The percent of creeping plants was negatively correlated to altitude and positively correlated to soil hardnes; indicateing high grazing and low possibility for plants to grow.

Key words: cork oak, creeping plants, shoot growth, overgrazing, Mediteranean climate

1. Introduction

The current state of cork oak stands is disturbing. Their progressive degradation, especially in southern Mediterranean forests, results from a combination of biotic and abiotic factors that are constantly intensifying (Palahi, 2004; Nsibi, 2006; Boussaidi & Rebai, 2017). Man has profoundly modified the

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equilibrium that exists in the ecosystem. He disrupted microclimates by clearing, burning, cutting trees, cork debarking badly done and especially grazing (Stiti *et al*., 2014). Actually, natural regeneration is difficult and almost absent (Hasnaoui, 1992; Abid, 2006). In Tunisia, trials of regeneration by direct sowing were attempted in 1988-1989 on more than 3000 ha, but they ended in total failure (Hasnaoui, 1992).

Numerous direct seeding trials have suffered the same fate in other Mediterranean regions (Messaoudene, 1984; Sondergaard, 1991; Louro 1999). Therefore, plantation has been the most widely used method for the rehabilitation of cork oak forests, especially because of the improvement of seedling production techniques and the modernization of forest nurseries (Stiti *et al*., 2014).Thereby, cork oak plantations were achieved in the forests of Kroumirie-Mogods (North-West and North) between 1995 and 1999 by Tunisian General Directorate of Forests. However, these planted cork oaks showed a problematic phenomenon that affected height growth and apical dominance and might last several years after planting. Instead of straight stems crawling plants were observed. Its negative influence on forest management is considerable given its effect on cork production, main product in this forest.

In Mediterranean countries, the shelters were suggested to be used after plantation to eliminate or reduce this problem but their use was controversial. Due to their ability to shield seedlings from browsing damage, tree shelters might play a key role in regeneration of cork oak in areas where animal browsing is a concern (Mechergui *et al*., 2013). They have been beneficial to the survival and the growth of plants in Italy (Ruiu & Pintus, 2010) whereas they have been considered ineffective or even negative in the eastern Pyrenees in France (Institut méditerranéen du liège, 2005). In Tunisia, in an experimental trial, the use of different types of shelters has generated a large proportion of young plants with stability problems due to the asymmetry between diameter and height growth (Chaar *et al*., 2008). While tree shelters might improve regeneration success, their effects on seedling growth and development might not be entirely beneficial. Although taller seedlings were produced, they had thin stems and smaller root systems that might not support the seedling when the shelter is removed (Mechergui *et al*., 2013). Besides this problem, the use of shelters, in a large scale, increase widely the cost of plantation. Therefore, a deep diagnostic on this dilemma among the whole cork oak plantations is required in order to find the best treatment to improve cork oak growth and to overcome the problem of creeping plants after plantation.This study aimed to estimate the actual percentage of the creeping plants among the cork oaks planted during the last decades and to make a diagnostic based on the shoot ramification in relation with risk factors and environmental determinants.

2. Methodology

The study was conducted in 13 cork oak plantations widespread in the region of Kroumirie-Mogods, situated in northern Tunisia. This region is characterized mainly by a mountainous landscape but influenced as well by its location in the South of the Mediterranean Sea (Figure 1). The region is characterized by a humid climate with a temperate winter presenting an average annual rainfall ranging from 800 to 1000 mm for Mogods and Kroumirie zones, respectively (Khemiri *et al.*, 2017). The forest area is also characterized by the existence of a local population living inside the forest, estimated at 1700 inhabitants in 2014 (according to the National Institute of Statistics). Despite the fact that cork oak forests are publicly owned, the local population benefits from free usage rights (Khalfaoui *et al*., 2020).

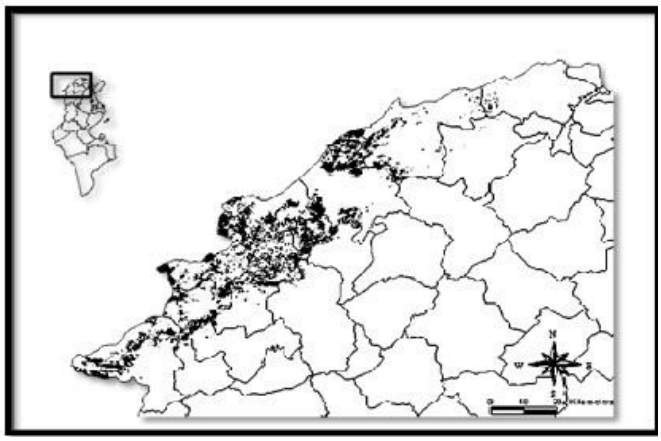

Figure 1. Location of study zone in Tunisia. Map based on data from IFPN (CNT-DGF-DGRST, 2010).

According to investigated perimeters, they were based between 1995 and 2008. These plantations were pure (*Quercus suber* L.) or mixed with stone pine (*Pinus pinea* L.). Sites vary in size between 1 ha in Ain Snoussi and 130 ha in El hanaia with an overall area estimated at 784 ha. Elevations vary between sites from 203 to 463 m (table 1).

Table1. Characteristics of the studied perimeters. Age: age of the cork oaks, Surface: surface of the planted area, Elevation: elevation of the perimeter.Mean ±standard deviation(minimum-maximum).

Variable	Value
Age (Years)	15.3±2.8(5-18)
Surface (Ha)	60.3±39.1(1-130)
Elevation (m)	307.9±114.6(203-463)
soil hardness (mm)	22.1±5.3(12-27.5)

35 squared plots (20mx20m) were selected for the investigation. Each plot contains 11 columns and 7 rows, totaling 77 measured plants per plot. Besides cork oak survival percent, plant height and crown diameter were recorded. As the plantations didn't have the same age, the evaluation was also made on mean annual increments. In addition, the percentage of creeping cork oaks was counted in each plot. Then, these plants were classified according to their ramification. Based on scientific literature (De Champs, 1971; Cline and Harrington, 2007; Kebrom, 2017) and field observations, the flushing stem types of creeping plants were identified and inventoried.

Furthermore, for all creeping plants the presence or absence of the terminal bud was recorded. Besides elevation, soil surface hardness was measured with a soil hardness meter (Push-Cone, DIK-5553; Daiki, Tokyo, Japan) at five points in the center and the four cardinal directions of each plot and the average value was calculated. This parameter estimates soil resistance (pressure) to grow plants with a measuring range between 0 and 40mm (0-49MPA).

Data processing was carried out using SPSS 20 software. The former enabled us by way of the GLM procedure (General Linear Models) to test the significance difference between the plots for all the studied variables and indicators and by means of Pearson coefficient to examine the correlation between the percent of creeping plants and the factors related to the sampling plots.

3. Results

The survival rate of cork oaks planted between 1995 and 2008 was estimated at 55±30% ranging largely from 0 to 100% according to sites (figure 2).

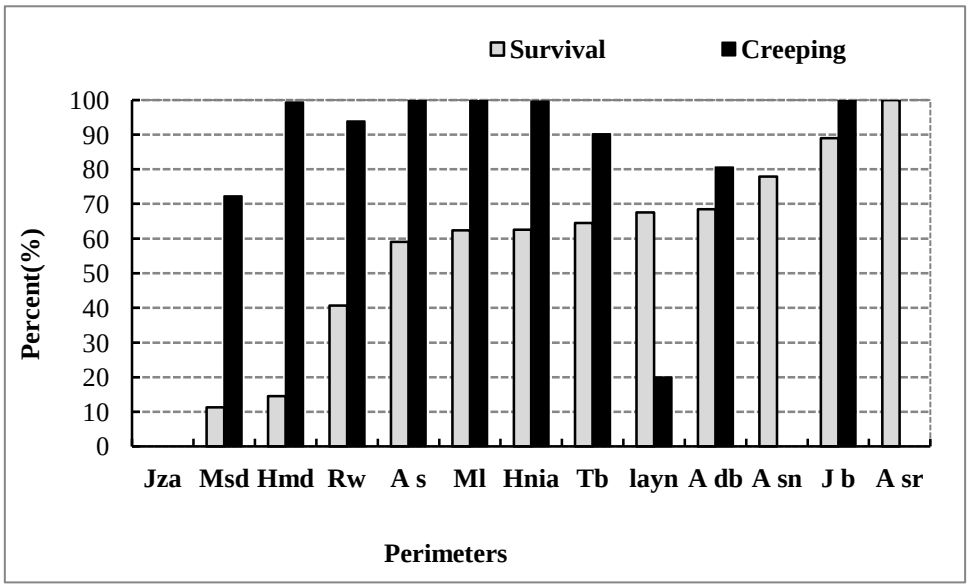

Figure 2. Survival percent of cork oaks in the studied perimeters and percentage of creeping plants (%).

Overall, height and crown diameter showed very low values for cork oaks considering their age (table 2). Annual increments in height and crown diameter showed a significant difference between the different sites (table 2).

Table2. Height, crown diameter, annual increment in crown diameter and height (mean ± standard deviation; minimum-maximum) of plants in the cork oak plantation perimeters. The difference between the sites, analyzed by ANOVA, is indicated by s when it is significant (ns: not significant) at the probability level of 0.05.

Plant variable	Height (m)	In H(m.year^{-1})	Crown diameter(m)	In Crown diameter(m.year^{-1})
Mean ± SD	1.14 ±1.61	0,078 ±0,108	0.83 ±0.63	0,056 ±0,042
Minimum-maximum	(0.04-8.45)	(0,002-0,563)	(0.045-4.12)	(0,003-0,275)
Signification	S(0<0.05)	S(0<0.05)	S(0<0.05)	S(0<0.05)

In the sampled plots located in the cork oak perimeters, the percentage of creeping plants relative to the number of living cork oaks was estimated at 82%, varying according to the plots from 0 to 100% (Figure 2). The classification of the creeping cork oak plants, according to branching, identified three pattern categories (figure 3):

1. Type I: plants with a Single dropped main stem ;
2. Type II: plants with two dominant growth shoots;
3. Type III: plants with three or more shoots (clump).

Figure 3. The 3 types of creeping plants classified according to branching. **a.** Type I, **b.**Type II, **c.** Type III.

This classification showed a dominance of type I plants (64.3%) compared to type II (12.41%) and type III (23.28%). Moreover, the terminal bud was missing in 42.26% of whole creeping cork oaks but no significant difference was noted for its presence or absence between the 3 plant types ($P=0.542>0.05$).

On the other hand, Pearson correlation analysis revealed that creeping plant percent (%) was significantly and positively influenced ($P=0.005<0.01$) by the soil surface hardness (0.834**) and significantly ($p=0<0.01$) and negatively affected by elevation (-0.611**) in the plots.

4. Discussion

In the present study, the average survival rate of cork oaks planted in Northern Tunisia between 1995 and 2008 was estimated across 13 perimeters at 55% ranging largely from 0 to 100. Actually, compared to previous investigations carried out in these plantations, this survival rate decreased since it be ranged between 53 and 81% depending on the site (Boussaidi, 1998; Khaldi, 2001; Aloui, 2001). Moreover, a phenomenon affecting the height growth of cork oaks and the fate of these plantations was observed. Our study has investigated this problem for the first time in Tunisia. The results showed a high average percentage of creeping plants estimated at 82% of viable cork oaks in the studied perimeters, varying from 0 to 100%. These results explain the low mean height (1.14 m) of plants, although most of them are over 15 years old. Indeed, the expression of a particular shape of the crown of a tree is commonly associated with these two phenomena: apical dominance and apical control (Zimmermann and Brown, 1971). It is determined in part by the difference between the growth rate of the stem and that of the side branches

(Chaar, 1998). Although the oak is characterized by a strong apical dominance and by a weak apical control (Collet *et al*., 1997), these creeping plants have lost apical dominance. In many studies, elevation has been used as a proxy for temperature because, on average, temperature drops by 5.5 K per vertical kilometer. Elevation gradients represent a powerful tool for investigating relationships between climate and vegetation (Boscutti *et al*., 2018), especially, under Mediteranean climate. The present study proved a negative significant correlation between elevation of the site and the percent of creeping corks oaks.

Actually, *Quercus suber* is commonly distributed at 300-600 m altitude (Kim *et al*., 2017). Furthermore, climate change has dried up many streams and resulted in a dissipation of a lot of water which reduced the amount of water available for low elevation plants. In addition, the results showed a positive significant effect of soil hardness on the percent of creeping cork oaks. This measurement gives an idea about soil condition and, commonly, about grazing and repeated trampling by animals as well as the potential for plant root insertion. The mean soil hardness estimated at 22.1 mm indicated a situation characterized by little possibility for roots to grow (Shoji *et al*., 2011, Yamasaki *et al*., 2020). For the plots having a high percent of creeping plants (100%), the values of soil hardness were equal to or greater than 24 mm which corresponds to wet damage for roots and difficulty to grow (Push-Cone, DIK-5553; Daiki, Tokyo, Japan).

In fact, this loss of apical dominance, apart from the natural tendency (Natividade, 1950), may be due to the removal of the terminal bud under the effect of browsing; with a shot of gel or sirocco. The results of the present study showed that the terminal bud was missing in almost the half of the creeping corks oaks. The diagnosis of this phenomenon in the investigated perimeters identified three types of creeping plants and allowed to better understand the branching in relation to the the period and the zone (terminal bud or apical zone) of the attack.

Type III of plants (23.28%) characherized by multiple flushing could be the consequence of the deterioration of the terminal bud during the first year of planting which suppressed the inhibition of lateral bud development and resulted in several stems. This same phenomenon was studied in the sessile oak (*Quercus petraeae* (Matt.) Liebl.) qnd the results showed the importance of the time of attack (period of latency or during the growth wave) and the area attack (terminal bud or apical zone) by herbivores or pathogens or even frost and have shown that for all types of attacks the number of lateral branches increases on the apical zone (Chaar *et al*., 1997). Type II plants (12.41%) distinguished by 2 dominant shoots would also be due to the same problem but the loss of apical dominance would be lost after the first year. Type I plants, which were the most frequently encountered (64.3%), are said to be the consequence of the attack at an older age. As the terminal bud was present in almost the half of these

plants from all types; overcome this problem is possible provided the management should take into account the risk factors, especially, grazing.

5. Conclusions

Given the importance of the cork oak forest in Tunisia, the present study was recommended to contribute to overcome the critical situation observed in the plantations of cork oak characherized by the occurrence of the creeping plants. Firstly, the average survival rate of cork oaks plants was estimated at 55% then the percent of creeping cork oaks was assessed among viable sapling (82%). The diagnosis showed a significant positive effect of soil hardness, considered as an indicator of excessive grazing, on the percent of creeping plants in the contrary with altitude which has a negative effect. Thus, before planning any forest management practice, it is necessary to investigate on the optimal conditions influencing the success of reforestation. Fencing or better an agreement that integrates local population during the first five years of plantation is recommended. Moreover, although late, an immediate solution to remedy this problem in areas already planted would be to do a reasonable coppicing followed by depressing after 2 to 3 years.To verify this hypothesis, the coppicing experiment has been carried out and the depressing is ongoing.

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