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Impact of ecological restoration techniques on the dynamics of degraded ecosystems of the mounts of Saida: Case of the forests of Doui Thabet (West Algeria)

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Abstract: The aim of the present study aims to establish the impact of different restoration techniques (soil and vegetation works) of five pioneer species of the Doui Thabet forest (Mounts of Saida, West of Algeria): *Pinus halepensis*, *Pistacia lentiscus*., *Tetraclinis articulata*, *Juniperus oxycedru*., and *Stipa capensis* (= *S. tenacissima* L.) between 2018 and 2020. An experimental field device covering an area of 1 ha has been installed in the Doui Thabet forest in a *Pinus halepensis* massive more than 80 years old. The following work was carried out: mechanical grinding of the vegetation (chopping), turning (scarification of soil) to a depth of 10 cm, tillage (Deep ploughing) to a depth of 20 cm, controlled burning of branches, clearing of *Stipa capensis*, seedlings planted in different seasons for certain species (*Stipa capensis* = *S. tenacissima* L.), monitoring of stump rejections and natural sowing. The sowing result varies according to the species and restoration techniques, it is high for *Pinus halepensis* and *Stipa capensis*. It is low for *Tetraclinis articulata* and *Juniperus oxycedrus* and none for *Pistacia lentiscus* while for *Stipa capensis* it is quite high when planted in autumn compared to spring. Turning and burning have proven to be the most abundant treatments for regeneration and growth. Grinding has medium seedling density and growth, while deep tillage and natural sowing showed low seedling density and growth.

Keywords: Doui Thabet, dynamics, ecological restoration, ecosystem degradation, techniques

Introduction

Among the pioneer plant species of the Mediterranean region are: *Pinus halepensis*, *Pistacia lentiscus*, *Tetraclinis articulata*, *Juniperus oxycedrus*, and *Stipa capensis*. These conifers are particularly drought-resistant and may develop in a wide range of ecological conditions (key vaults) [1]. Algerian forests play an essential role in the maintaining of the natural resources. They protect water supplies, soils and regulate the climate. As a result, they are a barrier against desertification. The phytodiversity of forest formations represents a wide range of benefits and services to society. Nevertheless, nowadays man's actions on these structures are numerous and usually lead to their destruction.

The forestry of these 5 species in the Mediterranean region still presents many interrogations, as long as, older stands do not always regenerate easily within the framework of traditional management [2]. Managers need to develop new techniques to facilitate the natural regeneration of these forest formations. Different conservation and reconstruction actions (NRP: National Reforestation Plans... etc.) have been conducted by the competent authorities without achieving the desired results [2, 3, 4, 5].

Strategies for restoring and conserving degraded natural ecosystems begin by understanding the behaviour of vegetation in its composition and dynamism and by approaching the process of degradation and the evaluation of these potentialities [6, 7, 8]. In this sense, we have processed a plant-ecological diagnosis of the ecosystems of the Doui Thabet (at Saida provenance) area at a first phase; to develop a strategy for the restoration of this degraded ecosystem in a second phase [7, 8].

As a result, this contribution aims to identify the related challenges facing the existing forest ecosystems and to propose appropriate restoration techniques. We are then eager to know the techniques to be implemented in order to facilitate the natural regeneration of this mixed plants formation (Forest of Doui Thabet, Mounts of Saida). These 5 pioneer species (already mentioned) do not have the ability to regenerate under their own cover without knowing precisely the causes of this phenomenon. Different vegetation and soil treatments have been tested to find out which soil and vegetation treatments are most favorable to the regeneration of this forest during period of (2018-2020).

Material and Methods

a- Introducing the experimental site

The experimental site is located at about the intersection of the parallel 34°54'54.63"N of North latitude and the meridian 0°0.04 'E of East longitude with an area of one (1) hectare. It is located 30 km West of the city of Saida and 20 km North of the Ain Baida conurbation at the place called Ras Ma. It is

characterized by a more or less flat relief at North exposure on low slope terrain de (2%) and an average altitude of 1150 m.

The choice of this site is justified by the presence of these 5 species in the same place to facilitate their management (fence, water, monitoring, and measurement) (Figure 1).

Figure 1. Localisation of the experimental site

b-Methods

An experimental 1hectare field device has been installed on the Doui Thabet forest in an 80-year-old pine forest. Various (technical) treatments of soil and vegetation (for pioneer species) were therefore tested from the period of 2018 to 2020 (Figure 2). Eight (8) soil and vegetation treatment methods were applied: mechanical grinding of vegetation, turning to allow soil work on about 10 cm, deep ploughing to 20 cm, burning, clearing of *Stipa capensis*, seedlings planted in different seasons for certain species, protected by fencing; followed by releases of strains and natural sowing (Control). The treatments were applied on surfaces of $1 \times 3 \text{ m}^2$ m for each treatment and repeated 6 times. The seed harvest of the 5 pioneer species of the Doui Thabet forest is controlled by the biology of each species (physiological maturation period) and on different tree feet (healthy and ripes). To know the mature seeds, we used the technique "floating test" (the planting date for each species and explain if you have been planting for three successive years or just the first year 2018.).

Figure 2. a-c: Tracing of the squares; d: Sowing; e: Watering in summer; f: Watering Vehicle; g: Mechanical turning of *Juniperus oxycedrus* L. seeds; h: Fencing; i: Grinding; j: Measurements; k: Turning; l: Tillage (Deep ploughing)

The survival and recovery rate of the plants and releases is counted every month for the three months following the planting. During the counts, a description of the surface of the ground was made by distinguishing the different elements: herbaceous; low woody and assigning them a lap class according to the following Braun-Blanquet [9] scale: 1 - present; 2 - 5%; 3 - 5-25%; 4 - 25-50%; 5 - 50-75% and 6 - 75-100%.

Growth measures using a tape-put have been: plant growth (made every month of 2018, 2019, and 2020), reject growth (made every month of 2018, 2019, and 2020), vegetation description and ground cover (performed every month of 2018, 2019, and 2020). In the end, after recording the number of seedlings per processing type in a notebook, we processed this data using Statistica software ver. 12, and drew the graphs using Excel (ANOVA).

Results

The application of soil and vegetation techniques has shown that turning and burning is very suitable for the regeneration of forest species from Doui Thabet. As for grinding, it is an average efficiency, but deep plowing is useless. In addition, regeneration by strain rejection is also suitable for pistachio lentisk and thuja berberie. The cleaning of the tufts of alfa also gave good results (increase in final height of 31 cm) compared to the control (17 cm), as well as the defense gave good results, as regards the recovery rate (80%), the number of varieties (58 taxa for the protected plot and 37 for the unprotected) and the final increase in height by rejection of the strain for the pistachio lentisk (12 cm in the defense) and 7.5 for the unprotected) and the thuja berberie (14.2 cm in the defense and 9.5 for the unprotected).

1. Growth of *Pinus halepensis* seedlings

The statistical analysis of the growth of *Pinus halepensis* plants, as a result of the various treatments, was very significant (Table 1). Different treatments influence the growth of this specie.

Turning proved to be the treatment with the greatest height. Deep ploughing and burning had a medium height, as did grinding, while natural sowing (Control) had a low height. This difference between different treatments seems to be increased from year to year. The maximum growth is recorded during the period of maximum biological activity and vegetation from March to May of each year (Figure 3).

Table 1. Average growth of *Pinus halepensis* per treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	1,131333	0,282833	45,133	0,000000***
May 2019	4	1,131333	0,282833	45,133	0,000000***
March 2020	4	0,476667	0,119167	35,0490	0,000000***

SC: Sum of squares, ddl: degree of freedom, MC: Average of squares, Fobs: F. observed, P: surplus value, ***: highly significant

Figure 3. Effect of soil treatments on the height growth of *Pinus halepensis* plants.

CRp: turning of *Pinus halepensis*; LBp: tillage of *Pinus halepensis*; Fp: burning of *Pinus halepensis*; BRp: Grinding of *Pinus halepensis*; Tp: Control of *Pinus halepensis*

2. Evolution of the density of *Pinus halepensis* seedlings

The statistical analysis of the density of *Pinus halepensis* plants, as a result of the various treatments, was very significant (Table 2). Different treatments influence the density of Aleppo pine. Once again, turning proved to be the treatment with the highest density. Deep ploughing, burning and grinding had medium density, while natural sowing (Control) had low density. This difference according to the type of treatments seems to be increased from year to year. The maximum density is recorded during the period of maximum biological activity and vegetation from March to May of each year (Figure 4).

Table 2. The average density of *Pinus halepensis* per treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	4587.0970000	1146.7740000	78.0632000	0.000000***
May 2019	4	1326.1250000	331.5313000	175.2527000	0.000000***
March 2020	4	54.6146700	13.6536700	226.3039000	0.000000***

Figure 4. Effect of soil treatments on the density of *Pinus halepensis* plants.

CRp: turning of *Pinus halepensis*; LBp: tillage of *Pinus halepensis*; Fp: burning of *Pinus halepensis*; BRp: Grinding of *Pinus halepensis*; Tp: Control of *Pinus halepensis*

3. Growth of *Tetraclinis articulata* seedlings

The statistical analysis of the growth of *Tetraclinis articulata* seedlings under the various treatments was very significant (Table 3). The different treatments have an influence on the growth of this species.

Turning was found to be the treatment with the highest height. Deep ploughing and burning had a medium height, as did chopping, while natural sowing (Control) had a low height. This difference between the different treatments seems to increase from one year to the next. Maximum growth is recorded during the period of maximum biological activity of the vegetation from March to May of each year (Figure 5).

Table 3. The average growth of *Tetraclinis articulata* by treatment at the end of each growth period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	3.1008	3.1008	79.8500	0.000000***
May 2019	4	28.2133	28.2133	70.2410	0.000000***
March 2020	4	63.9410	63.9410	80.2440	0.000000***

Figure 5. Effect of vegetation treatments on the growth of *Tetraclinis articulata*

CRt: turning of *Tetraclinis articulata*; LBT: tillage of *Tetraclinis articulata*; Ft: burning of *Tetraclinis articulata*; BRt: Grinding of *Tetraclinis articulata*; Tt: Control of *Tetraclinis articulata*

4. Growth of strain rejection of *Tetraclinis articulata*

The statistical analysis of the growth of the *Tetraclinis articulata* strain releases (role of fencing) was very significant (Table 4). Fencing has an influence on the growth of this specie (Figure 6).

Table 4. The average growth in rejections of *Tetraclinis articulata* strains by treatment at the end of each growth period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	3.1008	3.1008	79.8500	0.000000***
May 2019	4	28.2133	28.2133	70.2410	0.000000***
March 2020	4	63.9410	63.9410	80.2440	0.000000***

Figure 6. Effect of vegetation treatments on the growth of strain rejection of *Tetraclinis articulata*
Tt: Control of *Tetraclinis articulata*; RSt: Rejection of *Tetraclinis articulata* strain.

5. Evolution of the density of *Tetraclinis articulata*

The statistical analysis of the density of Berbery Thyua seedlings under the various treatments was very significant (Table 5). Turning was the treatment with the highest density. Deep ploughing and burning had a medium density, as did grinding, while natural sowing (Control) had a low density. This difference between the different treatments seems to increase from one year to the next. The maximum density is recorded during the period of maximum biological activity of the vegetation from March to May of each year (Figure 7).

Table 5. The average density of *Tetraclinis articulata* per treatment at the end of each growth period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	4.422	1.1055	7.0926	0.000000***
May 2019	4	72.942	18.2355	6.65028	0.000000***
March 2020	4	216.4113	54.1028	7.56204	0.000000***

Figure 7. Effect of soil treatments on the density of *Tetraclinis articulata*.

CRt: turning of *Tetraclinis articulata*; LBt: tillage of *Tetraclinis articulata*; Ft: burning of *Tetraclinis articulata*; BRt: Grinding of *Tetraclinis articulata*; Tt: Control of *Tetraclinis articulata*

6. Growth of *Juniperus oxycedrus* seedlings

The statistical analysis of the growth of *Juniperus oxycedrus* seedlings under the various treatments was very significant (Table 6). Turning was found to be the treatment with the highest height. Deep ploughing and burning had a medium height, as did chopping, while natural sowing (Control) had a low height. This difference between the different treatments seems to increase from one year to the next. Maximum growth is recorded during the period of maximum biological activity of the vegetation during the period of March to May of each year (Figure 8).

Table 6. The average growth of the *Juniperus oxycedrus* by treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	2.471333	0.617833	22.82635	0.000000***
May 2019	4	14.44533	3.61133	12.42146	0.000000***
March 2020	4	31.178	7.7945	19.14797	0.000000***

Figure 8. Effect of soil treatments on the growth of *Juniperus oxycedrus* plants.

CRg: turning of the *Juniperus oxycedrus*; LBg: tillage of the *Juniperus oxycedrus*; Fg: Fires: burning of the *Juniperus oxycedrus*; BRg: Crushing of the *Juniperus oxycedrus*; Tg: Control of the *Juniperus oxycedrus*

7. Changes in the density of *Juniperus oxycedrus* seedlings

The statistical analysis of the density of cade juniper seedlings under the various treatments was very significant (Table 7). The different treatments had influenced on the growth of the cade Juniper.

Turning was found to be the treatment with the highest density. Deep ploughing and burning had a medium density, as did chopping, while natural sowing (Control) had a low density. This difference between the different treatments seems to increase from one year to the next. The maximum density is recorded during the period of maximum biological activity of the vegetation during the period of March to May of each year (Figure 9).

Table 7. The average density of the *Juniperus oxycedrus* by treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	0.161333	0.040333	2.43952	0.000000***
May 2019	4	3.88800	0.972000	2.19578	0.000000***
March 2020	4	9.40800	2.35200	1.95565	0.000000***

Figure 9. Effect of soil treatments on the density of *Juniperus oxycedrus* plants.

CRg: turning of the *Juniperus oxycedrus*; LBg: tillage of the *Juniperus oxycedrus*; Fg: Fires: burning of the *Juniperus oxycedrus*; BRg: Crushing of the *Juniperus oxycedrus*; Tg: Control of the *Juniperus oxycedrus*

8. Growth of *Pistacia lentiscus* seedlings

The statistical analysis of the growth of *Pistacia lentiscus* plants under the effect of the different treatments was not very significant (null results). The different treatments did not influence on the growth of this species.

9. Growth of strain rejection of *Pistacia lentiscus*

The statistical analysis of the growth of the *Pistacia lentiscus* strain releases (role of fencing) was very significant (Table 8). Fencing has an influence on the growth of this specie (Figure 10).

Table 8. The average growth in rejections of *Pistacia lentiscus* strains by treatment at the end of each growth period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	5.20083	5.20083	96.015	0.000000***
May 2019	4	29.7675	29.7675	107.270	0.000000***
March 2020	4	71.053	71.053	132.233	0.000000***

Figure 10. Effect of vegetation treatments on the growth of strain rejection of *Pistacia lentiscus*.

TL: Control of *Pistacia lentiscus*; RSL: Rejection of *Pistacia lentiscus* strain

10. Growth of Alfa seedlings (autumn sowing)

The statistical analysis of the growth of Alfa plants (autumn sowing) under the effect of the different treatments was very significant (Table 9). The different treatments influence on the growth of this species.

Scarification was found to be the treatment with the highest height. Deep ploughing and burning had a medium height, as did chopping, while natural sowing (Control) had a low height. This difference between the different treatments seems to increase from one year to the next. Maximum growth is recorded during the period of maximum biological activity of the vegetation from March to May of each year (Figure 11).

Table 9. The average growth of Alfa (autumn sowing) per treatment at the end of each growth period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2019	4	531.1053	132.7763	15.32306	0.000000***
March 2020	4	2387.965	596.991	39.2071	0.000000***

Figure 11. Effect of soil treatments on the height growth of Alfa plants (autumn sowing).

Craa: Alfa turning (autumn sowing); Lbaa: Alfa tillage (autumn sowing); Faa: burning of Alfa (autumn sowing); Braa: Grinding of Alfa (autumn sowing); Taa: Control of Alfa (autumn sowing)

11. Evolution of the density of Alfa seedlings (autumn sowing)

The statistical analysis of the density of Alfa plants under the effect of the different treatments was very significant (Table 10). The different treatments have an influence on the growth of Alfa.

Turning proved to be the treatment with the highest density. Deep ploughing and burning had a medium density, as did grinding, while natural sowing (Control) had a low density. This difference between the different treatments seems to increase from one year to the next. The maximum density is recorded during the period of maximum biological activity of the vegetation during the period of March to May of each year (Figure 12).

Table 10. The average density of Alfa (autumn sowing) per treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2019	4	40.39667	10.09917	32.9178	0.000000***
March 2020	4	465.7180	116.4295	50.6700	0.000000***

Figure 12. Effect of soil treatments on the density of Alfa plants (autumn sowing).

Craa: Alfa turning (autumn sowing); Lbaa: Alfa tillage (autumn sowing); Faa: burning of Alfa (autumn sowing); Braa: Grinding of Alfa (autumn sowing); Taa: Control of Alfa (autumn sowing)

12. Growth of Alfa seedlings (spring sowing)

The statistical analysis of the growth of Alfa plants (spring sowing) under the effect of the different treatments was very significant (Table 11). The different treatments have an influence on the growth of this species.

Turning was found to be the treatment with the highest height. Deep tillage and burning had a medium height, as did chopping, while natural sowing (Control) had a low height. This difference between the different treatments seems to increase from one year to the next. Maximum growth is recorded during the period of maximum biological activity of the vegetation during the period of March to May of each year (Figure 13).

Table 11. The average growth of Alfa (spring sowing) per treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	14.96800	3.74200	31.4454	0.000000***
May 2019	4	271.9020	67.9755	8.68112	0.000000***
March 2020	4	688.509	172.127	7.71276	0.000000***

Figure 13. Effect of soil treatments on the height growth of Alfa plants (spring sowing).

Crap: Alfa turning (spring sowing); Lbap: Alfa tillage (spring sowing); Fap: burning of Alfa (spring sowing); Brap: Grinding of Alfa (spring sowing); Tap: Control of Alfa (spring sowing)

13. Evolution of the density of Alfa seedlings (spring sowing)

The statistical analysis of the density of Alfa plants (spring sowing) under the different treatments was very significant (Table 12). The different treatments have an influence on the growth of Alfa.

Turning was found to be the treatment with the highest density. Deep ploughing and burning had a medium density, as did chopping, while natural sowing (Control) had a low density. This difference between the different treatments seems to increase from one year to the next. The maximum density is recorded during the period of maximum biological activity of the vegetation during the period of March to May of each year (Figure 14).

Table 12. The average density of Alfa (spring sowing) per treatment at the end of each growing period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	4	0.852000	0.213000	28.5268	0.000000***
May 2019	4	51.2653	12.8163	19.2015	0.000000***
March 2020	4	152.972	38.243	20.0071	0.000000***

Figure 14. Effect of soil treatments on the density of Alfa plants (spring sowing).

Crap: Alfa turning (spring sowing); Lbap: Alfa tillage (spring sowing); Fap: burning of Alfa (spring sowing);

Brap: Grinding of Alfa (spring sowing); Tap: Control of Alfa (spring sowing)

14. Growth of Alfa tufts (Clearing of tufts)

The statistical analysis of Alfa Tufts growth, due to the clearing effect, was very significant (Table 13). Clearing action has an influence on the growth of this species (Figure 15).

Table 13. The verage growth of Alfa (Clearing of tufts) per treatment at the end of each growth period

Measurement date	ddl	SC	MC	F	P value and meaning
May 2018	2	12.4033	12.4033	111.075	0.000000***
May 2019	2	269.801	269.801	286.160	0.000000***
March 2020	2	635.108	635.108	259.634	0.000000***

Figure 15. Effect of vegetation treatments (cleaning of tufts) on the height growth of Alfa tufts.

Tna: Control to the cleaning of Alfa; Na: cleaning of Alfa

15. Description of the soil surface (importance of the fencing)

The obtained results which are summarized in Table 14, confirm that the effect of fencing in the forest ecosystem over a period of 3 years allows an appreciable increase in the recovery rate compared to the unprotected plot (Figure 16).

Table 14. Recovery rate of the two parcels fenced and unprotected

Year	May 2018		May 2019		March 2020	
Type	Parcel unprotected	Parcel protected	Parcel unprotected	Parcel protected	Parcel unprotected	Parcel protected
Recovery rate	55 %	55 %	55 %	75 %	50 %	80 %

Figure 16. Recovery rate for the two fenced and unprotected parcels

Discussion

This study aimed to identify the vegetation and soil treatments (Deep ploughing, chopping, scarification, burning, clearing and fencing) most favorable to the natural regeneration of the 5 pioneer species of the Doui Thabet forest:

Among the different treatments tested, it is the turning which proves to be the most effective for the acquisition of regeneration and its maintenance. In fact, this treatment was widely used in forest regeneration work. However and according to our knowledge, the turning was rarely tested on Mediterranean pines [10, 11].

Turning provides a high percentage of bare soil which will promote a good contact between soil and seed leads to better germination [12]. Soil decompaction also allows easier rooting and a better water supply [13, 14], which facilitates seedling growth and survival. The high percentage of pebbles found in this type of treatment due to the fracturing of the shallow rock slab and the upward movement of pebbles by turning may also play a role in limiting evaporation [15]. However, one important point should be noted for this treatment: - the progression of herbaceous plants is strong. So a study over a longer period of time is therefore necessary to monitor the survival of regeneration in response to the development of competitive vegetation. These results are in agreement with Prévosto et al. [11] and De Lombaered et al. [16] studies.

Burning also appears to be one of the favorable treatments allowing the regeneration of pioneer species in the Doui Thabet forest. Considerable regrowth of these species, especially in the 2nd and 3rd year (with the exception of *juniper oxychedron* and *Pistachio lenisque*) has been observed. These results are in

agreement with Prévosto et al. study [11]. Indeed, and according to many authors reviewed by Prévosto et al. [11], burning creates favourable conditions for their growth on an ashy soil highly enriched in nutrients.

Prescribed burning has two contrasting effects on regeneration depending on the presence or absence of slash, since slash determines the intensity of the fire [17]. High-intensity slash burning induces total destruction of the soil plant layer in its aerial compartment and partially in its subterranean compartment (roots, seeds). As a result, vegetation recovery is delayed and bare soil may persist longer, which are favorable elements for the acquisition and maintenance of regeneration. These results are in agreement with those of Prévosto et al. (11) and Prévosto et al. (18). In all cases, prescribed burning favored the development of competing vegetation on the ground [11, 18]. However, prescribed burning promoted the development of competing vegetation on the ground [18].

Mechanical grinding of the vegetation (chopping) is also a moderately favorable treatment for regeneration as described previously by Prévosto et al. [18]. That can be explain by the fact that chopping treatment leaves a layer of organic debris on the ground that creates a barrier for soil-seed contact [19]. Consequently, thus penalizes the establishment of seedlings, without however prohibiting the regeneration of vegetation whose root part has not been affected by the treatment. It is also possible that certain compounds produced by litter and shredded soil may have a negative influence on seedling germination and growth by allelopathic effect [20, 11]. The practice of chopping is beneficial for soil reconstitution, biological recovery of vegetation and repopulation of bare areas [21]. Nevertheless, Bourahla and Guittonneau [22] reported that chopping limits excess temperatures and increases soil water reserves by creating a microclimate favourable to plant germination and growth.

As reported recently by Tony et al. [23] the deep tillage treatment seems to be not very conducive for regeneration. According to Le Tacon and Malphettes [10], ploughing, as regular as possible, should be sufficiently deep (30 cm), adapted to the soil structure and the types of plants to be installed. In clayey soils, it is imperative to work the soil in such a way as to minimise the emergence of a plough sole, which is subsequently difficult to detect by tree roots. Ploughing must be carried out early enough to ensure that the soil is stale and that there are no lumps at planting time and to prevent the regrow of competing vegetation [24]. In Mediterranean areas, tillage should be carried out before the autumn rains to avoid any risk of erosion.

The present study consisted also to evaluate the effect of partial clearing of the clump (a mass of leaves that, although dead, still remain suspended from the tufts for a long time) on the regeneration of Alfa tufts for 3 years (2018-2020) in a protected (fenced) site. The obtained data were compared to the unprotected area. This experiment is original in forested areas and stems from an observation made on a cleaned area. Clearing Alfa tufts encourages the buds responsible for foliage to return to activity. The maximum activity of the buds, as determined by Mehdadi [25], takes place in the spring, during the active period of the Alfa tufts.

The increase in green foliar biomass was most likely induced by the clearing of Alfa tufts of their clumps and resulted from the activation of a large number of dormant buds. Removal of the dark, asphyxiating environment created by the clumping of Alfa clumps or tufts can only optimize the conditions for a good vegetative start of esparto [21, 5].

In addition and as reported by Fischer et al. [26], we confirmed that fencing remains one of the best actions allowing appreciable results on the regeneration of the vegetation in general and of the forest plant formation in particular. The comparison between the results obtained in the situation of fencing and those with free access, highlight the effect of the anthropic action. Which makes it possible to appreciate the quantitative and qualitative evolution of the plant cover. However, the beneficial effects of protection are evident in the structure, floristic composition and production of the herbaceous stratum and the dynamics of the woody stratum [27, 28]. At the floristic level, these effects are characterized by an increase in floristic diversity.

Conclusions

Chopping after soil turning is favorable to the acquisition and maintenance of natural regeneration, and is a treatment regularly practised in the sylviculture of pine forests in temperate zones. If DFAF (Defence of the forest against fires) conditions allow it, it is preferable to leave the slash from the cut formed by cone-bearing branches on the ground rather than export them. They represent an additional source of seeds that favours the emergence of seedlings at least in the first year. If the conservation of slash on the ground is of interest for the recruitment of future Aleppo pine seedlings, this management should of course be modulated according to the imperatives of DFAF control. For turning, at least partial burial of slash limits the fire risk, whereas for shredding, only the layer of debris on the ground limits regeneration while creating a combustible surface.

Prescribed fire also appears to be an interesting tool for regeneration provided that the burning is sufficiently intense. A fire that is too moderate leads in fact to dynamise the herbaceous vegetation in particular and thus to reduce the possibilities of installation and survival for seedlings.

Finally, it should be remembered that the abundance of natural regeneration also depends largely on favourable climatic conditions and sufficient seed production by seed companies; which is irregular over time. It is the conjunction of these factors with tillage that will modulate the abundance of regeneration. Overall, fencing remains one of the best actions allowing appreciable results on the regeneration of vegetation in general and forest plant formation in particular.

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