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Seedling Regeneration of Two *Cistus* Species After Experimental Disturbances*

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Abstract. The regeneration process of two *Cistus* species (*Cistus ladanifer* and *Cistus laurifolius*) was compared during the first four years after cutting, burning and ploughing in experimental plots, in León province (NW Spain). In the burnt plots, a quicker germination, followed by a higher death rate, was observed, especially for *Cistus laurifolius*. The number of seedlings tended to stabilize after one year in all experimental plots. During the whole study period, the burnt plots showed a higher number of seedlings. The ploughed plot presented the lowest number, while the cut plots kept intermediate values. The differences in cover values were not so marked in the different plots and, in the fourth year, there is still a tendency to increase. Neither the cover nor the height of the seedlings have attained the values they had before disturbance. By comparing the two species for the same disturbance, we found that the cover and height values were similar, but the number of *Cistus ladanifer* seedlings was higher. This fact can probably not be considered as a direct consequence of disturbance, as this difference was also observed previously.

Keywords: *Cistus*; Ecology; Regeneration; Seedbank.

Introduction

Shrub ecosystems are frequent in the Mediterranean basin, and are becoming more and more extended as a consequence of the progressive degradation of the forests and the abandoning of pastures and crop production. *Cistus* shrublands are a typical example of communities which have increased in distribution as a result of disturbance, particularly fire, provoked by human actions. *Cistus* spp. were classically described as "social pyrophytes" (Kuhnoltz-Lordat, 1938) or "active pyrophytes" (LeHouerou 1973; Naveh 1974)— pioneer plants spreading by seed and forming dense stands after fire. Numerous studies show that *Cistus* seed germination is stimulated by heat (Lopes 1988; Thanos and Georghiou 1988; Trabaud and Oustric 1989; Corral et al. 1990; Valbuena et al. 1992), with a strong recovery response after prescribed burning (Legrand 1993; Santiesteban et al. 1993). According to Keeley (1986), the rapid growth rate and early flowering of these species makes them resilient to relatively frequent fires. However, Trabaud (1987), on questioning the terminology of "pyrophytes," points out that *Cistus* spp. are not fire-favored species but rather opportunists occupying bare areas free of aggressive competitors.

The aim of this study is to comparatively analyse in two *Cistus* species, *Cistus ladanifer* and *Cistus laurifolius*, the recovery response to three of the degrading impacts to which they are more usually subjected: burning, cutting and uprooting. To do this, experimental plots were established in which these three types of disturbance were carried out, although in the *Cistus laurifolius* plots uprooting was not possible. Therefore, the aim is to compare on the one hand the recovery capacity of each species with relation to the disturbance and, on the other hand, their response to common disturbances (burning and cutting). In previous works (Alonso et al. 1992) better recovery was observed in the first year after burning rather than after cutting, shown both in a greater number of seedling as well as in greater cover percentages. The specific aim in this case is to determine whether the greater density in the burnt plots is maintained in the following years and in which way it affects seedlings' growth and the population dynamics. It is also aimed to establish whether mortality, if it exists, is provoked to a greater extent by low winter temperatures or by the dry summer season.

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Materials and Methods

The study was carried out in a shrubland ecosystem, at an altitude of approximately 900 m above sea level, at Destriana in the province of León (NW Spain) (M.T.U. coordinates 29TQG3929). Two *Cistus* shrublands were chosen in this area. The dominant species were *Cistus ladanifer* and *Cistus laurifolius*, respectively. They were in two areas of similar characteristics and very near one another. They were secondary stages started as a consequence of the giving up of old fields, as the *Cistus* plants are more than 15 years old. A series of plots was established in each area. In the first, with a high presence of *Cistus ladanifer*, three 10 x 10 m plots with a 1 m wide buffer were marked out. In one of them all of the woody species were cut at ground level, the second was burnt and the third was uprooted using a tractor. The *Cistus laurifolius* area was not large enough, maintaining similar characteristics, to allow the establishing of three plots. In this case only the cut and the burnt plots (10 x 10 m) were established. The experimental treatments, randomly allocated, were done in July 1989, after previously carrying out sampling to record the original conditions, quantifying the number of *Cistus* plants, their cover and the height of the tallest in each of the 100 1 m^2 units of each plot.

In the first year after treatment, a very detailed follow-up was done, with sampling every two months, the results of which are discussed in Alonso et al. (1992). Since then, two samplings were carried out each year in May and October. For each area and sampling period twenty sub-plots were analysed, each 0.5 x 0.5 m. For the first sampling session, the sub-plots were chosen at random, and these were then used in all of the latter sessions. In each inventory the number of *Cistus* seedlings, the height of each one as well as the total *Cistus* cover percentage (% of soil covered by the projection of the seedlings) were recorded. There was no evidence of vegetative sprouting. *Cistus* is considered to be an obligate seeder (Naveh 1974; Trabaud 1987).

Analysis of variance was carried out in order to compare the regeneration after each treatment. The significance of the results was tested with the Tukey-test (Tukey 1949).

Results

In the burnt plots of each species a very high germination response was observed, with a maximum of seedlings in February 1990 in the case of *Cistus ladanifer*, and in April 1990 in the case of *Cistus laurifolius* (Figure 1). A high mortality rate for the latter was observed in the following two months, the causes of which are discussed in Alonso et al. (1992). In the following samplings a tendency towards stability in the number of seedlings of this species was observed, with fewer variations than in the case of *Cistus ladanifer*. The standard error is also lower, which indicates a more even spatial distribution of the individuals. *Cistus ladanifer* has a notably greater density during the whole of the study period. This is also noted in the cut plots and corresponds to a greater initial density (an average of 4.5 individuals per metre square for *Cistus ladanifer* and 1.5 for *Cistus laurifolius*). On comparison of the response to different disturbances, a greater number of seedlings is observed in the burnt plots than in the cut ones, the lowest density values being recorded in the uprooted plot. The differences between the burnt plot and the others are statistically significant ($\alpha < 0.05$) in all the samples, but the differences between the uprooted and the cut plots only are statistically significant in the two first years after the treatments.

The variations in the number of seedlings are not very marked after the first year and they do not allow a detection of clear tendencies in relation to seasonal mortality. This could be slightly higher in winter (because of the effects of frost) or in the summer (dry weather), depending on the particular conditions each year and the way in which they affect each seedling in relation to its size and location. A certain stability has apparently been achieved, but it does not seem probable that this will be indefinitely maintained in later years. This is because, in all cases except the uprooted plot, the initial density has been exceeded (this is much more noticeable in the burnt plots). It is likely that as the seedlings increase in size, intraspecies competition will intensify, thus creating a greater mortality rate.

In accordance with this, in no plot has the cover reached the values obtained before the disturbances (between 63 and 77%, depending on the plot) and there is still a tendency to increase (Figure 2). The maximum values in the fourth year are seen in burnt plots and are less than 40% in the uprooted plot. The differences in relation to the treatment are not as marked as in the case of density, although it is possible to detect statistically significant differences between *Cistus* cover as a function of treatment until the third year, diminishing the differences afterwards. There are smaller differences between the graphs of both species which also showed similar cover in the original situation.

The average height trend of the seedlings with the passing of time is very similar in all cases (Figure 3). In the uprooted plot the values are slightly higher; only here are there values over 40 cm after four years. The apparent slowing of growth observed after the second year is due to the incorporation of new seedlings in each period in the average value. The dominant height (average of the tallest seedling per 0.25 m^2 subplot) at the fourth year is between 53 cm in the uprooted plot and 37 cm in the *Cistus laurifolius* cut plot, compared to the 150 cm in the both

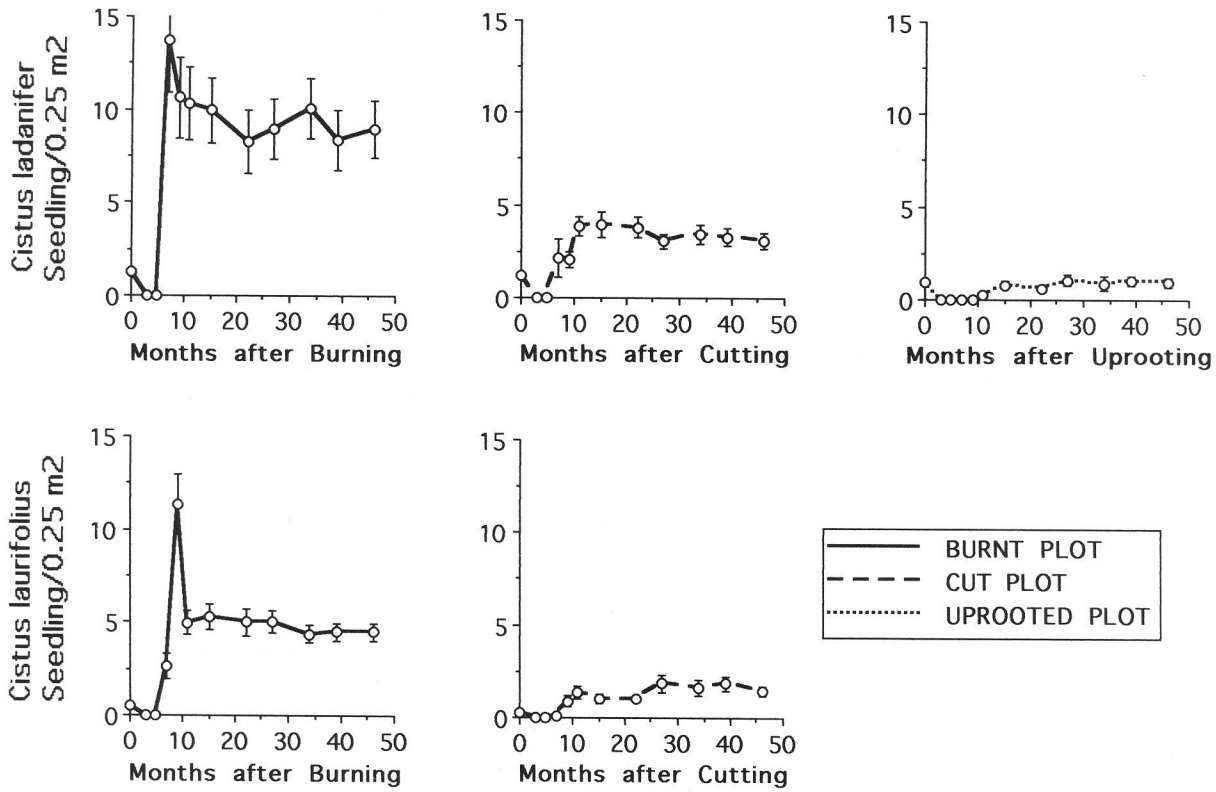


Figure 1. Mean and standard error of *Cistus ladanifer* and *Cistus laurifolius* seedling number (in 0.25 m^2) in the experimental plots.

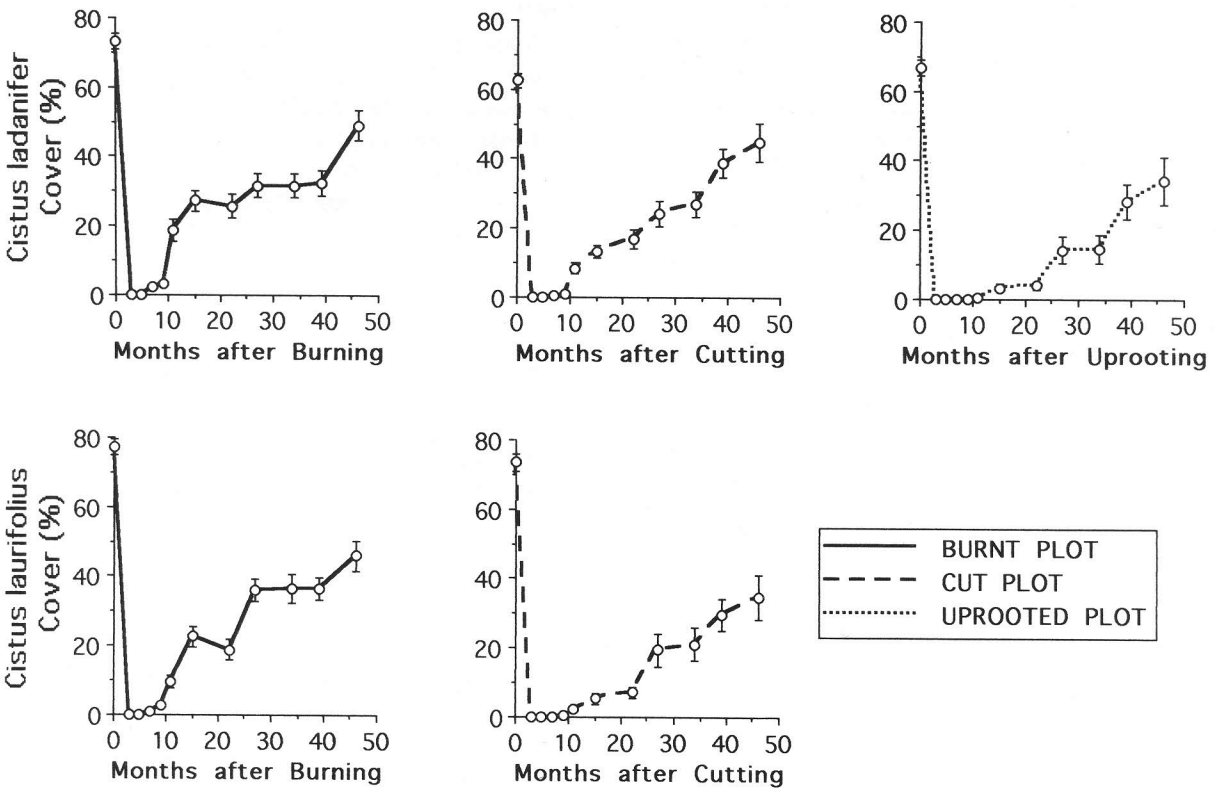


Figure 2. Mean and standard error of *Cistus ladanifer* and *Cistus laurifolius* cover in the experimental plots.

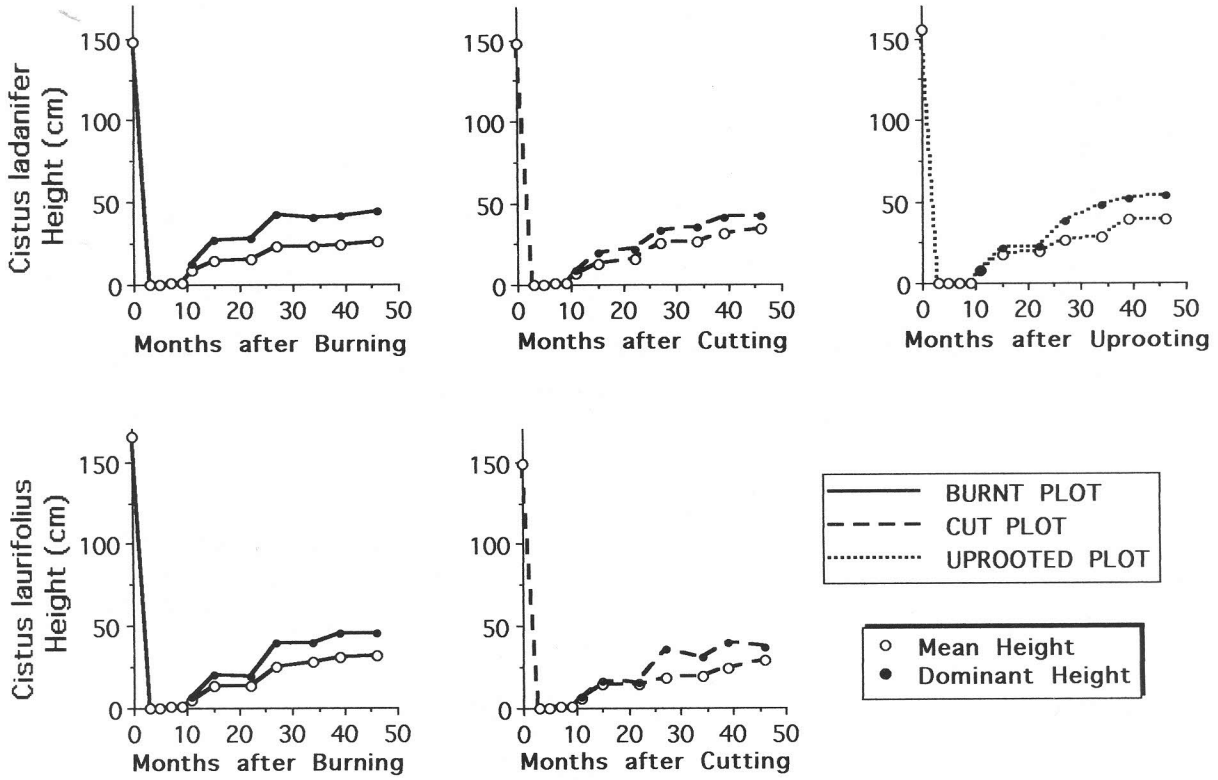


Figure 3. Mean of *Cistus ladanifer* and *Cistus laurifolius* seedling height and dominant height (average of tallest seedling per subplot) in the experimental plots.

Cistus shrublands before the treatments. There are statistically significant differences with the control, but not between treatments.

To better show the dynamics of both populations in relation to disturbance, Figures 4 and 5 show the frequency distribution of the different height values (expressed as a percentage in relation to the total number of individuals) and their variation in the following years (only the annual data for May is included). The seedling density per square metre is also indicated, which clearly reflects the differences pointed out in the discussion of Figure 1.

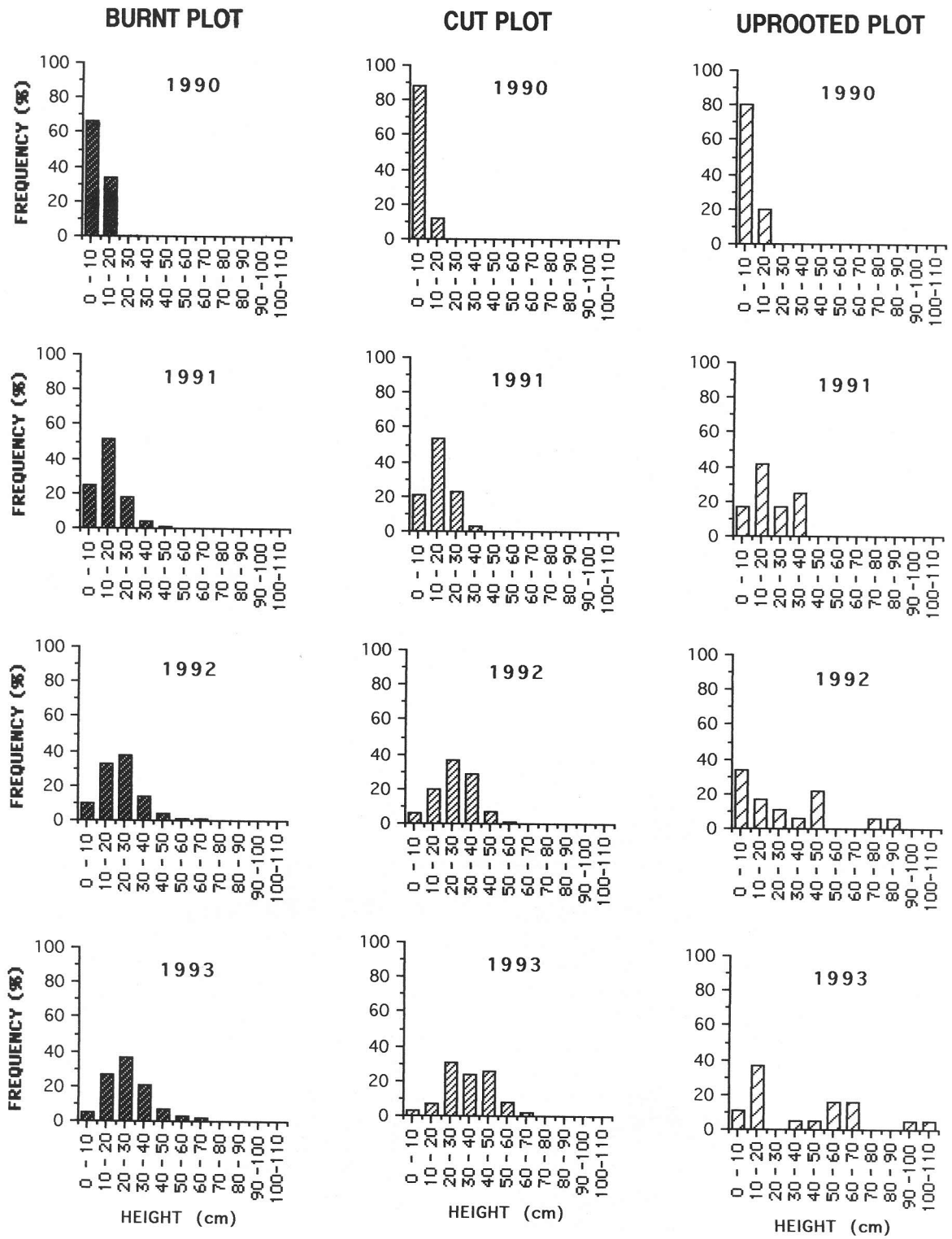
In the *Cistus ladanifer* plots (Figure 4) a clear predominance of individuals smaller than 10 cm is observed in all plots in the first year, although the proportion is lower in the burnt plot and there is also the occasional individual measuring 20 cm. In the second year the dominant group is the one including heights between 10 and 20 cm. In the third and fourth years the treatment related differences are more clearly seen, with similar tendencies in the burnt and cut plots, which come closer to a normal distribution, with the dominant plants between 20 and 30 cm and some individuals bigger than 60 cm. In the uprooted plot, with lesser density, greater dispersion values are observed. Once again plants of lesser height are more common, but in the other hand the two biggest shrubs were found here (over 1 m after the fourth year), with the highest growth between the second and third year after uprooting (almost 50 cm in one of the seedlings, growing from 39 cm, in May 1991, to 86 cm, in May 1992).

In the case of *Cistus laurifolius* (Figure 5), the large proportion of seedlings smaller than 10 cm in the first year stands out (almost 100% in the burnt plot). In the following years the proportion is greater in the cut plot. In the third year they once again become the dominant class, while in the burnt plot the dominant height is between 20 and 40 cm. By the fourth year, however, the distribution for both plots is quite similar.

On comparing both species, the smaller size of the *Cistus laurifolius* plants one year after prescribed fire is observed. This is probably a consequence of its later appearance, given that in the last two years a predominance of taller individuals of this species over *Cistus ladanifer* is observed for the same dates. In the cut plots *Cistus laurifolius* differs from the normal distribution values due to the higher number of smaller seedlings.

Discussion

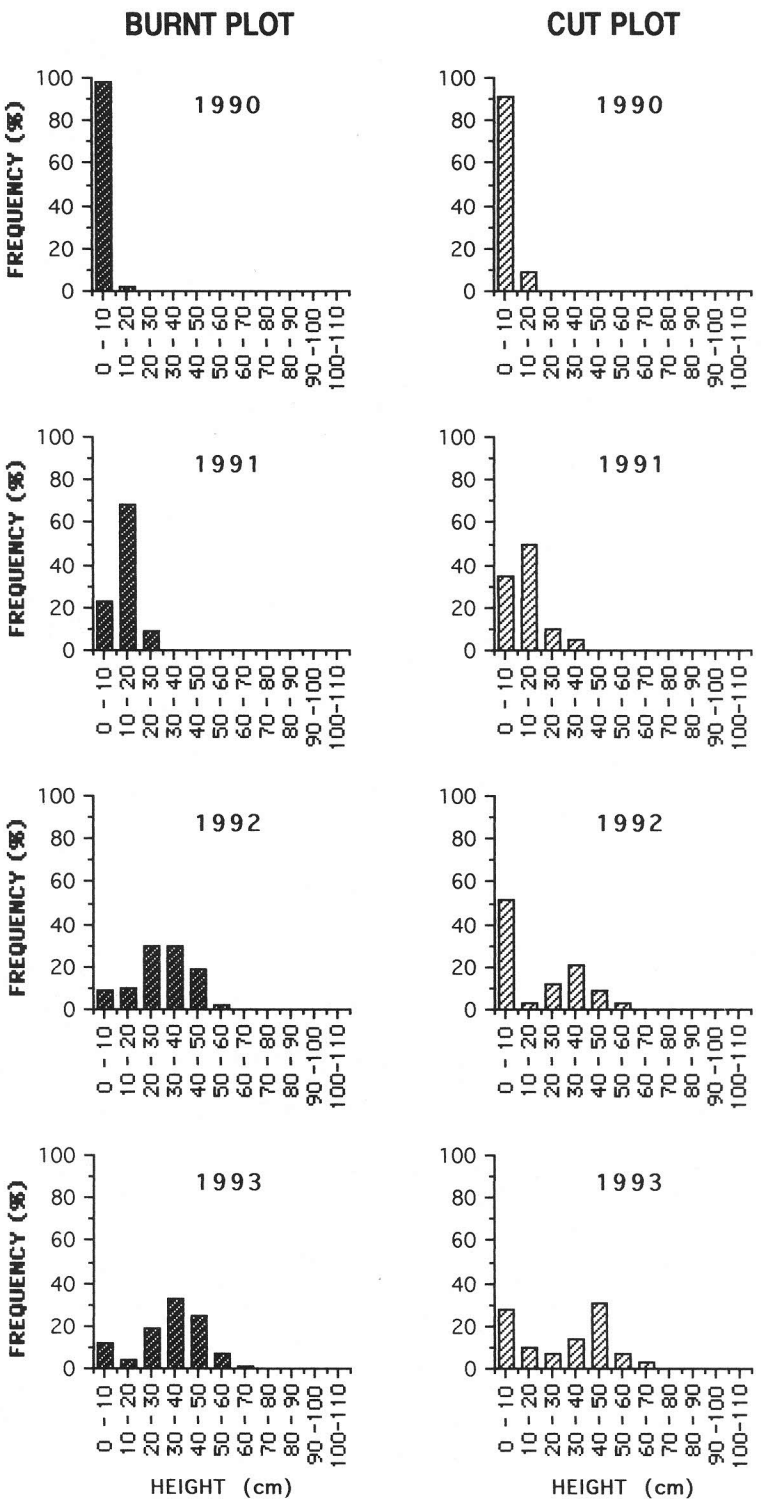
On comparing *Cistus* plant density before disturbance with the situation in the fourth year, the greatest differences are in the burnt plots, although in all the plots the density is higher than initially. Cover recovery is quite good, reaching 48% of the original cover in the *Cistus laurifolius* cut plot and 72% in the *Cistus ladanifer* cut



Density (No seedlings /m^2):

	1990	1991	1992	1993
Burnt Plot	41.2	33.0	40.2	35.8
Cut Plot	15.4	15.2	13.8	12.4
Uprooted Plot	1.0	2.4	3.6	3.8

Figure 4. Distribution of height values of *Cistus ladanifer* seedlings in the experimental plots during the study period. Density values (seedling number/m^2) in each plot and sampling year are included.



Density (No seedlings /m^2):

	1990	1991	1992	1993
Burnt Plot	19.8	20.0	17.4	18.0
Cut Plot	5.6	4.0	6.6	5.8

Figure 5. Distribution of height values of *Cistus laurifolius* seedlings in the experimental plots during the study period. Density values (seedling number/m^2) in each plot and sampling year are included.

plot the fourth year. Height recovery is not so good, only 25% respect to the initial dominant height in the *Cistus laurifolius* cut plot and 34% in the uprooted plot. This is because these average values and only small seedlings are in some subplots, as seed germination still occurs in the fourth year. On the other hand, in all the plots there are some seedling taller than 60 cm. Initially conditions the dominant height was more uniform, without small seedlings.

These results indicate that, although a high level of germination stimulated by fire occurs in the burnt plots, in the soil bank there are still enough seeds which continue to germinate in the following years. It is improbable that these come from areas close by, as the majority of *Cistus* spp. tend to disperse in time more than in space (Troumbis and Trabaud 1986). Flowering does not occur until two years after the treatments, in spring 1991, and only in the case of very few individuals of *Cistus ladanifer*. Extensive flowering does not occur until the third year, which coincides with what Trabaud (1987) observed in *Cistus mospeliensis*. In the case of *Cistus laurifolius* flowering has hardly been recorded.

The massive regrowth response after burning confirms the stimulating effect of fire on germination. However, it is clear that recovery is also good in the absence of fire, even after a disturbance as drastic as uprooting, which alters the soil structure and the situation of the seeds. This coincides with what Trabaud (1987) points out in relation to the opportunist character of these species.

Recovery of cover is similar for both species, although marked differences exist in relation to the number of seedlings. This is probably due to the different structure of both, as original conditions were the same, with similar cover but much less density in *Cistus laurifolius*. Legrand (1993) comments on the great variability in the density of seedlings appearing after prescribed burning in different *Cistus* species (54 plants/m^2 for *C. mospeliensis* compared to 1 plant/m^2 for *C. salvifolius*). In the two species considered in this study the field results coincide with the laboratory germination tests, which show a greater germination capacity in *Cistus ladanifer*, both after heat stimulation and in untreated control seeds (Valbuena et al. 1992).

The lower density of the uprooted plot could influence the greater height observed in some of the individuals in the last two years, and the same can be said for the predominance of slightly taller plants in the cut plots compared to the burnt plots. However, in this last case the differences are not so noticeable as to assure that it is a consequence of greater or lesser intra-species competition. On the other hand, four years after the disturbances the situation is still quite different from initial conditions. This necessitates continuation of the study in coming years to clearly establish the regeneration strategy.

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