*Israel Journal of Plant Sciences* *Vol. 48* *2000* *pp. 271–276*

# TEN YEARS OF RECOVERY OF *CISTUS LADANIFER* AFTER EXPERIMENTAL DISTURBANCES

ESTANISLAO LUIS-CALABUIG, REYES TÁRREGA,* AND LUZ VALBUENA
*Area de Ecología, Facultad de Biología, Universidad de León, 24071 León, Spain*

*(Received 29 November 1999 and in revised form 15 February 2000)*

## ABSTRACT

The aim of this study is to compare the recovery response of *Cistus ladanifer* L. to three experimental treatments in terms of seedling growth and population dynamics. A uniform area was chosen in the province of León (NW Spain), in which *C. ladanifer* was clearly dominant with a mean cover of 70%. Three plots were established and subjected to experimental burning, cutting, and plowing in July 1989. The changes in the *C. ladanifer* population were surveyed over 10 years (from 1990 to 1999). The number of *Cistus* seedlings, the height of each, and the total *Cistus* cover percentage were recorded for every sampling period. There were no *Cistus* shoots from vegetative sprouting. The lowest density was recorded in the plowed plot and the highest in the burned one, as was expected from a species whose germination is stimulated by heat; ten years after treatments, density in the burned plot is still significantly higher. A tendency towards stabilization in cover was observed in the three plots, with the highest values in the burned plot and the lowest in the plowed one in the first years but without any differences in the last years. A continuous increase in *Cistus* plant height was observed and was highest in the plowed plot; mean height was the lowest in the burned plot because there were some small seedlings (lower than 5 cm) until the seventh year. Although the differences among treated plots decrease in time, differences in height and density can still be detected 10 years after treatments. Moreover, complete recovery of initial conditions has not yet been attained.

## INTRODUCTION

Heathland ecosystems, which are typical to the Mediterranean basin, are frequently associated with repeated human impact. In addition, during the last decades the abandonment of pastures and croplands contributed to the spread of heathlands. *Cistus* communities that are associated with fires are quite frequent. *Cistus* spp. were classically described as "active pyrophytes" (Naveh, 1974): "pioneer plants spreading by seed and forming dense stands after fire". Numerous studies showed that *Cistus* seed germination is stimulated by heat (Lopes, 1988; Thanos and Georghiou, 1988; Corral et al., 1990; Valbuena et al., 1992; Trabaud, 1995; Castro and Romero-García, 1999), and its recovery after planned burning is fast (Legrand, 1993; Santiesteban et al., 1993). According to Keeley (1986), the rapid growth rate and early flowering of species makes them resilient to relatively frequent fires. However, Troumbis and Trabaud (1986) and Trabaud (1995) considered the survival mode of *Cistus* spp. as an adaptation to unpredictable disturbances and environmental constraints rather than adaptation to repeated fires. In any case, it seems that massive renewal of these species can only occur after a disturbance that eliminates the adult plants and competitors, and induces a dormancy break by mechanical or thermal means. In the absence of disturbances, these species are incapable of population reconstruction (Trabaud and Renard, 1999) and such stands may de-

*Author to whom correspondence should be addressed. E-mail: degelc@unileon.es

generate. For sustainable management of these ecosystems, a wide knowledge of the recovery response of these species is needed.

The aim of this study is to compare the recovery of *Cistus ladanifer* L. after three treatments to which they are frequently subjected: burning, cutting, and uprooting. Experimental plots were established to which these three types of disturbance were applied. The results obtained during the first few years of recovery have been reported previously (Alonso et al., 1992; Tárrega et al., 1995; Luis et al., 1996). Here, we present the long-term population dynamics (10 years), in order to determine whether the differences in seedling density, height, and percentage cover observed during the early recovery stages tend to mitigate with time, and whether the predisturbance situation has been attained.

## MATERIALS AND METHODS

The study was carried out in a *Cistus ladanifer* shrubland at an altitude of approximately 900 m asl, at Destriana in the province of León (NW Spain) (M.T.U. coordinates 29TQG3929). The site was a secondary succession stage of abandoned old fields. *Cistus ladanifer* was dominant with a mean cover of 70% and height of 150 cm, and the *Cistus* plants were about 15–20 years old. The climax vegetation in this area is a *Quercus pyrenaica* Willd. or *Quercus ilex* L. forest. The climate in the area, according to the Papadakis classification, is cool temperate Mediterranean (Ministerio de Agricultura, 1980), mean annual rainfall is 469.8 mm, the dry period is in July and August, and danger of frost occurs between October and May. The soil is formed on Silurian materials (Ministerio de Agricultura, 1973).

Three plots measuring 100 $m^2$ each were established and treated in July 1989. The first plot was subjected to experimental burning (imitating the traits of wildfires in these communities), the second plot was subjected to cutting of the woody species down to ground level, and the third plot was plowed with a tractor to a depth of 50 cm. The changes in the *Cistus ladanifer* population were surveyed for ten years. A total of 11 samplings were carried out: one before the treatments, and 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 years after the treatments, in June.

For every sampling period, 5 inventories measuring 1 $m^2$ in each plot, randomly selected and marked in the first sampling, were analyzed. In each inventory, the number of *Cistus* plants, the height of each plant and the total *Cistus* percentage cover (visually estimated as % of soil covered by the projection of the plants) were recorded. Total plant cover was evaluated at the same time as the *Cistus* sampling.

A two-factor repeated measures analysis of variance was carried out in order to compare regeneration after each treatment. Factors considered were plots (cut, burned, and plowed) and time since treatment (repeated measure). The significance of the results was tested with the Tukey-test (Tukey, 1949). Recovery after 10 years among the treated plots was compared by one-way ANOVA, and each treated plot compared to its pre-treatment situation by a paired *t*-test. Data normality was checked beforehand using the David et al. (1954) test. Percentage cover data were arcsin transformed before statistical analysis.

## RESULTS

No *Cistus* shoots appeared by vegetative sprouting, in agreement with most of the authors who consider *Cistus* species as obligate seeders (Naveh, 1974; Trabaud, 1987). Seedling density was significantly affected by the treatment ($F_2 = 6.95$, $p = 0.01$) and by the time since treatment ($F_9 = 5.48$, $p = 0.0001$). However, the interaction of the treatment and time factors was also significant ($F_{18} = 3.13$, $p = 0.0001$), meaning that time affected density differently in the different plots. The highest seedling density was observed in the burned plot throughout the study period, with statistically significant differences in comparison with the other two. In addition, the density in this plot decreased over time, although there were no significant differences ($F_2 = 0.35$, $p = 0.71$) during the last three years (from the 8th year on). The variability in seedling density was lower in the cut and plowed plots, without significant differences in time. The lowest density occurred in the plowed plot (Table 1a). Ten years after the treatments, the density in the burned plot was still significantly different ($F_2 = 6.7$, $p = 0.01$). Density was still higher in the burned plot and in the cut plot in comparison with the initial situation, and these differences are statistically significant ($t = 3.2$, $p = 0.03$, and $t = 11.3$, $p = 0.001$, respectively). Only the plowed plot maintained density values similar to those existing before the treatments throughout the study period ($t = 1.3$, $p = 0.26$).

Percentage cover of *Cistus* was highest in the burned plot and lowest in the plowed one (Table 1b), but these differences were only apparent in the first four years ($F_2 = 11.5$, $p = 0.002$); from the fifth year, there are no statistically significant differences between plots ($F_2 = 0.8$, $p = 0.46$). In addition, no significant differences can be observed from the seventh year when compared with the initial situation by a *t*-test.

Total plant cover one year after the disturbances is clearly higher in the cut plot (close to 80%), and the lowest value was in the plowed plot (less than 20% in the first year) (Fig. 1). Differences among plots were

Table 1
Mean values and standard deviation of (a) *Cistus* density, (b) *Cistus* percentage cover, and (c) *Cistus* maximal height (mean values of the highest plant in each one of the five quadrats) before and one to ten years after treatments

| | Plowed plot | | Cut plot | | Burned plot | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| *(a) Density values (No./m²)* | | | | | | |
| Before treatments | 1.8 | 1.3 | 2.4 | 0.9 | 2.4 | 1.5 |
| After treatments | | | | | | |
| 1 Year | 1.0 | 0.7 | 15.4 | 3.6 | 41.2 | 30.0 |
| 2 Years | 2.4 | 1.9 | 15.2 | 3.3 | 33.0 | 28.2 |
| 3 Years | 3.6 | 4.8 | 13.8 | 3.6 | 40.2 | 28.1 |
| 4 Years | 3.8 | 4.2 | 12.4 | 1.3 | 35.8 | 22.3 |
| 5 Years | 2.4 | 1.7 | 12.0 | 2.6 | 27.6 | 17.1 |
| 6 Years | 3.0 | 3.2 | 10.6 | 2.2 | 29.4 | 19.9 |
| 7 Years | 2.4 | 2.1 | 10.8 | 1.9 | 31.2 | 21.5 |
| 8 Years | 2.2 | 1.3 | 11.2 | 1.3 | 23.6 | 16.0 |
| 9 Years | 2.4 | 1.1 | 10.2 | 1.3 | 24.2 | 17.2 |
| 10 Years | 3.0 | 1.4 | 10.4 | 2.3 | 22.4 | 14.4 |
| *(b) Percentage cover values (%)* | | | | | | |
| Before treatments | 65.0 | 18.0 | 66.0 | 16.4 | 78.0 | 12.0 |
| After treatments | | | | | | |
| 1 Year | 0.3 | 0.4 | 8.3 | 2.5 | 18.8 | 10.9 |
| 2 Years | 3.9 | 2.9 | 16.8 | 6.5 | 25.8 | 7.9 |
| 3 Years | 14.6 | 12.0 | 27.0 | 4.4 | 31.7 | 6.7 |
| 4 Years | 34.5 | 25.4 | 44.9 | 3.3 | 49.1 | 7.8 |
| 5 Years | 42.7 | 18.8 | 53.0 | 4.1 | 44.3 | 6.4 |
| 6 Years | 43.5 | 15.0 | 49.4 | 6.3 | 46.4 | 7.8 |
| 7 Years | 55.8 | 23.1 | 59.9 | 4.4 | 64.3 | 9.3 |
| 8 Years | 57.5 | 25.7 | 61.8 | 5.9 | 66.8 | 11.7 |
| 9 Years | 65.0 | 22.2 | 74.0 | 7.5 | 70.5 | 13.7 |
| 10 Years | 63.0 | 21.4 | 69.5 | 6.4 | 75.5 | 8.2 |
| *(c) Maximal height values (cm)* | | | | | | |
| Before treatments | 164.0 | 14.1 | 131.4 | 22.5 | 146.6 | 8.1 |
| After treatments | | | | | | |
| 1 Year | 7.4 | 4.3 | 11.6 | 3.8 | 17.2 | 3.7 |
| 2 Years | 30.8 | 8.9 | 29.6 | 5.7 | 34.4 | 9.9 |
| 3 Years | 65.0 | 20.4 | 45.0 | 6.4 | 46.6 | 10.5 |
| 4 Years | 84.0 | 37.8 | 53.8 | 6.3 | 52.4 | 11.8 |
| 5 Years | 103.3 | 33.8 | 65.4 | 4.8 | 69.0 | 12.9 |
| 6 Years | 112.8 | 18.7 | 69.4 | 3.1 | 74.4 | 12.6 |
| 7 Years | 118.3 | 18.9 | 76.2 | 5.6 | 77.8 | 9.4 |
| 8 Years | 117.5 | 33.3 | 83.4 | 8.7 | 89.6 | 10.9 |
| 9 Years | 137.5 | 20.4 | 95.0 | 13.2 | 106.4 | 16.5 |
| 10 Years | 141.8 | 20.9 | 100.6 | 15.0 | 114.8 | 19.3 |

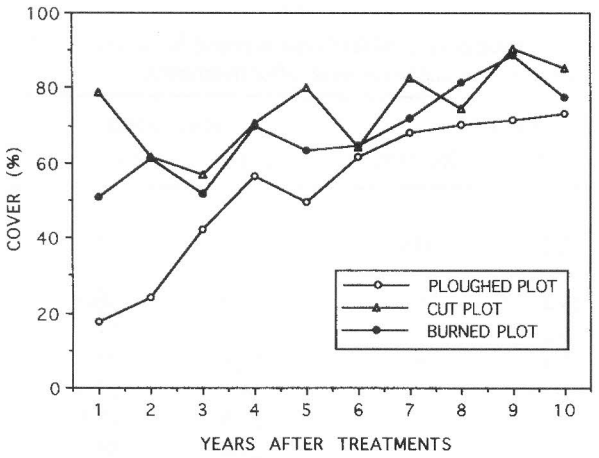


Fig. 1. Total plant cover in the experimental plots during the study period.

detected during the first five years ($F_2 = 8.7$, $p = 0.005$), but not from the sixth year after treatments ($F_2 = 1.1$, $p = 0.37$).

The mean height of all the *Cistus* plants was greatest in the plowed plot and lowest in the burned one, except for the year of the disturbances when the opposite occurs, the differences being statistically different 10 years after treatments ($F_2 = 17.2$, $p = 0.0001$). The maximal height registered in the pre-treatment situation was still not attained in any of the plots ($t = 6.3$, $p = 0.003$, for the plowed plot, $t = 2.9$, $p = 0.04$, for the cut plot, and $t = 3.7$, $p = 0.02$, for the burned plot). The lower mean height in the burned plot was due to the fact that there were some small seedlings (lower than 5 cm) until the seventh year after burning; in the other two plots the minimal height was higher than 10 cm from the fifth year. There were some *Cistus* plants higher than 1 m from the fourth year in the plowed plot, but this maximal height was not attained until the eighth or ninth years in the burned and cut plots, respectively (Table 1c, Fig. 2 ).

## DISCUSSION

The fast recovery response of *Cistus ladanifer* was shown in previous papers (Alonso et al., 1992; Luis et al., 1996), although four years after the disturbances the situation was still quite different from initial conditions.

The higher density in the burned plot than in the other two agrees with the stimulation effect of heat pointed out by various authors (Thanos and Georghiou, 1988; Trabaud, 1995). Germination percentages close to 100% were found in laboratory tests on *C. ladanifer* seeds subjected to heating, and this was attained in less than one month (Valbuena et al., 1992). It is clear that this stimulating effect also occurs under field conditions, but in this case the stimulation appeared to persist for several years after the fire. The seedlings appearing in the plots until the third year came from the soil seed bank, as there was no flowering until three years after the disturbances (Luis et al., 1996), and the difficulty for these species to colonize from neighboring areas has been pointed out (Trabaud, 1995). This has also been observed in other *Cistus* species (Legrand, 1993). The evolutionary advantage of such a mechanism seems obvious, since it guarantees survival, even if the clima-

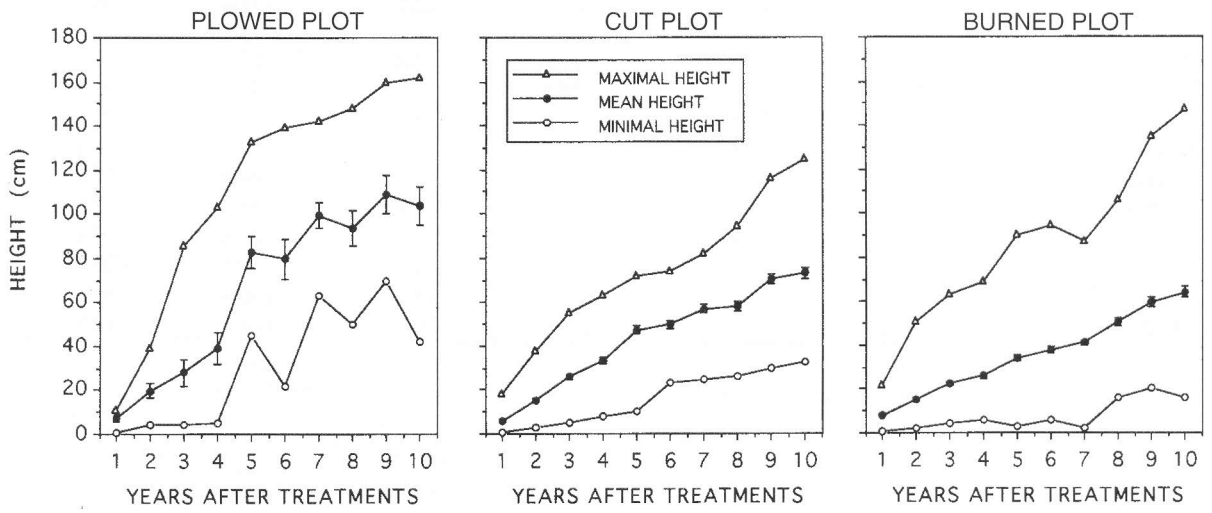


Fig. 2. Maximal, minimal, and mean values (with standard error) of *Cistus ladanifer* height in the experimental plots (all of the seedlings and plants in the five 1 $m^2$ sampling units) during the study period (June 1990–June 1999, one to ten years after treatments).

tological or any other conditions in the year following the fire are unfavorable. Less evident are the factors which regulate germination spread out over time once dormancy has been broken by the effect of heat.

On the other hand, there was a massive germination response in the cut plot without any type of thermal scarification. It has been stated that the non-heated seed germination rate is low, below 10% in other *Cistus* species, (Trabaud, 1995; Castro and Romero-García, 1999); however, Valbuena et al. (1992) recorded percentages close to 60% for *C. ladanifer*. The good recovery response of *C. ladanifer* in the cut plot happened despite the plant cover in the first year being considerably greater than in the other two plots, above all due to herbaceous species which were not eliminated and which spread when competition with the woody species disappeared temporarily (Tárrega et al., 1995). This contrasts with the statement by Legrand (1993), who observed that competition with the herbaceous stratum has a negative effect on the regeneration of other *Cistus* species.

The lowest seedling density was in the plowed plot; the effect of disturbing the soil by using a tractor could contribute to the mechanical scarification of the seeds, but it also impoverished the surface seed bank by burying many of the seeds at a great depth (50 cm). An increase in density was also not observed from the third year on, when the *Cistus* plants flowered abundantly, although competition was lower in this plot than in the other two, with significant lower plant cover until the fifth year (inclusive). The recovery response in the cut and plowed plot confirms the results of Thanos et al. (1992) and Trabaud and Renard (1999), who found that neither greater light intensity nor litter elimination stimulates *Cistus* germination.

Although the decrease in density in the burned plot in the first years seemed to suggest a trend for differences among plots to diminish, in the last years changes with time were not observed. Differences in density were still significant after ten years and also higher than the initial situation in the cut and burned plots. On the contrary, percentage cover was similar among plots in the last years and there were no differences as regards pretreatment conditions.

The faster growth in height in the plowed plot could be the result of lower intra- and interspecies competition in this plot, since it had the lowest *Cistus* density as well as the lowest total plant cover in the first years. Seedlings lower than 5 cm appeared until the seventh year (inclusive) in the burned plot, whereas there were no plants so small in the other two plots from the fourth year. This could indicate that germination continued for more years in the burned plot but also that competition with higher plants caused a delay in growth. Roy and Sonié (1992) found that *Cistus* recruitment diminished rapidly after fire and stopped from the fifth year.

Recovery was faster in the first years in the burned plot. However, in the last years the plowed plot was the one most similar to the situation existing before the disturbances. In any case, the recovery response was relatively rapid in the first few years in all the plots, although with a tendency to slow down over time, which means that the conditions after ten years were not yet the same as those existing before the experimental treatments.

The lack of small seedlings in the final years confirms the character of transitory stages of these communities and their dependence on disturbances for self-perpetuation, although the concrete factors regulating the regeneration responses are not clear (Trabaud and Renard, 1999). The time needed for replacement by more mature stages has also not been established, since a new disturbance usually occurs in most of the areas before these communities disappear due to senescence.

## REFERENCES


Alonso, I., Luis, E., and Tárrega, R. 1992. First phases of regeneration of *Cistus laurifolius* and *Cistus ladanifer* after burning and cutting in experimental plots. International Journal of Wildland Fire 2: 7–14.

Castro, J. and Romero-García, A.T. 1999. Dormancy and germination in *Cistus clusii* (Cistaceae): Effect of biotic and abiotic factors. Revue Ecologie, Terre et Vie 54: 19–28.

Corral, R., Pita, J.M., and Perez-García, F. 1990. Some aspects of seed germination in four species of *Cistus* L. Seed Science and Technology 18: 321-325.

David, H.A., Hartley, M.O., and Pearson, E.S. 1954. The distribution of the ratio, in a single normal sample of range to standard deviation. Biometrika 41: 482–493.

Keeley, J.E. 1986. Resilience of mediterranean shrub communities to fires. In: Dell, B., Hopkins, A.J.M., and Lamont, B.B., eds. Resilience in Mediterranean-type ecosystems. Dr. W. Junk Publishers, Dordrecht, pp. 95–112.

Legrand, C. 1993. Regeneration of two *Cistus* species after prescribed burning. In: Trabaud, L. and Prodon, R., eds. Fire in Mediterranean ecosystems. Ecosystems Research Report, 5. Commission of the European Communities, Brussels, pp. 183–192.

Lopes, A. 1988. Alguns aspectos sobre a germinaçao de *Cistus ladanifer*. In: Congreso Mundial sobre el Bosque y Matorral Mediterráneos. September 21–25 1988. Cáceres (Spain).

Luis, E., Tárrega, R., and Alonso, I. 1996. Seedling regeneration of two *Cistus* species after experimental disturbances. International Journal of Wildland Fire 6: 13–19.

Ministerio de Agricultura, 1973. Mapas provinciales de suelos de León. Ministerio de Agricultura. Instituto Nacional de Investigaciones Agrarias. Departamento Nacional de

Ecología. Madrid.

Ministerio de Agricultura, 1980. Caracterización agroclimática de la provincia de León. Dirección General de la Producción Agraria. Madrid.

Naveh, Z. 1974. Effects of fire on Mediterranean region. In: Kozlowski, T.T. and Ahlgren, C.E., eds. Fire and ecosystems. Academic Press, New York, pp. 401–434.

Roy, J. and Sonié, L. 1992. Germination and population dynamics of *Cistus* species in relation to fire. Journal of Applied Ecology 29: 647–655.

Santiesteban, E., García-Plé, C., and Morey, M. 1993. Dynamics of *Cistus monspeliensis* seedlings after fire. In: Trabaud, L. and Prodon, R., eds. Fire in Mediterranean ecosystems. Ecosystems Research Report, 5. Commission of the European Communities, Brussels, pp. 193–199.

Tárrega, R., Luis, E., and Alonso, I. 1995. Comparison of the regeneration after burning, cutting and plowing in a *Cistus ladanifer* shrubland. Vegetatio 120: 59–67.

Thanos, C.A. and Georghiou, K. 1988. Ecophysiology of fire-stimulated seed germination in *Cistus incanus* ssp. *creticus* (L.) Heywood and *C. salvifolius* L. Plant, Cell and Environment 11: 841–849.

Thanos, C.A., Georghiou, K., Kadis. C., and Pantazi, C. 1992. Cistaceae: a plant family with hard seeds. Israel Journal of Botany 41: 251–263.

Trabaud, L. 1987. Fire and survival traits of plants. 65–89. In: Trabaud, L., ed. The role of fire in ecological systems. SPB Academic Publishing, The Hague, pp. 65–89.

Trabaud, L. 1995. Modalités de germination des cistes et des pins méditerranéens et colonisation des sites perturbés. Revue Ecologie, Terre et Vie 50: 3–14.

Trabaud, L. and Renard, P. 1999. Do light and litter influence the recruitment of *Cistus* spp. stands? Israel Journal of Plant Sciences 47: 1–9.

Troumbis, A. and Trabaud, L. 1986. Comparison of reproductive biological attributes of two *Cistus* species. Acta Oecologica. Oecologia Plantarum 7: 235–250.

Tukey, J.W. 1949. Comparing individual means in the analysis of variance. Biometrics 5: 99–114.

Valbuena, L., Tárrega, R., and Luis, E. 1992. Influence of heat on seed germination of *Cistus laurifolius* and *Cistus ladanifer*. International Journal of Wildland Fire 2: 15–20.