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Post-Fire Dynamics of *Cistus* spp. in a *Pinus brutia* Forest*

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Abstract: The population dynamics of 2 species of *Cistus* L. (*C. salviifolius* L. and *C. creticus* L.) were studied along a post-fire successional gradient in *Pinus brutia* Ten. forests in Marmaris National Park, Turkey. The population density of *Cistus* spp. was 16 individual m⁻² at the end of the first year after fire and then decreased exponentially ($r^2 = 0.926$, $P < 0.001$) the second year after fire to later successional stages. Total projected foliage cover of *Cistus* spp. was 26% by the end of the first year after fire, it increased to approximately 38% during the second year after fire and decreased linearly ($r^2 = 0.872$, $P < 0.01$) beyond this time. Rates of establishment of *Cistus* spp. were high in the first year after fire but were low in subsequent years and most of the *Cistus* plants flowered during the second year after fire. There was a significant positive relationship between the density of new seedlings of *Cistus* and cover of *Pinus brutia* trees in the sixth year after fire ($r^2 = 0.242$, $P = 0.002$). Seed yield of *Cistus* was reduced due to predation of seed capsules by Bruchid insects. Both species of *Cistus* were shown to be typical post-fire colonisers in terms of timing of recruitment and post-fire population dynamics. The major factors responsible for the decrease in density of seedlings of *C. salviifolius* and *C. creticus* are likely to be the mortality of young seedlings due to summer drought and competition among seedlings and with *P. brutia* trees. It is suggested here that the species considered have fire-dependent establishment behaviour and an increase in population is restricted to early post-disturbance in *P. brutia* forests in Turkey, as in other Mediterranean regions.

Key Words: Post-fire colonisers, post-fire succession, *Cistus creticus*, *Cistus salviifolius*, Turkey

Bir *Pinus brutia* Ormanında Yangın Sonrası *Cistus* spp. Dinamikleri

Özet: *Cistus salviifolius* L. ve *C. creticus* L.'un populasyon dinamikleri, Marmaris Milli Parkı'nda *Pinus brutia* Ten. ormanlarında bir yangın sonrası süksesyonel gradiyent boyunca araştırılmıştır. *Cistus* spp. populasyon yoğunluğu yangından sonra birinci yılın sonunda 16 birey m⁻² iken, yangın sonrası ikinci yıldan ileri süksesyonel evrelere kadar üssel olarak azalmıştır ($r^2 = 0.926$, $P < 0.001$). Yangın sonrası birinci yılın sonunda *Cistus* spp.'un örtme derecesi %26 iken, yangın sonrası ikinci yılda yaklaşık %38'e kadar artmış ve daha sonra doğrusal olarak azalmıştır ($r^2 = 0.872$, $P < 0.01$). *Cistus* spp.'un alana yerleşme oranının yangın sonrası ilk yılda yüksek, takip eden yıllarda ise düşük olduğu görülmüştür. Yangın sonrası ikinci yılda birçok *Cistus* bitkisi çiçeklenmiştir. Yangın sonrası altıncı yılda, yeni ortaya çıkan *Cistus* fidelerinin yoğunluğu ile *Pinus brutia* ağaçlarının örtme derecesi arasında önemli bir pozitif ilişki gözlenmiştir ($r^2 = 0.242$, $P = 0.002$). *Cistus* spp.'un tohumlarının bir kısmının tohum kapsüllerinden beslenen Bruchid böcekler tarafından predasyona uğradığı saptanmıştır. Her iki *Cistus* türü de alana yerleşme zamanları ve yangın sonrası populasyon dinamiklerine göre kolonici tür özelliği göstermektedirler. *C. salviifolius* ve *C. creticus* fidelerinin yoğunluğunun azalmasında rol oynayan en önemli etmenler arasında genç fidelerin yaz kuraklığından kaynaklanan mortalitesi ile diğer fideler ve *P. brutia* ağaçlarıyla aralarındaki rekabet sayılabilir. Araştırılan türlerin, diğer Akdeniz civarı ülkelerde olduğu gibi, Türkiye'deki *P. brutia* ormanlarında da yangına bağımlı yerleşme davranışına sahip oldukları ve populasyonlarındaki artışın müdahale sonrası erken dönemle kısıtlı olduğu sonucuna varılmıştır.

Anahtar Sözcükler: Yangın sonrası koloniler, yangın sonrası süksesyon, *Cistus creticus*, *Cistus salviifolius*, Türkiye

Introduction

Species of *Cistus* L. are considered the most common post-fire colonisers in the Mediterranean Basin (Troumbis & Trabaud, 1986; Moravec, 1990; Thanos, 1999). Even if they are absent in mature forests, they generally persist

in soil seed banks and may reappear in these areas after a fire (Troumbis & Trabaud, 1986; Thanos et al., 1992; Thanos, 1999). The opportunistic nature of *Cistus* species is reflected in their reproductive characteristics (Thanos & Georghiou, 1988). For example, seeds of most

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species of *Cistus* spp. have hard coats (Thanos & Georghiou, 1988; Thanos et al., 1992) which inhibit uptake of water from the environment (Corral et al., 1990), allowing seeds to remain dormant for long periods of time (Trabaud et al., 1997; Thanos, 1999). Seed dormancy can be broken by high temperatures such as those produced during fire (Trabaud & Oustric, 1989; Pugnaire & Lozano, 1997) or mechanically by other disturbances such as tilling or ploughing the soil (Troumbis & Trabaud, 1986). In recently burnt areas in the Mediterranean Basin, species of *Cistus* germinate in massive numbers and reach high seedling densities in a short period of time (Arianoutsou-Faraggitaki & Margaris, 1982; Thanos & Georghiou, 1988; Thanos et al., 1989; Skourou & Arianoutsou, 1998; Eshel et al., 2000).

Forests of *Pinus brutia* Ten. occupy large areas in the east Mediterranean Basin (Davis, 1965-1985; Panetsos, 1975). Species of *Cistus* are often associated with *P. brutia* as an understorey layer in the Aegean region of Turkey and East Aegean Islands (Carlström, 1987; Thanos & Marcou, 1991; Spanos et al., 2000). Although light intensity under the mature canopy of *P. brutia* is low (Neyişiçi, 1987), germination of species of *Cistus* is not affected by light availability (Thanos & Georghiou, 1988; Thanos et al., 1992; Keeley & Baer-Keeley, 1999; Trabaud & Renard, 1999). Despite this, seedling establishment does not generally occur in mature *Pinus* forests (Skourou & Arianoutsou, 1998; Trabaud & Renard, 1999; Eshel et al., 2000). Consequently, in burnt *Pinus* forests, populations of *Cistus* increase in size in the first few years after fire (Peşmen and Oflas, 1971; Thanos et al., 1989), and generally decrease gradually with time (Schiller et al., 1997). Early on, seedling death is likely to be due to competition for resources (Ne'eman et al., 1995; Vilà & Sardans, 1999), and later as a consequence of the short life span of these shrubs (Arianoutsou-Faraggitaki & Margaris, 1982; De las Heras et al., 2002).

Although this general process is well known, the population dynamics of species of *Cistus* have not previously been studied in Turkey. The aim of the present study was to determine the post-fire dynamics of 2 species of *Cistus* (*C. salviifolius* L. and *C. creticus* L.) along a post-fire successional gradient in *P. brutia* forests in Marmaris National Park, Turkey. This study will contribute to the current literature on this subject.

Methods

Study site

The study area was located in Marmaris National Park in south-western Turkey. The climate is typically Mediterranean with frequent drought during summer and cool, wet winters. Using Emberger's method (Akman, 1999; Dufour-Dror and Ertas, 2004), a climatic classification type based on photoperiodism, temperature and precipitation regimes, and the long-term climatic data of the study area (1961-2000, Turkish State Meteorological Service), a bioclimatic analysis was conducted. Of the bioclimatic parameters, maximum mean temperature of the hottest month (M) is 45.2 °C, minimum mean temperature of the coldest month (m) is -3.5 °C, mean yearly precipitation (P) is 1233 mm, and the pluvio-thermic quotient (Q) is 86.1. The quotient Q is an estimate of M , m and P , and gives the bioclimatic type of the study area with m . After the values for Q and m are calculated and placed in the Emberger's "climagram" (Akman, 1999; Dufour-Dror and Ertas, 2004), they indicate that the National Park area has a 'sub-humid Mediterranean climate with very cold winters'.

Three sites that had been burnt in different years (1999, 1995 and 1979) and a fourth site, which had not been burnt for at least 45 years, were selected for the study. The sites were located very close to each other (site burnt in 1999: 36°50'11"N, 28°18'10"E; site burnt in 1995: 36°51'16"N, 28°17'14"E; site burnt in 1979: 36°49'37"N, 28°19'34"E; long unburnt site: 36°50'47"N, 28°17'24"E) and each was at least 1 ha in size. Dominant plant species included *Pinus brutia*, *C. salviifolius*, *C. creticus*, *Quercus infectoria* Olivier, *Phillyrea latifolia* L. and *Smilax aspera* L. Nomenclature of the plant species follows Davis (1965-1985).

Estimation of cover and density

Forty 1 x 1 m plots were established randomly in each of the 4 sites. Individuals of *Cistus salviifolius* and *C. creticus* were counted and percentage projected foliage cover determined in each plot. As *C. salviifolius* and *C. creticus* share similar post-fire regeneration strategies and they are both typical post-fire pioneer species, germination and cover were evaluated together to give a generic rather than a specific response.

Assessment of populations of sites burnt in 1999 and 1995 were conducted in September 2000 and September 2001, and assessments of the site burnt in 1979 were

carried out in September 2000 and July 2001. The long unburnt site was assessed in September 2000. According to the synchronic approach, these sampling times were equivalent to 1 and 2 (for the site burnt in 1999), 5 and 6 (for the site burnt in 1995), 21 and 22 (for the site burnt in 1979), and 45 (for the long unburnt site) years after fire. Additional monthly assessments were conducted from March 2001 to September 2001 to determine whether any new seedlings had emerged. Total projected foliage cover of seedlings of both species of *Cistus* and mature trees of *Pinus brutia* were assessed in each plot. Seed capsules of *Cistus* were collected from randomly selected individuals in each site in September 2001 to determine whether they were infested by seed parasites.

Statistical analysis

Regression analysis was used to test for significant changes in the density and cover of the 2 species of *Cistus* with time after fire. The statistical significance of regression curves was tested with *t*-statistics (Fowler & Cohen, 1990) after transformation of curves to linear lines by log-transformation of ordinate data or, if needed, both ordinate data and axis data. Regression curves were drawn only if they were statistically significant. Spearman's rank correlation coefficient (r_s , Sokal & Rohlf, 1981) was used to test if there was any significant relationship between cover of *P. brutia* and emergence of seedlings of *Cistus*.

Results

C. salviifolius were always found in greater densities and with greater foliage cover than *C. creticus* at all sites and sampling times. When both species were considered together, the population density of *Cistus* spp. was approximately 16 individuals m^{-2} within 1 year of fire and density decreased exponentially ($P < 0.001$) from the second year after fire to later successional stages (Figure 1). The exponential decrease in density was due to the death of individuals of *C. salviifolius* rather than of *C. creticus*. Although the regression curve was not statistically significant in the latter species ($y = 3.26x^{-0.7063}$, $r^2 = 0.619$, d. f. = 4, $P > 0.05$), there was also a considerable decline in population density with time. The long unburnt site had very low densities of *Cistus* (0.21 individuals m^{-2}) throughout the study period.

Total cover of *Cistus* spp. was 26.0% by the end of the first year after fire and had increased to 37.6% by the second year. Total cover decreased linearly beyond the second year after fire (Figure 2, $P < 0.01$), and in the long unburnt plots the total combined cover of *Cistus* was only 4.3%.

It was observed that most of the individuals of *Cistus* (especially *C. creticus*) had flowered and produced seed (that is, reached maturity) in the second after-fire year. It was also observed that the major factor responsible for

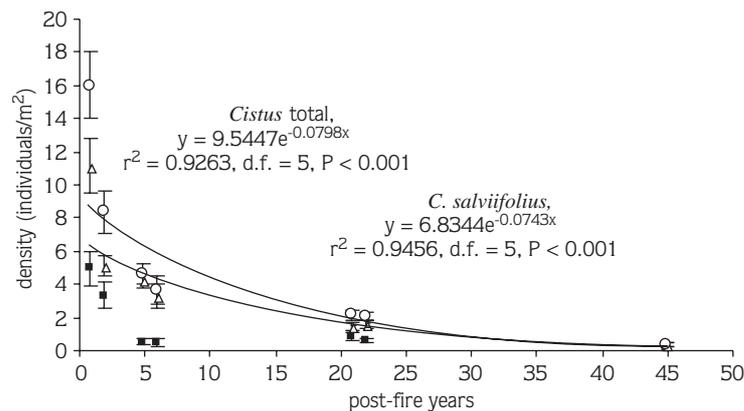


Figure 1. Post-fire decrease in the total density of *Cistus* spp., *C. salviifolius* and *C. creticus*. Circles and the upper regression curve represent the total densities of *Cistus*, triangles and the lower curve represent the densities of *C. salviifolius*, and black squares represent the densities of *C. creticus*. The values are means and the error bars represent \pm SE.

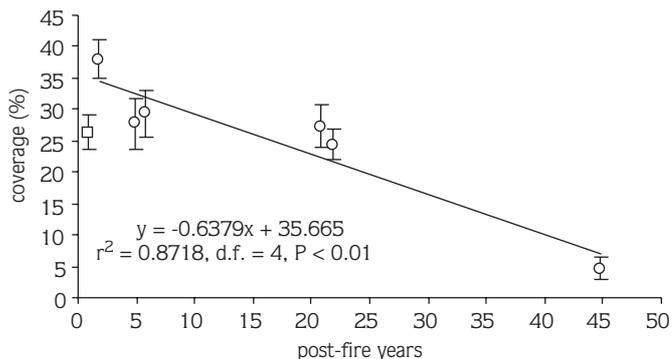


Figure 2. Post-fire (from second year after fire) decrease in the total cover of *Cistus* spp. (*C. salviifolius* and *C. creticus*). Note that the square is the cover value of the first year after fire and the circles are the cover values of successive years after fire. The values are means and the error bars represent \pm SE.

loss of *Cistus* seed yield was infestation of seed capsules by Bruchid insects (34.5% of capsules *C. creticus*, $n = 226$, and 28.1% of *C. salviifolius* capsules, $n = 892$) in all study sites.

New seedlings of *Cistus* emerged only during May 2001 at the site burnt in 1999 and for a more extended period (June, July, August and September 2001) at the site burnt in 1995. No new *Cistus* seedlings emerged at the site burnt in 1979 or at the long unburnt site during the study period. Newly emerged seedlings of *Cistus* appeared in late spring at the site burnt in 1999; however, they did not become established and had disappeared by the time of the next monthly assessment. Seedlings that had emerged during spring at the site burnt in 1995 remained alive until early summer, and additional seedlings could be counted until September (Table 1). It was observed that the spatial distribution of these new *Cistus* seedlings was restricted to locations beneath *Pinus* saplings in the site burnt in 1995. Indeed, there was a significant relationship between *Cistus* seedling number and *Pinus* sapling cover values in study plots in this site ($r_s = 0.242$, $P = 0.002$, $n = 160$).

Discussion

The density and cover of *Cistus* reached very high values in a short period of time after fire and this can be attributed to increased rates of germination immediately after disturbance (Troumbis & Trabaud, 1986; Thanos & Georghiou, 1988; Trabaud & Oustric, 1989; Thanos,

Table 1. Mean densities of newly emerged seedlings of *Cistus* spp. (mean individuals $m^{-2} \pm$ SE) as measured monthly in 2001 at the study sites burnt in 1999 and 1995.

	site 1999	site 1995
March-April	0	0
May	1.5 \pm 1.1	0
June	0	0.9 \pm 0.8
July	0	1.1 \pm 0.6
August	0	1.3 \pm 1.0
September	0	1.2 \pm 0.8

1999). The population density showed a marked decrease in the second year after fire, while cover values continued to increase. The increasing cover values were likely to be due to the rapid growth and development of *Cistus* seedlings after fire.

The decrease in the population density of *Cistus* spp. slowed with successional time and the overall trend followed an exponential curve. Such a pattern is similar to that found by Schiller et al. (1997) for *Cistus* growing in *Pinus halepensis* Mill. forests. The summer drought and intense competition for resources may be responsible for the abrupt decline in the population density of *Cistus* spp., especially in the early and mid-successional stages (Vilà & Sardans, 1999).

As a result of such decreases, *Cistus* had very low densities in the long unburnt site, although later deaths

may be attributed to the biological properties of *Cistus* rather than to the effects of competition. In the absence of competition, a decline in the population is to be expected as they are short-lived species (De las Heras et al., 2002). In a mature *P. brutia* forest in which seedling establishment does not readily occur if there is no disturbance, species of *Cistus* apparently disappear locally with time (Trabaud & Renard, 1999). The general trend in decreasing population density of *Cistus* spp. with successional time fits a recent simulation model predicting decreases in *Cistus* populations with increasing fire-free period (Pausas, 1999).

Most of the individuals of both species of *Cistus* flowered and reached maturity in the second year after fire. Although there have been accounts of flowering being delayed until 3 years after fire (Ferrandis et al., 1999; Trabaud & Renard, 1999; Eshel et al., 2000; Ferrandis et al., 2001), the early flowering of *C. salviifolius* (Thanos et al., 1989; Ferrandis et al., 1999) and *C. creticus* (Thanos et al., 1989) has also been documented. This short juvenile period may be an adaptation against the possibility of a repeated fire. Pausas & Vallejo (1999) suggested that if the timing of the recurrence of fire is shorter than the age of maturity, the species would be locally eliminated. Species of *Cistus* guarantee maintenance of their population within a very short period by producing seeds in their second or third years and having them accumulate in the soil seed bank.

The seed yield of both species of *Cistus* was reduced by predation by the seed beetle *Bruchidius biguttatus* Olivier (Coleoptera: Bruchidae) at all study sites. However, since large numbers of seeds are produced every year and these seeds accumulate and can remain viable in the soil seed bank, this loss may not impact on the maintenance of populations of *Cistus* in the area. Moreover, the population density of *B. biguttatus* is not likely to be high enough to cause widespread damage to plants in Turkey (Lodos, 1998). Despite the fact that seed predation of Bruchids on *Cistus* species was also shown in another study (Bastida & Talavera, 2002), more investigations are needed to confirm if these and other seed-predatory insects have sufficient negative effects on seed accumulation in the soil seed bank and therefore on post-fire seedling establishment of *Cistus*.

Except for the first year after fire, *Cistus* had very low rates of establishment. By the second year after fire and thereafter, the density of new *Cistus* seedlings was extremely low (approximately 1 individual m⁻²). These results supported a post-fire 3-year period study conducted in a *Cistus-Erica* shrubland (Quintana et al., 2004). In addition, in the present study, it was found that the spatial distribution of new seedlings of *Cistus* was restricted to beneath saplings of *Pinus* L. in the 6-year-old site (1995 site), and these seedlings remained alive during the summer (Table 1). Since low light levels have no effect on the germination of seed of *Cistus* (Corral et al., 1990; Keeley & Baer-Keeley, 1999; Trabaud & Renard, 1999) and the temperature range for germination is restricted to 15-20 °C (Troumbis & Trabaud, 1986), the emergence of seedlings beneath *Pinus* saplings may improve seedling survival. This would be particularly important during summer drought by decreasing the surface temperatures of the ground and protecting seedlings from solar radiation by shading.

In conclusion, the findings of the study support the current literature on *Cistus* population dynamics in Mediterranean *Pinus* forests. There was an increase in population density and cover of *Cistus* spp. in the first year post-fire; however, this trend changed during the second year and density and cover decreased with successional time. Mature individuals of *Cistus* were very rarely found in mature forests of *P. brutia*. It is suggested here that *C. salviifolius* and *C. creticus* are fire-dependent species and an increase in population is restricted to early post-disturbance in *P. brutia* forests in Turkey, as in other Mediterranean regions.

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