

## Seed Production and Fruit Parasitism in *Cistus salviifolius* L. (Cistaceae) along a Post-Fire Successional Gradient

Cagatay Tavsanoğlu

Department of Biology, Division of Ecology, Hacettepe University,  
Beytepe, 06800, Ankara, Turkey

**Abstract:** The dynamics of seed production and fruit parasitism in a fire-following obligate seeder species, *Cistus salviifolius* L. were investigated along a post-fire successional gradient in Marmaris, southwestern Turkey. Four sites of different post-fire age (1, 5, 21 and 45 years) were studied for three consecutive years. Fruit samples were collected and plant size was measured in the field. Then fruit infestation rates of individuals and seed numbers of fruits were determined. Mean seed numbers per fruit showed inter-annual variation during the study period and the amount of spring rainfall, especially in March may be responsible for this fluctuation. Mean seed numbers per fruit also showed a decreasing trend with increasing post-fire stand age. This result reflected the seed bank dynamics of *Cistus* L. in relation to time since fire. Rates of infestation of *C. salviifolius* by Bruchid beetles were lower, however, there were no patterns related to infestation rates except for a negative relationship between mean seed number per fruit and fruit infestation rate. This study indicated that several factors may affect the dynamics of seed production in species of *Cistus* independent of fire itself such as pre-dispersal seed predators, plant size and spring rainfall.

**Key words:** Bruchidae, infestation rate, fire, plant size, rainfall, seed production

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### INTRODUCTION

Seed production is of great importance for species in which recovery of populations from disturbance depends completely on only seed germination after fire (Neeman and Dafni, 1999). This strategy of post-fire regeneration has been described as obligate seeding strategy and is one of the three main post-fire response types of plants in Mediterranean-type ecosystems. The other two are obligate resprouting strategy and facultative resprouting strategy (Pausas and Vallejo, 1999). *Cistus salviifolius* L. is a typical example of the obligate seeder species in the Mediterranean basin (Pausas, 1999a). All individual plants burn and die after a crown fire and the recovery of species depends completely on the germination of seeds found in the soil seed bank. Therefore, *C. salviifolius* needs to reconstitute its soil seed bank to be resilient to fire before a recurrent fire occurs.

Since fire has an important place in the life history of species of *Cistus* L. the post-fire response of populations of *C. salviifolius* has been well studied throughout the Mediterranean basin (Trabaud and Oustric, 1989; Corral *et al.*, 1990; Roy and Sonié, 1992; Neeman *et al.*, 1993; Hanley and Fenner, 1998; Chamorro-Moreno and Rosua-Campos, 2004). It is known that seeds of *C. salviifolius* found in the soil seed bank germinate

massively immediately after fire (Thanos *et al.*, 1989). Moreover, studies on the population dynamics of *C. salviifolius* after fire showed that their population size increases in the first post-fire years but thereafter decreases (Schiller *et al.*, 1997; Tavsanoğlu and Gurkan, 2005). This behavior is the result of hard-coated seeds of *C. salviifolius* that do not have the ability to germinate without disturbances such as fire (Thanos and Georghiou, 1988). However, a small fraction of the seed set is soft-coated in species of *Cistus* and they are not dormant like hard-coated ones and have the ability to germinate in the absence of a disturbance (Thanos *et al.*, 1992).

The patterns of resource allocation and partitioning in reproductive modules of *Cistus* have been studied (Acosta *et al.*, 1997) and it is stated that UV-B radiation level (Stephanou and Manetas, 1998) plant density (Metcalfe and Kunin, 2006) and amount of rainfall (Troumbis and Trabaud, 1986) may affect seed production in *Cistus*. However, the dynamics of seed production in *Cistus* in relation to fire remain unknown (but see Delgado *et al.*, 2001) for the effect of pre-germination heating and (Clemente *et al.*, 2007) for seed bank dynamics in relation to fire.

Fruit parasitism is one of the factors responsible for reducing seed yield of plant species (Jermy and Szentesi, 2003) and moreover, might result in a plant population gradually becoming endangered by interrupting the

recruitment of plant species (Or and Ward, 2007). It is known that the major cause of seed loss in species of *Cistus* is pre-dispersal seed predators such as Noctuid (Lepidoptera) (Serrano *et al.*, 2001) and Bruchid (Coleoptera) (Bastida and Talavera, 2002) insects.

In the study to characterize the relationships among seed production and fruit infestation in *C. salviifolius* and time since fire the following questions were considered: how does seed production change in relation to post-fire successional age? What is the relationship between plant size and seed production and how does fruit infestation affect the seed yield and what is its relationship with post-fire successional age?

To answer the questions above four sites of different post-fire age were selected and studied in three consecutive years. Fruit samples of *C. salviifolius* were collected at each site and infestation rates of plant individuals by seed predators and seed numbers of each fruit were determined. The size of *C. salviifolius* individuals from which fruit samples were obtained was also measured.

**MATERIALS AND METHODS**

**Study site:** The study was conducted in Marmaris National Park, Mugla, southwestern Turkey (36°49'-36°51'N, 28°17'-28°19'E). The climate is sub-humid Mediterranean with a dry summer period (Tavsanoğlu and Gürkan, 2005). According to the data obtained from the Turkish State Meteorological Service (1975-2006; Marmaris Meteorological Station at 19 m a.s.l.), mean annual amount of rainfall is 1212 mm and annual mean temperature is 18.7°C. The xerothermic period lasts five months from May-September (Fig. 1). Mean total amount of rainfall during this period is just 56.8 mm. Rainfall values of the first 6 months of the years of the 3 year sampling period and of the long-term average are shown in Table 1. Total amount of rainfall in spring 2001 was lower than that in 2000 and 2002. In particular, March 2001 stands out with nearly zero rainfall in contrast with previous and subsequent years and long-term mean values.

The dominant vegetation cover was *Pinus brutia*. Ten forests throughout the National Park. However, the fires that occurred in the past 30 years have also created a mosaic of post-fire successional stages within and around the park area. In these sites the vegetation consisted of Mediterranean maquis shrubs and phrygana sub-shrubs, predominantly *Phillyrea latifolia* L., *Quercus infectoria* olivier, *Cistus salviifolius*, *C. creticus* L and *Smilax aspera* L.

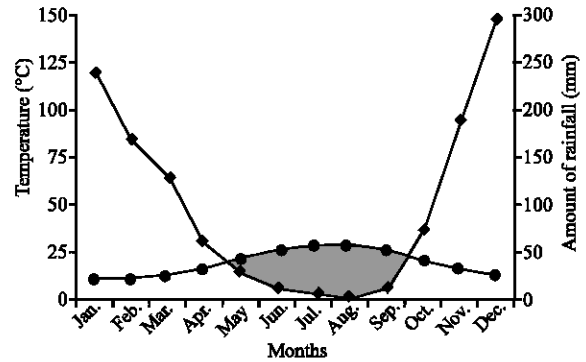


Fig. 1: Ombrothermic (rainfall-temperature) climatic diagram of Marmaris for the period of 1975-2006. Dark-colored area shows the xerothermic period

Table 1: Monthly total amount of rainfall (mm) for winter and spring periods in Marmaris during 2000-2002 years and the long term average for 31 years (1975-2006)

Months	Amount of rainfall (mm)			
	2000	2001	2002	Long-term average
January	157.0	235.7	168.0	240.7
February	97.2	173.9	85.9	169.2
March	129.9	2.7	76.4	128.6
April	151.5	101.1	76.1	58.1
May	11.3	21.6	21.3	27.9
June	1.7	0.0	2.0	11.1
Total of 6 months	548.6	535.0	429.7	635.5
Total of spring	292.7	125.4	173.8	214.5

**Study species:** *C. salviifolius* (Cistaceae) is a Mediterranean sub-shrub distributed over both the eastern and the western parts of the Mediterranean Basin (Moretti *et al.*, 2006). The recovery from disturbance takes place completely from seeds and the germination rates of hard-coated seeds increase after fires (Thanos and Georghiou, 1988). These make *C. salviifolius* a typical fire-following species throughout the Mediterranean Basin (Schiller *et al.*, 1997; Tavsanoğlu and Gürkan, 2005). *C. salviifolius* flowers in early spring and the fruits mature during the late spring and early summer.

Seed dispersal starts in September and continues up to late winter. After the dispersal, the seeds accumulate and remain viable in the soil seed bank for several years (Pausas, 1999b). *Bruchidius biguttatus* Olivier Coleoptera (Bruchidae) has a wide distribution including North Africa, South Europe, Northern Caucasia and the East Mediterranean and there are many records about the presence of this species throughout Turkey (Mergen, 1996; Lodos, 1998). Although, it is already known that species of *Cistus* are the main host plant of *B. biguttatus* (Lodos, 1998; Kergoat *et al.*, 2004), the biology of this seed beetle is still unclear. Among the species of bruchids, *B. biguttatus* is one of the few species using a member of a plant family other than

Fabaceae (Leguminosae) as host plants and is unique in using Cistaceae in Europe (Kergoat *et al.*, 2004). In contrast to the species of bruchids that infested individual seeds directly and developed within them in Leguminosae (Ramos, 1976; Takakura, 2002; Derbel *et al.*, 2007; Gianoli *et al.*, 2007), *B. biguttatus* individuals infested the whole fruit not only one seed of their host plant. Since each fruit capsule consists of five locules in *C. salviifolius*, the larvae should drill additional holes to reach the seeds in other locules. After larval development completed within the fruit, the individuals pupate within a locus in the fruit. After pupation, emerging adults exit the fruit by drilling an exit hole in the external wall of the fruit.

**Sampling procedure:** Successional studies frequently use an approach named synchronic to be able to sample the long successional process within a short time. With this approach, the study sites at different successional stages are selected and studied simultaneously. On the other hand, there is another approach named diachronic including studies that monitor the successional process in subsequent years within a site (Trabaud, 2000). The present study used both the synchronic and the diachronic approaches. To construct a post-fire successional gradient, three study sites that burned in different years (burned in 1999, hereafter the 1999 site; burned in 1995, hereafter the 1995 site and burned in 1979, hereafter the 1979 site representing 1-3, 5-7 and 21-23 years after fire, respectively) and a study site that had not burned for at least 45 years by the beginning of the study (hereafter the unburned site; representing 45-47 years after fire) were selected within an area 16 km<sup>2</sup> (4×4 km) in size. The study sites were at least 1 ha in size and were on the same geologic material (ophiolitic rocks). Four study sites of different post-fire ages were sampled for three consecutive years (in 2000, 2001 and 2002). The 1999 site could not be sampled in 2000 because only 1 year old non-reproductive seedlings of *C. salviifolius* were present at this site.

The fruit samples were collected in early September for each sampling year after the maturation of the fruits and before the beginning of seed-dispersal. The fruit samples were collected from randomly selected individuals in the field and were taken to the laboratory in paper envelopes. The envelopes were stored in boxes at room temperature and humidity until they were opened for seed counts. The number of seeds per fruit was estimated by manually counting seeds. The fruits to be counted for seeds were chosen randomly from the fruit-set of each individual sampled in the field. Only fully matured seeds were counted, undeveloped ones were ignored. For each fruit, evidence of parasitism by *B. biguttatus* indicated by

holes in the fruit wall and fragments of partially eaten seeds within the fruit was noted. However, the fruits that had been parasitized were not used for seed counts. Fruits in which the capsules were partially open, wide enough to allow the seeds to fall out were not used for seed counts either but were included in the analysis of fruit parasitism rate. A total of 3333 fruit capsules from 180 individuals were checked for fruit infestation and a total of 2674 capsules from 163 individuals were included in the seed count analyses.

For 2001 and 2002 sampling years, coverage and maximum height measures were also taken from the individuals sampled for fruits. Maximum height was determined by measuring from the ground to the top of the individual plant. Coverage was determined visually as individual cover of plants in a quadrat 1 m<sup>2</sup> in size and expressed as a percentage. When the cover exceeded the quadrat size additional quadrats were included therefore, cover of some of the individuals exceeded 100%. A total of 122 individuals were measured for coverage and maximum height.

**Data analysis:** Mean seed number per fruit was calculated for each individual plant and fruit infestation rate (%) was determined for each individual by multiplying by 100 the proportion of the number of infested fruits to total number of fruits sampled. Mean values of seed number per fruit of individuals were evaluated as single measurements for comparisons of sampling year and of study site with regard to seed production. Mean fruit infestation rate (%) was also calculated to compare the study sites and sampling years with regard to fruit infestation. Use of the term reproductive effort instead of mean seed number per fruit is avoided here because if such a term had been included data on total seed production of an individual would have been needed and there were no data on the total number of fruits of sampled individuals in the present study.

Differences in mean seed number per fruit and in mean fruit infestation rate (%) among different sampling years and among the study sites representing different post-fire successional stages were tested by one-way Analysis of Variance (ANOVA) not by a two-way procedure as the sample sizes of groups were not equal and the 1999 site could not be sampled in 2000. Prior to analysis, the data were tested for normality with Kolmogorov-Smirnov test and for homoscedasticity with Levene statistics. When various types of transformations could not fit the data to normal distribution and homoscedasticity could not be obtained, respectively, non-parametric Kruskal-Wallis test and ANOVA with Welch statistics (F') were used to test differences among groups (Zar, 1996). Tukey's HSD test was used for

multiple comparisons. In the case of the two groups to be compared, Student's t-test or Mann-Whitney U test was used according to whether the data met the prerequisites of parametric tests. Associations between variables (mean seed number per fruit, fruit infestation rate, post-fire year, plant height and coverage) were tested using the parametric Pearson's correlation or the non-parametric Spearman's rank correlation methods according to whether the data met the prerequisites of parametric tests.

**RESULTS AND DISCUSSION**

The mean fruit infestation rate ( $\pm$ SE of the mean, n = 180) and mean seed number per fruit ( $\pm$ SE of the mean, n = 163) of *C. salviifolius* over the 3 years period were 22.2% ( $\pm$ 1.49) and 30.9 ( $\pm$ 0.76) seeds/fruit, respectively. However, mean fruit infestation rates were higher in 2000 and 2001 samples (respectively, 26.8 and 33.9%) than in 2002 samples (9.26%) (F = 42.8, p<0.001). Mean seed numbers per fruit, similarly showed inter-annual variation and the value for the 2001 sample (22.7 seeds/fruit) was lower than that for the 2000 and 2002 samples (respectively, 31.9 and 35.3 seeds/fruit) (F = 28.6, p<0.001). This overall pattern was also seen within sampling sites representing different successional stages (Table 2). Mean seed numbers per fruit were significantly different among the sampling sites for each sampling year (Table 2) and the overall pattern showed a decreasing trend with increasing post-fire stand age (Fig. 2, r = -0.502; p<0.001, n = 163). On the other hand, although mean fruit infestation rates (%) were significantly different among sampling sites for each sampling year (Table 2), there was not a correlation between mean fruit infestation rate (%) and the post-fire stand age (r = -0.012, p>0.05; n = 180). There was also a significant negative correlation between mean seed number per fruit and fruit infestation rate (%) (Fig. 3, r = -0.180, p = 0.021, n = 163). Although there was a decrease in mean seed number per fruit with plant height increases (r = -0.289, p = 0.003, n = 105), there

was a positive but not significant relationship between mean seed number per fruit and plant coverage (r = 0.118, p = 0.229, n = 105). As expected, post-fire year was strongly positively correlated with plant height (r = 0.541, p<0.001, n = 122) and coverage (r = 0.297, p = 0.001, n = 122). Furthermore, the ratio of mean seed number per fruit to plant size significantly decreased with increasing post-fire year (for plant height, r = 0.603, p<0.001, n = 105 for coverage, r = 0.471, p<0.001, n = 105). On the other hand, no relationship between fruit infestation rates and plant size variables (plant height and coverage) was found (r = 0.090, p>0.05, n = 122 and r = -0.114, p>0.05, n = 122, respectively).

The results demonstrate that mean seed number per fruit decreased with increasing time since fire and with increasing unit plant size and depended strongly on spring rainfall. Although, fruit infestation rates showed inter-annual variation, no trend was found in relation to either time since fire or plant size. Mean seed number per fruit and fruit infestation rate were negatively correlated.

To my knowledge, this study is the first attempt to present results on seed production along a post-fire successional gradient and on the relationship between seed production and plant size in *C. salviifolius*. The present study also gives the first comprehensive numerical results on the parasitizing rates of fruits by a species of Bruchidae feeding on seeds of a species of *Cistus* (Bastida and Talavera, 2002; Tavsanoglu and Gurkan, 2005). However, the results of the present study could not be used to determine reproductive effort in *C. salviifolius* because of the lack of data on total seed production of the individuals sampled for fruits. Therefore, only mean seed number per fruit could be taken as a variable of seed production of plants. Consequently, all results presented before regarding seed production should be evaluated as just a predictor of plant reproductive effort or plant fitness.

Table 2: Differences in mean ( $\pm$ SE of the mean) seed numbers per fruit and in mean ( $\pm$ SE of the mean) fruit infestation rate (%) among different sampling years and study sites

Study sites	Sampling year			Statistics	p-value
	2000	2001	2002		
<b>Mean seed number per fruit</b>					
Site 1999	-	29.9 $\pm$ 1.8 <sup>aA</sup>	38.8 $\pm$ 1.3 <sup>bA</sup>	t = -3.806	0.001
Site 1995	39.8 $\pm$ 1.6 <sup>aA</sup>	22.7 $\pm$ 1.7 <sup>baB</sup>	38.3 $\pm$ 1.2 <sup>aA</sup>	F = 34.72	<0.001
Site 1979	31.8 $\pm$ 1.5 <sup>ab</sup>	20.6 $\pm$ 2.5 <sup>baB</sup>	35.1 $\pm$ 1.2 <sup>aA</sup>	F = 9.763	<0.001
Unburned site	23.2 $\pm$ 1.5 <sup>abC</sup>	18.6 $\pm$ 2.0 <sup>ab</sup>	28.2 $\pm$ 1.6 <sup>bB</sup>	F = 5.173	0.009
Statistics	F = 28.60	F = 5.736	F = 5.521		
p-value	<0.001	0.003	0.004		
<b>Mean fruit infestation rate (%)</b>					
Site 1999	-	44.8 $\pm$ 6.0 <sup>aA</sup>	2.81 $\pm$ 0.7 <sup>bA</sup>	U = 0	<0.001
Site 1995	39.4 $\pm$ 3.5 <sup>aA</sup>	18.8 $\pm$ 4.3 <sup>bB</sup>	12.4 $\pm$ 2.2 <sup>bB</sup>	F <sup>2</sup> = 20.80	<0.001
Site 1979	23.9 $\pm$ 2.4 <sup>ab</sup>	28.1 $\pm$ 13 <sup>aaB</sup>	13.0 $\pm$ 2.7 <sup>ab</sup>	F = 2.541	0.092
Unburned site	16.0 $\pm$ 2.3 <sup>ab</sup>	41.2 $\pm$ 5.2 <sup>ba</sup>	11.0 $\pm$ 3.2 <sup>aaB</sup>	F = 17.70	<0.001
Statistics	F = 17.69	F = 3.922	X <sup>2</sup> = 15.18		
p-value	<0.001	0.014	0.002		

Different superscript capital letters and lower-case letters show significant differences among study sites and among sampling years, respectively

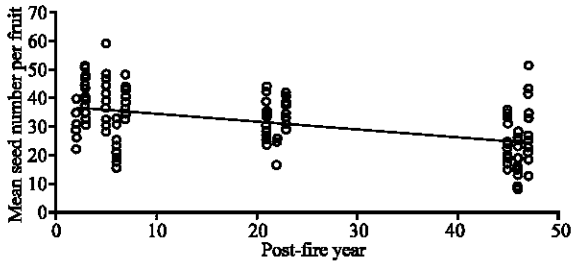


Fig. 2: Change of mean seed number per fruit through post-fire succession. Circles represent *C. salviifolius* individuals. Both synchronic and diachronic approaches were used that is the study sites sampled for three consecutive years were included (except the site 1999 sampled for two years)

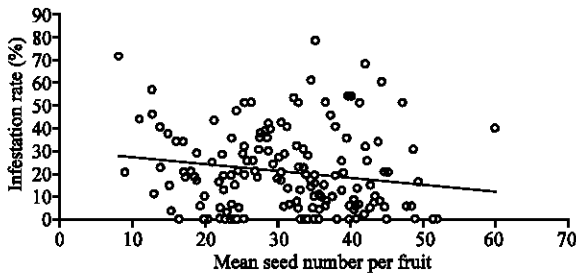


Fig. 3: Relationship between mean seed number per fruit and fruit infestation rate (%). Circles represent *C. salviifolius* individuals

Although seed production in *Cistus* through post fire succession has not been studied, numbers of seeds of *Cistus* in the soil seed bank have been studied in different stages of succession (Ferrandis *et al.*, 1999; Neeman and Izhaki, 1999; Clemente *et al.*, 2007). Moreover, it has been shown that soil seed density is driven by seed production in *C. monspeliensis* (Clemente *et al.*, 2007). Therefore, it is possible to compare the results on seed banks dynamics of *Cistus* over time since fire with the results on seed production in the present study. It is known that soil seed density of *Cistus* decreases immediately after fire because of massive seed germination promoted by fire (Ferrandis *et al.*, 1999). Within 2 (Thanos *et al.*, 1989; Roy and Sonié, 1992; Tavsanoglu and Gürkan, 2005) or 3 (Trabaud and Renard, 1999; Ferrandis *et al.*, 2001) years of fire, *Cistus* seedlings reach maturity and produce seeds. Consequently the seeds accumulate in the soil seed bank after this time. Then soil seed density increases with time during the early stages (up to 10 years, Neeman and Izhaki, 1999; up to 20 years, Clemente *et al.*, 2007). It has also been shown that seed production in *Cistus* plants at

five years is comparable to that in plants at 12-14 years (Roy and Sonié, 1992) and that number of fruits of young and old individuals of *Cistus* does not differ significantly (Acosta *et al.*, 1997). However, soil seed density decreases after this early stage (Neeman and Izhaki, 1999; Clemente *et al.*, 2007). The decreasing trend of mean seed numbers per fruit in *C. salviifolius* with increasing post-fire age in the present study is consistent with post-fire seed bank dynamics of *Cistus*.

Studies on the population dynamics of *Cistus* have shown that their density and cover increase immediately after fire and then decrease drastically with time since fire (Schiller *et al.*, 1997; Tavsanoglu and Gurkan, 2005). Moreover, simulation models predict a decrease in populations of *Cistus* with increasing fire-free period (Pausas, 1999b). According to the hypothesis of demographic effects of cost of reproduction (Obeso, 2002) in declining populations future reproduction can be proportionally more important than current reproduction and vice versa. Therefore, there should be an advantage of early intense reproductive output in expanding populations but individuals from populations threatened by extinction would take advantage of delayed reproduction (Obeso, 2002). Moreover, life-history differences among obligate seeders may contribute to variation in reproductive production measured over any given year since the last fire, as some species peak in seed production relatively soon after fire while others take longer to reach maximum fecundity (Henery and Westoby, 2001). Because of the declining nature of populations of *Cistus* with time since fire, it may be expected to observe the predictions of the hypothesis of demographic effects of cost of reproduction in *Cistus*. Further research is needed to show if this hypothesis can be applied to populations of *Cistus* in post-fire successional environments.

Individuals of *C. salviifolius* flower from late February to late April and the flowers of individuals initiate to become immature fruits by April in the Marmaris region. Most of the individuals have mature fruits or at least immature fruits by the end of May. Thus, March and April are the critical months for energy allocation to reproductive structures in *C. salviifolius* in the Marmaris region. In the present study, however during the spring of the sampling year of 2001, lower amounts of rain fell than in previous and subsequent sampling years. Moreover, nearly zero rainfall was recorded for March 2001. Simultaneously, mean seed numbers per fruit in 2001 were significantly lower than they were in 2000 and 2002. Consequently, the amount of spring rainfall, especially that in March may be the main factor responsible for the inter-annual variation in mean seed numbers per fruit. A

similar conclusion was reached by Troumbis and Trabaud (1986), who found that annual fluctuations in fruit numbers of *Cistus* are strictly related to fluctuations in the amount of spring rainfall.

It is known that water deficit negatively affects growth (Sánchez-Blanco *et al.*, 2002) and production of reproductive units (Tielborger and Valleriani, 2005; Giménez-Benavides *et al.*, 2007) in plant species. *Cistus* species are distributed mostly in areas with a Mediterranean climate (Moretti *et al.*, 2006) with a pronounced summer-dry period. Therefore, physiological mechanisms of drought resistance already exist in species of *Cistus* (Sánchez-Blanco *et al.*, 2002). However, the occurrence of an unexpected water limitation, while a plant individual is developing its reproductive structures is likely to negatively affect the energy allocation to reproduction with increasing cost of developing fruits and seeds. Therefore, it may be concluded that the dependence of the production of reproductive units (i.e., fruits and seeds) on the amount of spring rainfall in *Cistus* may be a result of increasing costs of developing fruits and seeds in plant individuals under stressful conditions of water deficit.

There is evidence that fruit infestation rates by Bruchid insects can be high enough (>99%) to cause a plant population to become gradually endangered by interrupting the recruitment of plant species (in *Acacia* trees; Or and Ward, 2007). In the present study however, the relatively low rate of infestation of *B. biguttatus* on *C. salviifolius* suggests that the populations of *Cistus* would not be in danger at least not in the study area because of seed predation. This result supports Lodos (1998), who stated that the population density of *B. biguttatus* was not likely to be high enough to cause widespread damage to plants in Turkey. Moreover, the mean infestation rate found in the present study (22%) is comparable with 38% in *C. ladanifer* by a moth larvae (Metcalf and Kunin, 2006), 43 and 12% in two populations of *C. ladanifer* by Bruchid insects (Bastida and Talavera, 2002) and 34% in *C. creticus* by *B. biguttatus* (Tavsanoglu and Gurkan, 2005) as well. On the other hand, the fruit infestation rate in *C. libanotis* by Bruchids was surprisingly found to be 1% (Bastida and Talavera, 2002).

No patterns related to infestation rates of *C. salviifolius* were found except for a slight but significant negative relationship between mean seed number per fruit and fruit infestation rate. Since the production of more seeds per fruit might indicate higher fitness of an individual plant and low infestation rates might be related to high resistance to Bruchid infestation, the negative correlation between mean seed number per

fruit and fruit infestation rate (Fig. 3) might support the conclusion of individuals of *C. salviifolius* with higher fitness may resist more to fruit infestation. However, this is just a hypothesis and further research is needed to obtain more data to evaluate it. No relationship was found between fruit infestation rate and size variables of plant height or plant coverage. A similar result was reported by Acosta *et al.* (1997), who found no effect of plant size of *C. ladanifer* on insect predation rates of fruits.

The irregular annual variation in fruit infestation rate over the sampling years in different sampling sites shows that fruit infestation by *B. biguttatus* may not depend on fire-created (time since fire) or climate-related (spring rainfall) factors. Although, the design of the present study cannot provide a comprehensive explanation of this result, such a variation may be related to the biology of *B. biguttatus*, which remains unknown (Lodos, 1998).

## CONCLUSION

Although the post-fire response of species of *Cistus* is well known and fire-related population dynamics have been studied in these species, little attention has been given to the dynamics of seed production of species of *Cistus* after fire. However, the present study shows that there may be several factors affecting these dynamics independent of the fire itself such as infestation of fruits by pre-dispersal seed predators, plant size and spring rainfall. Further research is needed to examine the post-fire dynamics of seed production in *Cistus* from a more detailed perspective.

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