International Journal of Botany 5 (1): 107-111, 2009
ISSN 1811-9700

Post-Fire Regeneration of a *Pinus brutia* (Pinaceae) Forest in Marmaris National Park, Turkey

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Abstract: Post-fire recovery of a *Pinus brutia* Ten. forest on ophiolithic rocks was studied in Marmaris National Park, southwestern Turkey. Three study sites burned in different years (1999, 1995 and 1979) and a study site not burned for at least 45 years were studied from September 2000-2001. Although some opportunistic species had established in one-year-old site, species composition had been recovered again in older sites. Change in the plant species cover during early post-fire succession was basically different between seeders and resprouters; cover of the seeders increased, but that of resprouters did not change. Post-fire growing line of *P. brutia* individuals during 22 year period was fitted to a linear regression model ($r^2 = 0.9995$, $p<0.001$). In conclusion, post-fire regeneration of *P. brutia* forests on ophiolithic rocks in Marmaris National Park fits to the general autosuccessional model in Mediterranean Basin and fire is a complementary element for these forest ecosystems.

Key words: *Pinus brutia*, post-fire regeneration, seeder, resprouter

INTRODUCTION

Pinus brutia Ten. forests cover large areas in the east Mediterranean Basin, from the Aegean islands to northern Iraq. Their main range, however, is the Mediterranean and Aegean coasts of Turkey (Boydak *et al*., 2006). *P. brutia* ecosystems are subject to frequent fires during the dry summer period (Boydak, 2004) just as in other Mediterranean ecosystems (Naveh, 1994). Besides, fire has an important ecological role in shaping plant communities (Trabaud, 1994; Verdú and Pausas, 2007). Plant species have some adaptive or pre-adaptive traits in order to survive after fire, such as fire-stimulated seed-germination, resprouting or fire-stimulated seed release (serotiny) (Keeley, 1995). Consequently, post-fire rapid regeneration of plant communities in Mediterranean Basin is a typical event (Moravec, 1990; Trabaud, 1994; Buhk *et al*., 2005; Türkmen and Düzenli, 2005).

Although post-fire regeneration patterns of *Pinus brutia* ecosystems (Thanos *et al*., 1989; Thanos and Doussi, 2000) and regeneration of *P. brutia* after fire as an individual species (Spanos *et al*., 2000; Boydak, 2004) has been studied, there is still a shortage of information regarding post-fire successional processes of *P. brutia* ecosystems in Turkey, especially when compared with studies on its close relative *P. halepensis* Mill. (Moravec, 1990; Kazanis and Arianoutsou, 2004; Pausas *et al*., 2004). Full and fast recovery of plant community after fire in *P. brutia* forests is a general processes as shown in studies mentioned earlier. The aim of the present study was to contribute the current literature on whether this process is also valid for *P. brutia* forest ecosystems of Marmaris National Park, Turkey.

MATERIALS AND METHODS

Marmaris National Park located in the southwest of the Anatolian Peninsula in the East Mediterranean Basin is one of the largest National Parks in Turkey, covering nearly 34000 ha area. The plant cover is mostly dominated by *Pinus brutia*.

The climatic data of Marmaris meteorological station (19 m above sea level) for the period from 1961 to 2000 from Turkish State Meteorological Service shows that the climate is typical Mediterranean, with dry summers and wet winters (Fig. 1).

Three study sites burned once in 1999, 1995 and 1979 and a site not burned for at least 45 years were selected. The study sites are on the same geological material (ophiolithic rocks) and located very near to each other (site 1999: 36°50'11"N, 28°18'10"E; site 1995: 36°51'16"N, 28°17'14"E; site 1979: 36°49'37"N, 28°19'34"E; long-

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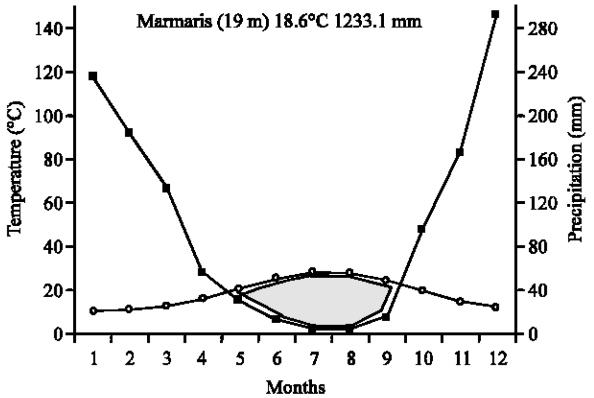

Fig. 1: The ombrothermic climatic diagram of Marmaris for the period of 39 years (1961-2000). The area filled with dark color shows the xerothermic period

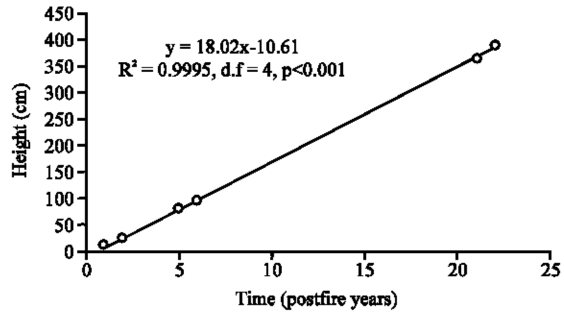

Fig.2: Post-fire growth of *P. brutia* individuals during 22 years. The circles are based on data from the sites 1999, 1995 and 1979 (September 2000-2001)

unburned site: 36°50'47"N, 28°17'24"E). The sites were sampled monthly (except December 2000; January and March, 2001) from September 2000-2001.

Forty temporary 1×1 m plots were established randomly in each site in each sampling date. The plant taxa found in the plots were recorded in all sites and total projected foliage cover of each taxon was determined visually in each plot in site 1999. Plant regeneration modes of the taxa (resprouter, seeder and intermediate) were assessed by both individual observations during the study and from literature (Kazanis and Arianoutsou, 1996). The heights of randomly selected *P. brutia* individuals were measured in each burned site in September 2000-2001.

Nomenclature follows the Flora of Turkey and the East Aegean Islands (Davis, 1965-1985).

Regression analysis was used to test for significant change in growth of *Pinus* seedlings with time after fire and in yearly cover of the dominant seeder species. Statistical significance of regression lines were tested with t-statistics (Fowler and Cohen, 1990). Mann-Whitney-U test (Zar, 1996) was used to compare the cover of resprouters between September 2000-2001 in site 1999.

RESULTS

Totally 55 plant taxa were collected and identified to species or genus level during the study. The list of plant taxa collected, their distribution to the study sites and their regeneration strategies are given in Table 1.

Change in cover values of resprouters and seeders for the period of September 2000-2001 followed different trends in site 1999. There was no significant difference in the cover of dominant resprouters between the two years (Mann Whitney U-test, $p>0.05$). But the cover of dominant seeders increased during the same period (*C. creticus*, from 8.05 to 10.4%; *C. salviifolius*, from 18.0 to 27.2%; *P. brutia*, from 2.08 to 2.60%). Moreover, the linear increase of *C. salviifolius* coverage was statistically significant in the site 1999 during the sampling period ($y = 1.35x-3.55$, $r^2 = 0.70$, $p<0.01$), even the increase of coverage of other two species were not significant ($p>0.05$). Although the growth of *P. brutia* seedlings were not significant in the first and second year after fire, overall post-fire growth of *P. brutia* individuals during 22 year period was fitted to a linear regression model ($y = 18.02x-10.61$, $r^2 = 0.9995$, $p<0.001$, Fig. 2).

DISCUSSION

Most plant communities can regenerate in a short period of time (5-20 years) after fires in Mediterranean Basin (Trabaud, 1994). All species found in pre-fire communities emerge in the first post-fire years and the ecosystem returns its initial vegetation structure (Lavorel, 1999). The present study supports this generalization for *P. brutia* ecosystems of Marmaris National Park, Turkey. Most of the species that found in other sites burned at different years appeared in the one-year-burned area (site1999) as well. The plant composition of the site 1999 was also consisted of some opportunistic species which have an invader character and that disappeared in older sites (Table 1). The growth of seeders with high densities such as *Cistus* sp. may be responsible for the elimination of the opportunistic species (Kazanis and Arianoutsou, 2002). This is actually a common process of autosuccession (Zedler, 1981; Lavorel, 1999) as it has been showed in different studies carried out throughout the Mediterranean Basin (Trabaud, 1994).

Table 1: The list of plant taxa collected from study sites and their distribution to study sites

Species	RM	1999	1995	1979	Long-unburned
Amaranthaceae					
Amaranthus chlorostachys Willd.	R	+	-	-	-
Anacardiaceae					
Pistacia lentiscus L.	R	+	+	+	+
Pistacia terebinthus L. ssp. *palaestina* (Boiss.) Engler	R	+	+	+	+
Boraginaceae					
Heliotropium hirsutissimum Graver	s	+	-	-	-
Capparaceae					
Capparis spinosa L.	s	+	-	-	-
Caprifoliaceae					
Lonicera nummulariifolia Jaub. and Spach	?	+	-	-	-
Cistaceae					
Cistus creticus L.	s	+	+	+	-
Cistus salviifolius L.	s	+	+	+	+
Compositae					
Centaurea L. sp.	s	+	-	-	-
Cirsium Miller sp.	?	+	+	-	+
Echinops L. sp.	?	+	+	+	-
Helichrysum Gaertner sp.	R?	-	+	-	+
Inula graveolens (L.) Desf.	s	+	-	-	-
Inula viscosa (L.) Aiton	R, s	+	+	-	-
Lactuca saligna L.	s	+	-	-	-
Lactuca serriola L.	s	+	-	-	-
Ptilostemon chamaepeuce (L.) Less.	s	+	+	+	+
Cruciferae					
Alyssum L. sp.	s	+	+	-	-
Cupressaceae					
Cupressus sempervirens L.	s	-	+	-	-
Ericaceae					
Arbutus andrachne L.	R	+	-	+	+
Erica manipuliflora Salisb.	R, s	+	+	+	+
Fagaceae					
Quercus aucheri Jaub. and Spach	R	+	+	+	+
Quercus coccifera L.	R	+	+	+	+
Quercus infectoria Olivier ssp. *boissieri* (Reuter) Schwarz	R	+	+	+	+
Hamamelidaceae					
Liquidambar orientalis Miller	s	-	+	+	+
Juncaceae					
Juncus L. sp.	R	-	+	-	-
Labiatae					
Lavandula stoechas L.	R, s	+	+	+	-
Phlomis lycia D.Don.	s?	-	-	+	+
Satureja thymbra L.	s	+	-	-	-
Teucrium divaricatum Sieber	s?	-	+	+	+
Lauraceae					
Laurus nobilis L.	R	-	+	-	+
Leguminosae					
Calicotome villosa (Poiret) Link	R, s	+	+	+	+
Cytisopsis dorycniifolia Jaub and Spach ssp. *reeseana* (Guyot) Hub.-Mor.	s	+	+	-	+
Genista acanthoclada DC.	R, s	+	+	+	+
Spartium junceum L.	R, s	+	+	-	+
Liliaceae					
Asparagus acutifolius L.	R	+	+	+	+
Asparagus aphyllus L. ssp. *orientalis* (Baker) Davis	R	+	+	+	+
Bellavalia Lapeyr. sp.	R	-	-	+	-
Colchicum L. sp.	R	-	-	+	-
Ruscus aculeatus L.	R	+	+	+	+
Smilax aspera L.	R	+	+	+	+
Lythraceae					
Lythrum salicaria L.	?	+	-	-	-
Malvaceae					
Malope malacoides L.	?	+	-	-	-
Myrtaceae					
Myrtus communis L.	R	+	+	+	+

Table 1: Continued

Species	RM	1999	1995	1979	Long-unburned
Oleaceae					
Olea europea L.	R	-	-	+	-
Phillyrea latifolia L.	R	+	+	+	+
Pinaceae					
Pinus brutia Ten.	s	+	+	+	+
Rhamnaceae					
Rhamnus oleoides L.	R	-	+	+	+
Rosaceae					
Rubus sanctus Schreber	R	-	+	+	+
Sarcopoterium spinosum (L.) Spach	R, s	-	+	+	+
Rubiaceae					
Asperula arvensis L.	s	+	-	-	+
Cruciata Miller sp.	s	-	+	+	+
Solanaceae					
Solanum nigrum L.	?	+	-	-	-
Tamaricaceae					
Tamarix L. sp.	s	+	-	-	-
Umbelliferae					
Eryngium L. sp.	R	-	+	-	+

RM is the regeneration mechanism; R, s and ? signs represent resprouter, seeder and unknown, respectively. The presence and non-presence of taxa in the study sites was shown as + and - signs

After the first post-fire year that the resprouters were regenerated, the cover of dominant seeders was increased within a year. This difference is likely since the resprouters have a high regenerating ability with their basal resprouts that the seeders have not. Long-term post-fire growth of *P. brutia* in Marmaris National Park can be described by a linear regression model ($r^2 = 0.9995$, $p<0.001$). Such a linear relationship has been also shown in similar studies conducted in burned *P. brutia* (Spanos *et al*., 2000) and *P. halepensis* forests (Thanos *et al*., 2002).

In conclusion, post-fire regeneration of *P. brutia* forests in the study area is an autosuccessional process as it is in the other regions of Mediterranean. When a forestry practice is applied to forests or burned stands of *P. brutia,* therefore, it should be remember that fire is a natural and complementary process of these forests.

ACKNOWLEDGMENTS

The authors thank Burçin Y. Kaynaş and Sinan Kaynaş for their assistance in the field, Birol Mutlu and Haşim Altınözlü for their helps during the plant identification, Fatma Güngör for correcting English of the manuscript. The authors also thank National Parks and Game-Wildlife General Directorate of Turkey for providing accommodation in Marmaris. This study was a part of the project supported by Hacettepe University Research Foundation (Project No: 00.02.601.005).

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