Effect of repeated fire on plant community recovery in Penteli, central Greece

G. Goudelis[1,4], P.P. Ganatsas[2], I. Spanos[3] & A. Karpi[1]

[1]*Technological Education Institute of Lamia, Department of Forestry, 36100 Karpenissi, Greece.* [2]*Aristotle University of Thessaloniki, Department of Silviculture, P. Box. 262, 54124 Thessaloniki, Greece.* [3]*NAGREF, Forest Research Institute, 57006 Vassilika, Thessaloniki, Greece, e-mail: ispanos@fri.gr.* [4]*Corresponding author**

Key words: Aleppo pine, postfire revegetation, regeneration, wildfire

Abstract

In a *Pinus halepensis* Mill. forest of central Greece, we studied the effects of two fires on postfire plant community recovery by comparing a site that was burned once and another adjacent that was burned twice. During the first 15 months after fire, we monitored plant species recruitment, plant density and growth. Lower species richness and plant density were observed in the site burned twice compared to that burned only once. The growth of woody species did not differ between the two treatments and presented high variability even within the same plot. Resprouting plant species appeared earlier than obligatory seeders. Fifteen months after fire, the ecosystem was dominated by the maquis species that existed in the prefire period, mainly *Quercus coccifera* L., *Pistacia lentiscus* L., *Phillyrea latifolia* L., with a low contribution of *Pinus halepensis* seedlings and a greater proportion of *Cistus* species (*Cistus monspeliensis* L., *C. creticus* L., *C. salvifolius* L.).

Introduction

Wildfires comprise a significant factor for ecosystem status in many areas around the world (see Arianoutsou (2001) for a review). However, wildfires play a potentially important role in the Mediterranean basin (Naveh, 1991) where, in combination with human actions such as animal grazing and fuel overexploitation, contribute to long-term land degradation (Thirgood, 1981). According to the data obtained worldwide, some general conclusions have been extracted concerning the postfire process; these can be summarized as follows (Trabaud, 1994): the establishment of the previous communities is usually a rapid phenomenon and in most cases there is no actual succession but an auto-succession process. The plants that persist are those that appear immediately after fire and that existed previously.

However, the above mentioned process seems to be true when fires occur after a long time interval and depends on the type of ecosystem burned (Hatzibiros, 2001; Polakow and Dunne, 1999); in the case of *Pinus halepensis* Mill. Forests, full recovery requires more than 30 years (Arianoutsou and Ne'eman, 2000; Schiller et al., 1997; Trabaud, 2000). However, some land degradation probably takes place (Dafis, 1987; Tsitsoni, 1997). The problem of land degradation increases when grazing of the burned areas occurs after the fire (Spanos, 1992; Spanos et al., 2000). Even though land degradation is more possible in the case of frequent fires repeated within short intervals, there is a scarcity of data concerning the influence of repeated fires on ecosystem recovery and the degree of the degradation process. Such studies can show in real terms if the hypothesis of land degradation after repeated fires is true and to what extent they cause problems to ecosystem resilience with regard to the fire effect.

The aim of this study was to investigate differences in ecosystem recovery after one (area burned in 1998) or two fires (area burned in 1995 and 1998). The findings could result in conclusions about the degradation probability after repeated fires. Thus, postfire community recovery was studied in a *P. halepensis* woodland in Penteli, central Greece, during the early, crucial

* E-mail: ggoudelis@teilam.gr

postfire time of 15 months. Repeated measures were carried out and were focused on plant species regeneration, density and growth. Site characteristics were recorded in order to correctly compare the areas burned once and twice.

Materials and methods

Study area

The study was carried out in Penteli, central Greece, and 30 km from the city of Athens. The region consists of part of the Mount Penteli whose altitude ranges from 100 to 1107 m. Geologically, the area belongs to the Attiko-Cyclades geotectonic zone. The parent rock materials are mainly limestone and schists and a small part is covered by sedimentary formations (Mountrakis, 1985). The slope gradient was 15%–30%. The vegetation of the area belongs to the lower Mediterranean vegetation zone, *Quercetalia ilicis* and particularly to the association *Oleo-lentiscetum*. The climate is characterized as Mediterranean type (Csa) according to Koeppen classification. The annual amount of rainfall is 413 mm and the dry period has an average duration of 5–6 months, lasting from April to September. The ecosystem studied prefire was dominated by *P. halepensis* Mill. with a shrub story of maquis species. The area was burned in July 1995 and a large part of the area was burned again in August in1998. The age of *P. halepensis* stands ranged from 30 to 40 years as shown by tree ring measurements. The entire area is subjected to high human pressure due to animal grazing, illegal claims and trespassing.

Sampling

Sixteen permanent plots of 100 m^2 were established just after the fire in the burned areas in different locations; 11 were established in areas burned twice (B_2), in 1995 and 1998, and five in areas burned once only (B_1) in 1998. The distinction of burned areas was based on maps created by the local forest administration office. Within each of them, five subplots of 1 m^2 were selected systematically within the plots; four in the corner of each plot at a distance of 2 m from the corner, and the fifth in the center of the plot. In each plot, all woody plant species were recorded, as well as their density and height. The monitoring took place during the 15 months after fire, in January 1999 (before spring, to record the early plant regeneration), June 1999 (after spring and before summer) and in October 1999 (after the first postfire summer). Site characteristics were also recorded; these concerned altitude, aspect, topography, angle and postfire management.

Data analysis

Statistical analysis was performed using the SPSS package, version 11.5 for Windows. The differences in stem density, species richness and plant growth between B_1 and B_2 were assessed using t-tests ($P < 0.05$, Norusis, 2002). All figure bars indicated by different letters were statistically different. Error bars represent standard error of the mean. The nomenclature of plant species follows Flora Europea (Tutin et al., 1964–1980).

Results

Effect of repeated fire on woody species richness

Generally, plant species regeneration was delayed and started quite late during the next postfire winter and spring in both B_1 and B_2. Two functional groups, resprouters and seeders were regenerated in the burned areas. The revegetation pattern appeared to be the same in both cases; initially, during the late autumn and winter, only a few woody plant species (resprouters) appeared, whilst most species regenerated later during the spring and summer. The same woody plant species regenerated at both sites and were those which existed before the fire. Therefore, neither of the respouter or seeder species lost the ability to repopulate the area.

Analysis of the monitoring data showed that the species richness was significantly higher in B_1 during the early postfire phase, at all monitoring dates (Figure 1). The species recorded in January, were those regenerating vegetatively: *Quercus coccifera* L., *Pistacia lentiscus* L., *Phillyrea latifolia* L., *Erica arborea* L., *Arbutus unedo* L., *Arbutus andrachne* L., *Nerium oleander* L., *Cotinus coggygria* Scop. Only a few resprouters appeared later (in spring) such as *Pistacia terebibthus* L., *Dittrichia viscose* (L.) W. Greuter , *Calicotome villosa* (Poir.) Link and *Lonicera implexa* Ait. Species regeneration continued during the whole period. Woody species richness was low in January, and increased with time; the average number of species

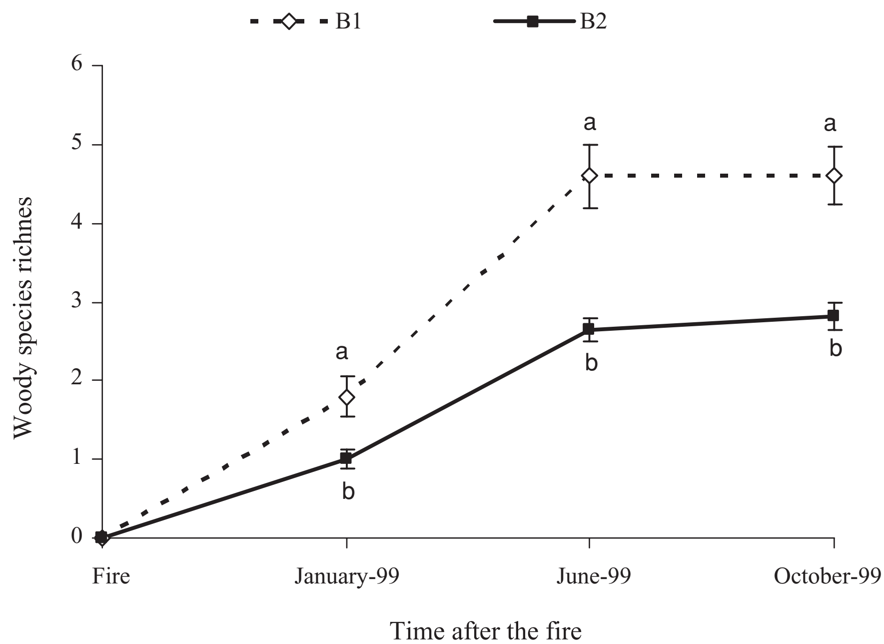

Figure 1. Effect of one or two fires on the postfire number of woody species. Values are the number of species per subplot (1 m^2); values at the same date followed by different letters are significantly different ($p > 0.05$, t- test).

recorded in June was 4.6 species per subplot in B_1 and 2.6 in B_2. Finally, 15 months after the fire, the woody species richness per subplot was significantly greater in B_1 compared to B_2. Repeated fire seems to cause some regeneration problems in certain species e.g. *C. coggygria*, *A. andrachne* and *E. arborea* which were extremely limited in B_2.

Species regenerating from seeds colonized both burned areas much later, mainly during the postfire spring and summer. These species included some seasonal dimorphic sub-shrubs such as the *Cistus* species (*C. monspeliensis* L., *C. creticus* L. and *C. salvifolius* L.) and the tree species *P. halepensis*, as well as many herbaceous species.

Q. coccifera was found in all plots in both B_1 and B_2, whereas *N. oleander* and *A. andrachne* were recorded in only one plot. *L. implexa*, was regenerated in two plots in the spring, but died back during the summer. However, the absence of plant regeneration during the early postfire phase, autumn and early winter, was noticed, and there was a high risk of soil erosion due to the relatively high amount of rainfall that usually happens during this period of the year (average monthly amount of rainfall was 49, 66 and 72 mm for the months October, November and December, respectively).

Effect of repeated fire on stem density

The rate of species regeneration was significantly higher in B_1 than in B_2; thus, stem density was always significantly lower in B_2 during the whole period studied. In October of the next postfire year, regeneration was found to be approximately one third lower in B_2 compared B_1. The average density at this time was 16.1 stems per m^2 and 24.5 stems per m^2 respectively (Figure 2). The stem density appeared to follow the same pattern in both cases, but always with lower values in B_2 due to the differences in the initial plant regeneration. Thus, stem density increased with time until the next spring because of continued plant regeneration; it then decreased due to the summer drought that affected survival of both resprouters and seeders. Specifically, the stem density increased 1.8 times from January to June at both sites; afterwards, it decreased to 78% and 76%, for B_1 and B_2 respectively. Therefore, repeated fire affected early plant density but the pattern of regeneration and survival was unaffected.

Species which had regenerated vegetatively had higher densities, especially during the early postfire months, compared to the seeders (Table 1). These resprouters contributed 83.3% to total density in B_1, and 76.7% in B_2. Seeders contributed only 16.7% and

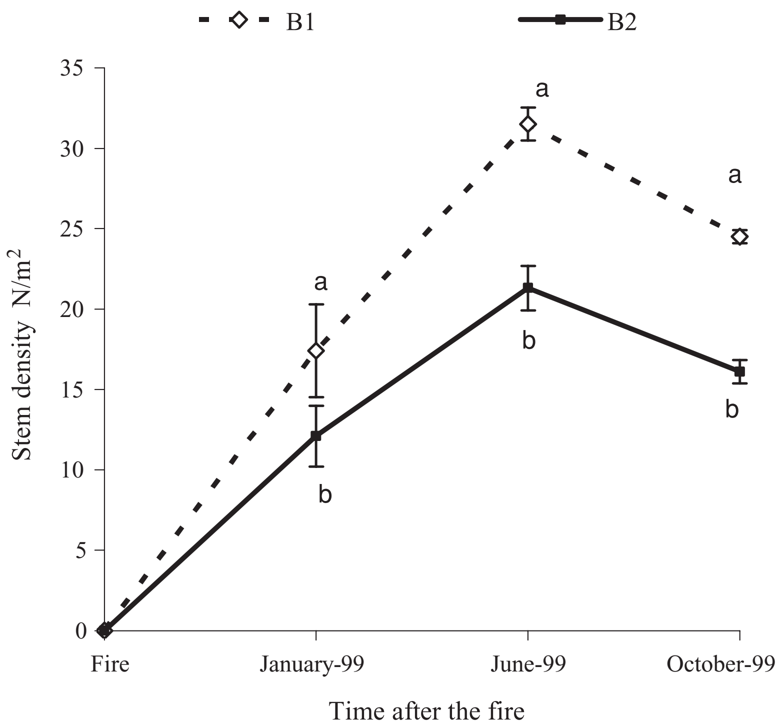

Figure 2. Effects of one or two fires on the postfire vegetation stem density. Values at the same date followed by different letters are significantly different ($P > 0.05$, *t*-test).

Table 1. Postfire density and growth of woody species, in B_1 and B_2, 15 months after the fire

	B_1 areas			B_2 areas		
Species	Density stems/m^2	Mean height (mm)	Maximum height (mm)	Density stems/m^2	Mean height (mm)	Maximum height (mm)
Resprouters						
Quercus coccifera	12.78a	308ns	520	7.37b	371ns	647
Pistacia lentiscus	0.20*	581ns	600	1.55*	632ns	877
Phillyrea latifolia	0.54*	771a	940	0.68*	392b	610
Arbutus unedo	0.84*	443b	575	1.05*	880a	1400
Arbutus andrachne	1.90*	536*	590	–	–	–
Nerium oleander	–	–	–	0.66*	579*	1170
Calicotome villosa	0.40*	663ns	920	0.51*	633ns	970
Erica arborea	2.12a	244a	360	0.02b	60b	60
Cotinus coggygria	1.24*	267*	455	0.00	–	–
Dittrichia viscose	0.12*	220b	220	0.49*	306a	420
Pistacia terebinthus	0.28*	1190a	1400	0.02*	470b	470
Seeders						
Pinus halepensis	0.40*	78ns	140	0.49*	103ns	160
Cistus monspeliensis	2.58ns	125ns	180	2.24ns	108ns	188
Cistus creticus	1.00*	145ns	210	0.82*	137ns	205
Cistus salviifolius	0.12*	138ns	175	0.20*	133ns	180
Total	24.52a			16.11b		

Values of the same species for the same parameter followed by different letters are significantly different, ns = nonsignificant differences ($p > 0.05$, *t*-test).
*insufficient data for the test.

23.3% of the total density in B_1 and B_2 respectively. The density of the main seeder species (*Cistus* species) was slightly affected by the repeated fire and density was lower in B_2 than in B_1 (3.26 and 3.70 individuals/m^2 respectively) but with no significant differences. On the contrary, *P. halepensis* density was not affected by the repeated fire. This can be explained from the fact that the fire did not destroy all the forest stands, but some forest patches remained unaffected; thus, these stands produced seeds that colonized the adjacent burned areas. However, the regeneration of *P. halepensis* seedlings was relatively low in both cases (0.40 and 0.49 seedlings per m^2 respectively, 15 months after the fire) and many seedlings died during the summer drought in B_2 (Table 1).

The most abundant species in B_1 were the resprouters *Q. coccifera, E. arborea* and the seeders of the *Cistus* species. This pattern was also found in B_2 (except for *E. arborea*), but the density was significantly lower in these areas. *Q. coccifera* possessed the highest overall resprouting ability (Table 1).

Effect of repeated fire on vegetation growth

Plant growth greatly varied between species and plots as well as within plots for the same species, and did not significantly differ between B_1 and B_2. However, resprouting species were the dominant postfire ecosystem elements due to their high density and greater height (Table 1). On the contrary, the seeders exhibited quite low growth (Table 1). Some species e.g. *P. latifolia*, *E. arborea* and *P. terebinthus* exhibited significantly greater growth in B_1. On the contrary, other species were taller in B_2 e.g. *A. unedo* and *D. viscosa* (Table 1). *A. andrachne* and *C. coggyria* dominated in some plots of B_1, in terms of height growth, but were scarce in B_2 (Table 1). To sum up the above data, it seems that there was a high variability in plant growth that can mainly be attributed to site variability rather than to the effect of the repeated fire.

Effect of repeated fire on P. halepensis natural regeneration

P. halepensis is an obligatory seeder that was the dominant structural element in the prefire ecosystem. Its natural regeneration was relatively low in both cases, in terms of individual density and growth (Table 1). An average density of 0.40 and 0.49 of 1-year-old seedlings per square meter were found 15 months after fire, in B_1 and B_2. The seedling emergence was delayed in both cases and appeared in the next postfire spring. No seedlings were recorded in January. Seedling growth was low in both cases and did not differ between the two areas. No seedlings died in B_1 during the summer dry period whereas 26.8% of the seedlings died in B_2.

Discussion

The findings of the study indicated that even though there were significant differences in woody species richness and stem density between B_1 and B_2, the community recovery takes place following a similar revegetation pattern. As in other cases (Arianoutsou, 2001; Ganatsas et al., 2004; Trabaud, 1994), an auto-succession process took place and the prefire dominant floristic elements composed the new postfire communities. However, repeated fire affected initial plant regeneration by reducing the early woody species richness and especially the stem density. This resulted in lower values of these plant parameters in B_2 compared to B_1. Species regeneration in both cases started in the late autumn and winter and continued during the entire period studied. Only few species colonized the burned areas during the first postfire months as the January inventory showed. Thus, species richness and density was low. Species richness and stem density then increased until the following spring because of continued plant colonization and then decreased due to the summer drought that affected plant survival. The increase in stem density from January to June as well the decrease from June to October (summer drought effect) was similar in both B_1 and B_2. Finally, the early growth of woody species was highly variable and was similar between the two sites.

Contrary to the results of other studies (Ganatsas et al., 2004; Hatzistathis et al., 1996; Thanos et al., 1996), revegetation took place within a given time delay, i.e. the revegetation process started in the late autumn. Initially, resprouting species occurred and obligatory seeders appeared later, during the next spring and summer. Contrary to the results of other studies (see Arianoutsou and Ne'eman (2000) for a review), which report that seeds germinate after the onset of the rainy season, no seedlings of *P. halepensis* appeared between autumn and January. This can be attributed to the time of fire occurrence, as the fire happened in August, at the end of the growing season; thus, there was not enough time for species to regenerate. This resulted in a fragile, bare land during the first postfire months, a period in which the denuded land was subjected to autumn and winter rainfalls, thus there was a high soil erosion risk. However, this risk was greater in B_2, since in these areas the stem density was much lower than in B_1.

Fifteen months after the fire, the ecosystems were dominated by the maquis species that existed in the prefire period, with a small contribution of the tree species *P. halepensis* and a relatively high proportion of *Cistus* species. The plant community was mainly composed of evergreen broadleaf shrubs: *Q. coccifera*, *P. lentiscus*, *P. latifolia*, *E. arborea*, *A. unedo*, *A. andrachne* and some seasonal dimorphic sub-shrubs e.g. *C. creticus*, *C. salviifolius*, *C. monspeliensis* and *C. villosa*. However, natural regeneration of the prefire dominant tree species *P. halepensis,* was low in terms of stem density and seedling growth was also low. A high percentage of stems in several species died back during the postfire summer due to drought stress.

All the woody species existing before the fires maintained their regeneration ability despite the short interval between the two fires in B_2. Species regenerating vegetatively did not loose their resprouting ability and seeders managed to regenerate either from the soil seed bank or the seeds produced by the new young plants (3 years old in the case of *Cistus* species) or by the aerial seedbank of the adjacent un-burned stands as for *P. halepensis*. Thus, repeated fires in real terms did not affect the floristic elements of the burned areas, even though some species were scarce in B_2; these were few and were also found locally in B_1. In general, both resprouters and seeders kept their regeneration capacity, but this capacity was significantly lower in B_2. What causes this difference seems to be the young age of the plants (3 years old), that affect either their resprouting ability for the species regenerating vegetatively or the fruition of the seeders. In particular, it has been well documented that *P. halepensis* needs at least 7 years before producing mature seeds (Thanos, 2000). However, *Cistus* species are able to produce seeds early; full flowering ability is reached during the third year after a fire (Trabaud, 1987).

Finally, it can be said that despite the short period of this study, the findings indicate that there are differences in the rate of postfire revegetation processes between B_1 and B_2. Repeated fire seems to affect the species regeneration capacity, thus vegetation cover will be lower and the risk of soil erosion greater in the case of repeated fires. In comparison with the postfire process recorded in other ecosystems, usually burned only once (Arianoutsou, 1999; Ganatsas et al., 2004; Trabaud, 1994), the following conclusions can be made; (i) in our case there was a delay in species appearance that can be attributed to the time of fire occurrence (late summer), (ii) average values of species richness and stem density were relatively low, probably due to the dry climate and the influence of grazing animals and (iii) the number of naturally regenerated *P. halepensis* seedlings was low compared to other studies, because of high postfire human pressure at the burned areas.

References

Arianoutsou M 1999 Effects of fire on vegetation demography. *In* Proceedings of the International Symposium “Forest Fires: Needs and Innovations”. DELFI Concerted Action, CINAR-EC, DGXII, Athens, pp 265–273.

Arianoutsou M 2001 Landscape changes in Mediterranean ecosystems in Greece: implication for fire and biodiversity. J. Mediterr. Ecol. 2, 165–178.

Arianoutsou M and Ne’eman G 2000 Post-fire regeneration of natural *Pinus halepensis* forests in the East Mediterranean basin. *In* G Ne’eman and L Trabaud (eds), Ecology, Biogeography and Management of *Pinus halepensis* and *P. brutia* Forest Ecosystems in the Mediterranean Basin, pp 269–289. Backhuys Publishers, Leiden, The Netherlands.

Boydak M 2004 Silvicultural characteristics and natural regeneration of *Pinus brutia* Ten.—a review. Plant Ecol. 171, 153–163.

Dafis S 1987 Ecology of *Pinus halepensis* and *P. brutia* forests. *In* Proc. of the 1st Scientific Conference on *Pinus halepensis* and *Pinus brutia* forests. Ed. Hellenic Forestry Society, pp 17–25. Chalkida, Greece.

Daskalakou E N and Thanos C A 1996 Aleppo pine (*Pinus halepensis*) postfire regeneration: the role of canopy and soil seed bank. Int. J. Wildland Fire 6, 59–66.

Ganatsas P, Zagas T, Tsakaldimi M and Tsitsoni T, 2004 Post-fire regeneration dynamics in a Mediterranean type ecosystem in Sithonia, northern Greece: ten years after the fire. *In* Proc. of the 10th MEDECOS Conference, April 25–May 1, 2004, Rhodes, Greece, M Arianoutsou and V Papanastasis (eds), Millpress, Rotterdam.

Hatzibiros K 2001 Setting priorities for wildfire suppression policy in Greece, using a relation between yearly burned areas and recovery time. Global Nest. Int. J. 3, 37–43.

Hatzistathis A, Tsitsoni T, Ganatsas P, Zagas T and Goudelis G 1996 Post-fire vegetation dynamics, in Sithonia peninsula (Chalkidiki, Greece). *In* Proc. of the Second Balkan Scientific Conference on Study, Conservation and Utilisation of Forest Resources, Sofia, pp. 168–173.

Kazanis D and Arianoutsou M 2004 Long-term post-fire vegetation dynamics in *Pinus halepensis* forests of central Greece: a functional-group approach. Plant Ecol. 171, 101–121.

Mountrakis D. 1985 Geology of Greece (in Greek). University Studio Press. Thessaloniki.

Naveh Z 1991 The role of fire in Mediterranean vegetation. Botanical Chronicles 10, 609–615.

Norusis M J 2002 SPSS 11.0 Guide to Data Analysis, 637 p. Prentice Hall, Englewood Cliffs, NJ.

Polakow D A and Dunne T T 1999 Modeling fire-return interval T: stochasticity and censoring in the two-parameter Weibull model. Ecol. Model. 121, 79–102.

Schiller G, Ne'eman G and Korol L 1997 Post-fire vegetation dynamics in a native *Pinus halepensis* forest in Mt Carmel Israel. Israel J. Plant Sci. 45, 297–308.

Spanos I A 1992 Structure analysis and natural regeneration of *Pinus brutia* forests in Thasos island, Ph.D. thesis. Department of Forestrty & Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece.

Spanos I A, Daskalakou E N and Thanos C A 2000 Postfire, natural regeneration of *Pinus brutia* forests in Thasos island, Greece. Acta Oecol. 21, 13–20.

Thanos C A 2000 Ecophysiology of seed germination in *Pinus halepensis* and *P. brutia*. *In* G Ne'eman and L Trabauld (eds) Ecology, Biogeography and Management of*Pinus halepensis* and *P. brutia* Forest Ecosystems in the Mediterranean basin, pp 37–50. Backhuys Publishers, Leiden, The Netherlands.

Thanos C, Daskalakou E N and Nikolaidou S 1996 Early post-fire regeneration of a *Pinus halepensis* forests on Mount Parnis, Greece. J. Veg. Sci. 7, 273–280.

Thirgood J V 1981 Man and the Mediterranean Forest. A History of Forest Depletion, 194 p. Academic Press, New York.

Trabaud L 1987 Fire and survival traits of plants. *In* L Trabaud (ed) The Role of Fire in Ecological Systems, pp 65–89. SPB Academic Publishing, The Hague.

Trabaud L 1994 Postfire plant community dynamics in the Mediterranean Basin. *In* JM Moreno and WC Oechel (eds) The Role of Fire in Mediterranean Type Ecosystems. . Ecological Studies, vol. 107, pp. 1–15. Springer-Verlag, New York.

Trabaud L 2000 Post-fire regeneration of *Pinus halepensis* forests in the West Mediterranean Basin. *In* G Ne'eman and L Trabaud (eds), Ecology, Biogeography and Management of *Pinus halepensis* and *Pinus brutia* Forest Ecosystems in the Mediterranean Bain, pp. 257–268. Backhuys Publishers, Leiden, The Netherlands.

Tsitsoni T 1997 Conditions determining natural regeneration after wildfires in the *Pinus halepensis* (Miller, 1768) forests of Kassandra Peninsula (North Greece). For. Ecol. Manage. 92, 199–208.

Tutin T G, Heywood V H, Burgers N A, Moore D M, Valentine D H, Walters S M and Wedd D A 1964–1980. Flora Europaea I-V. Univ. Press, Cambridge.