Proceedings 10th MEDECOS Conference, April 25 – May 1, 2004, Rhodes, Greece, Arianoutsou & Papanastasis (eds)

Effect of post fire treatments on the natural regeneration of *Pinus brutia* in northern Greece

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Keywords: Mediterranean pine forest, post-fire forest management, natural regeneration, seedling growth

ABSTRACT: This paper deals with the effect of post fire treatments on the evolution of natural regeneration of *Pinus brutia* after wildfire, in the periurban forest of Thessaloniki. This forest was burnt in the summer of 1997. In the research area three different post fire treatments were applied, in different locations on northern and southern aspects. The first treatment comprised felling (all the trees were cut down and removed after the fire) and soil ripping, without reforestation. The second treatment comprised felling, soil ripping and branch – meshing, without reforestation. The third treatment comprised felling, soil ripping, branch – meshing with reforestation. Only on the northern aspects were there areas suitable for a control plot [no felling, no soil ripping, no branch – meshing, no reforestation], because in all other aspects felling had taken place, the trees had been removed, the soil had been ripped. In total, 35 sample plots [10m x 10m] were randomly selected. On the northern aspect 5 plots for each of the three treatments plus 5 plots for the control. On the southern aspect 5 plots for each of the three treatments [No control – see above] In each sample plot the number of individuals of *P. brutia,* the diameter at ground level in cm, the total height in m, the vitality and the development tendency according to I.U.F.R.O classification, were measured. The relationship among the number of seedlings, diameter and height on the one hand and the post fire treatments, on the other, was tested by analysis of variance. The significance of the results was tested using the Duncan test.

1 INTRODUCTION

Fire is an ecological factor which has played an important role in shaping plant communities of the Mediterranean ecosystems (Naveh 1975, Trabaud 1980, Pons and Thinon 1987, Tsitsoni 1997) and the most common disturbance in a wide variety of forest ecosystem types which affects their dynamic and productivity (Susa 1984, Dafis 1987, Barnes et al.1998, Agee 1993). Species that are common to these communities have adapted themselves to fire in various ways and their persistence depends on periodic fire (Kruger 1983, Trabaud 1987, Thanos et al. 1989, Naveh 1991, Thanos and Marcou 1991, Tsitsoni 1997, Arianoutsou 1998, Habrouk et al. 1999). *P. brutia* and *P. halepensis* are Mediterranean conifers, with the above-mentioned attributes, which form extensive forests in the Mediterranean Basin. These forests have often been the targets of arsonists. This is because these ecosystems extend mostly in areas of high touristic development due to the Mediterranean climate and the denude men of the land increases its value (Dafis 1987, Tsitsoni 1991, Tsitsoni 1997). However, when the fires destroy mature stands of the above species in Mediterranean ecosystems, the forest regeneration is ensured provided the burnt area is protected from grazing (Le Houerou 1974, Naveh 1975, Tsitsoni 1997)

In spite of the many investigations of the post fire natural regeneration of Mediterranean forest ecosystems (Abbas et al. 1984, Trabaud et al. 1985, Tsitsoni and Zagas 1988, Moravec 1990, Thanos and Marcou 1991, Tsitsoni 1991, Spanos 1992, Thanos and Marcou 1993, Ne'eman et al. 1995, Daskalakou and Thanos 1996, Tsitsoni 1997, Spanos et al. 2000, Thanos 2000, Thanos and Daskalakou 2000, Tsitsoni and Karagiannakidou 2000), there have been very few studies which have tried to determine effects of different management practices in recently burnt Medierranean forests (May 1992, Ne'eman et al. 1993, Seracino and Leone 1993, Martinez-Sànchez et al 1999).

Felling and removal of dead trees after fire for timber use is a traditional practice in Greece because the turning over of the soil facilitates the germination of pine and secondly the reducing of the dangers of xylophagous insects increases the possibility of new pine survival by trunk dragging during wood removal of dead wood operation.

The aim of this study is to determine, the effect of post fire treatments on the natural regeneration of *P. brutia* forest ecosystem, on northern and southern aspects, based on the following: The first treatment comprised felling (all the trees were cut down and removed after the fire) and soil ripping, without reforestation. The second treatment comprised felling, soil ripping and branch – meshing, without reforestation. The third treatment comprised felling, soil ripping, branch – meshing with reforestation. Only on the northern aspects were there areas suitable for a control plot [no felling, no soil ripping, no branch – meshing, no reforestation], because in all other aspects felling had taken place, the trees had been removed, the soil had been ripped.

2 MATERIAL AND METHODS

2.1 *Study area*

The study area is the artificial periurban forest of Thessaloniki and especially the part of the forest that was burnt in 1997. This area was selected because this forest, named Kedrinos Lofos**,** presents great interest due to the fact that it constitutes a unique source of oxygen for a fast developing city. This forest extends to the NE part of the city and occupies an area of 2,979 ha. It was composed of reforestation mostly of *P. brutia* age 40-50 and *Cupressus sempervirens,* in places a few *Pinus pinea* and *Pinus halepensis*, while in gorges and wet places *Platanus orientalis, Populus sp*.,and *Salix sp.* were to be found. After the large fire of July 1997 an effort to convert in mixed stands with broadleaved species has taken place. The altitude of the area ranges from 50 m to 450 m.

The climate is Mediterranean with 135 dry days on the average, the dry period lasts from the middle of May to the end of September (Fig. 1). The mean annual precipitation is 386.75 mm, mean annual temperature is 15.95 ^{o}C, minimum temperature of the coldest month is 6.38 ^{o}C and maximum temperature of the warmest month is 26.35 ^{o}C, according to the data from the meteorological station of the University of Thessaloniki 1992-2001 (Table 1).

Table 1. Climatic data from the meteorological station of the University of Thessaloniki 1992-2001

Months	Temperature ^{0}C			Precipitation (mm)
	MAX	MIN	MEAN	
J	10,35	3,15	6,38	33,87
F	11,92	3,45	7,38	35,05
M	14,62	5,75	9,9	21,8
A	19,17	9,43	14,26	35,98
M	24,75	14,4	19,42	52,49
J	29,65	18,57	24,05	17,55
J	31,99	20,9	26,35	25,32
A	32,14	21,13	26,29	13,76
S	27,53	16,78	21,71	18,42
O	22,16	12,79	16,9	35,25
N	15,58	7,98	11,45	50,11
D	11,27	4,19	7,36	47,15
Mean annual precipitation				386,75

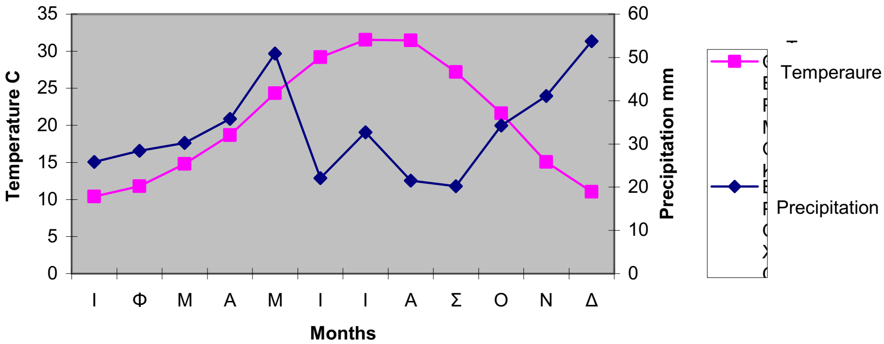

Figure 1. Ombrothermic diagram of Thessaloniki area for the period 1992-2001.

The soils of the area are slightly acid up to neutral, shallow up to middle depth, poor of nutritious ingredients, with a high percentage of stones and pebbles. The vegetation of the area belongs to the Quercetalia pubescentis zone and especially to the Ostryo-Carpinion alliance (Tsitsoni and Zagas 1988). The vegetation of the studied area is dominated by *P. brutia* which comprises the overstory. The understory, which is dense in some places and absent in others, consists mainly of *Quercus coccifera* and less of *Phillyrea latifolia* and *Paliurus spina-cristi.* In good site qualities the species *Crataegus monogyna, Jasminus fruticans* are found and in a shrubby form the species *Fraxinus ornus* and *Ulmus campestris.* In these areas the ground flora vegetation is limited because the stand canopy is quite closed. In medium site qualities the more xerothermic species *Cistus incanus, Sarcopoterium spinosum* and *Anthyllis hermanie* can be found. In these areas the ground flora appears richer because the canopy density is thin (Tsistoni et al. 2004).

2.2 *Methods*

The first actions which took place after the fire in the study area were:

- Soil ripping throughout the burnt area with the exception of the control plot.
- Felling and removal of the burnt trees with the exception of the control plot.
- Constructions of branch-meshing from the felled tree branches in many parts of the forest.
- Reforestation: More than 800 ha were reforested in a vary short space of time and were completed in March 1998.

For the research on the effect of the different treatments and the evolution of regeneration of *P. brutia,* in total, 35 sample plots [10m x 10m] were randomly selected. On the northern aspect 5 plots were selected for each of the three treatments plus 5 plots for the control. On the southern aspect 5 plots for each of the three treatments [No control – see above]. The main factors for the selection of the positions of sample plots were the aspects (N, S) and the different postfire treatments which are the followings:

- The first treatment comprised felling (all the trees were cut down and removed after the fire) and soil ripping, without reforestation.
- The second treatment comprised felling, soil ripping and branch-meshing, without reforestation.
- The third treatment comprised felling, soil ripping, branch-meshing with reforestation.
- Only on the northern aspects were there areas suitable for a control plot [no felling, no soil ripping, no branch – meshing, no reforestation], because in all other aspects felling had taken place, the trees had been removed, the soil had been ripped.

The measurements were taken during the winter of 2003, six years after the fire. In each sample plot the number of individuals of *P. brutia,* the diameter at ground level in cm, the total height in m, the vitality and the development tendency according to I.U.F.R.O classification, were measured (Dafis 1990) (Vitality: Grade 10 the vigorous saplings, grade 20 the normally growing saplings, grade 30 the declining growing saplings. Developmental tendency: Grade 1 the overgrowing saplings in height, grade 2 the normally growing saplings in height, grade 3 the saplings with reduced growth in height).

The relationship among the number of seedlings, diameter and height on the one hand and the four post fire stand treatments, on the other, were tested by analysis of variance. The significance of the results was tested using the Duncan test (Norusis 1994).

3 RESULTS

The situation concerning the effect of post fire treatments on the natural regeneration in the studied area is as the following:

3.1 *Seedling density*

The natural regeneration six years after the fire on the two aspects and in the four treatments is depicted in Table 2. On the northern aspects the density was higher in the first treatment (feeling and soil ripping without reforestation), 1600 individuals/ha, and the control, 1500/ha, and the differences were not statistically significant. However seedling density in the other two treatments [second (feeling, soil ripping and branch-meshing, without reforestation) and third (feeling, soil ripping and branch-meshing, with reforestation)] was much sparer 967 and 767 individuals/ ha respectively and the differences were not statistically significant either (Table 2). On the southern aspects where there was no control, the greatest seedling density values were recorded in the second treatment (feeling, soil ripping and branch-meshing, without reforestation), 2525 individuals/ha, the third treatment (feeling, soil ripping and branch-meshing, with reforestation) followed, 1950 individuals /ha, while the density in the first treatment (feeling and soil ripping without reforestation) much less 600 individuals /ha. The average number of individuals was high in both treatments (second and third) on the southern aspects.

Table 2. Seedling density of *Pinus brutia,* 6 years after the fire in the four treatments applied. The values are the means ± Std. error of the mean (in parenthesis).

Treatment	Seedling density (seedlings /100 m^2)	
	Northern aspects	Southern aspects
1	16.00 (1.41) a	6.00 (1.84) b
2	9.67 (1.33) bc	25.25 (5.08) a
3	7.67 (1.55) c	19.50 (5.20) a
4	15.00 (2.41) ab	-

Within the same column values followed by different letter are significantly different P<0.05, Duncan test.

The first treatment (feeling, soil ripping without reforestation) presented statistically significant differences from the second and third treatments because the branch-meshing which was imposed on both these treatments reacted negatively on the density of the regeneration on the northern aspects (Table 2). On the southern aspects the opposite results can be seen i.e. the branch-meshing improved the natural regeneration (Table 2). The remains of the burnt trees in the control plot positively affected the regeneration of the seedlings in the northern aspects.

In the treatments with branch-meshing on both aspects, natural regeneration was better where reforestation had not taken place. In the above treatments, however, there were no statistically significant differences presented (Table 2).

It is important to point out the relatively high values of density of the natural regeneration on the southern aspect where branch-mashing had occurred. This might be due to the retention of moisture in the soil because of the branch-meshing although the southern aspects have a shallow ground depth.

3.2 *Seedling growth*

The growth of seedlings of natural regeneration was average to satisfactory as can be seen in Tables 2 and 3. The annual growth of height ranges from 10.40-17.34 cm. And the diameter from 0.28– 0.39 cm. On the whole, the treatments did not affect the growth of the seedlings, neither in height nor in diameter with very few exceptions. These were seen where the treatment had been felling, soil ripping and branch-meshing, with reforestation on southern aspects where the seedlings had grown the least in height and diameter. In this treatment the height value differs significantly from the other two treatments. However the differences in diameter values were not statistically significant in any of the treatments (Table 4).

Table 3. Regeneration characteristics of *Pinus brutia* 6 years after the fire and after the four treatments applied in northern aspects. The values are the means ± Std. error of the mean (in parenthesis).

Treatment	Mean height (cm)	Mean diameter (cm)	Mean annual height increment (cm)	Mean annual diameter increment (cm)
1	74.30 (3.80) ns	1.71 (0.14) b	12.38 (0.70) ns	0.29 (0.02) b
2	70.52 (4.68) ns	1.67 (0.17) b	11.75 (0.78) ns	0.28 (0.03) b
3	81.76 (2.68) ns	2.33 (0.15) a	13.63 (0.45) ns	0.39 (0.03) a
4	86.67 (4.12) ns	1.74 (0.13) b	17.34 (0.69) ns	0.29 (0.02) b

ns: non significant differences, P>0.05.

Within the same column values followed by different letter are significantly different P<0.05, Duncan test

Table 4. Regeneration characteristics of *Pinus brutia* 6 years after the fire and after the four treatments applied in southern aspects. The values are the means ± Std. error of the mean (in parenthesis).

Treatment	Mean height (cm)	Mean diameter (cm)	Mean annual height increment (cm)	Mean annual diameter increment (cm)
1	72.20 (1.56) a	2.09 (0.09) ns	12.03 (0.35) a	0.35 (0.01) ns
2	71.08 (1.74) a	2.07 (0.07) ns	11.85 (0.29) a	0.34 (0.01) ns
3	62.38 (2.39) b	1.81 (0.09) ns	10.40 (0.40) b	0.30 (0.02) ns

ns: non significant differences, P>0.05.
Within the same column values followed by different letter are significantly different P<0.05, Duncan test.

On the other hand the seedlings, which had been treated the same, but on the northern aspect displayed a statistically significant difference in diameter which was wider than the seedlings from the other two treatments - but not greater than the control (Table 3). However the differences in height values were not statistically significant in any of the treatments (Table 3).

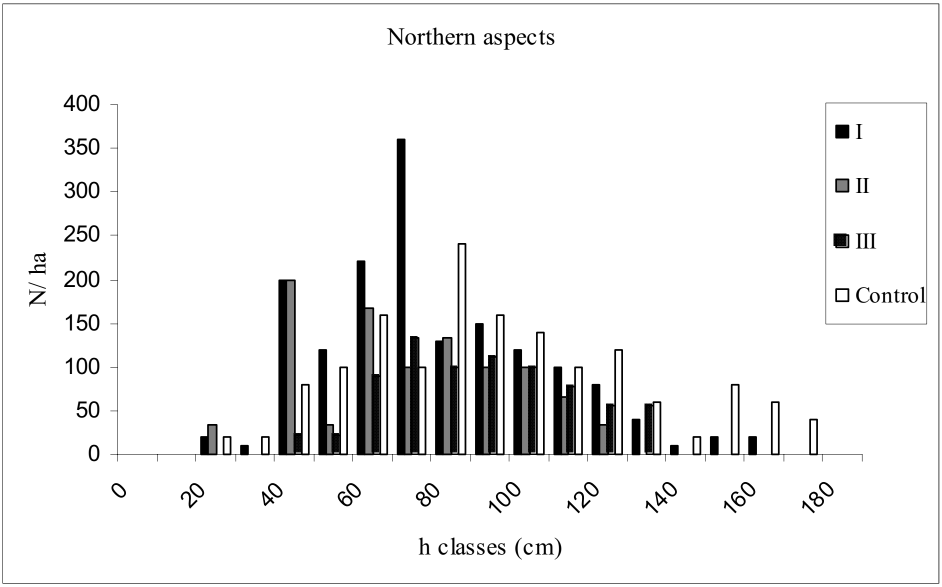

Figure 2. Distribution of tree height in the three treatments and Control plot

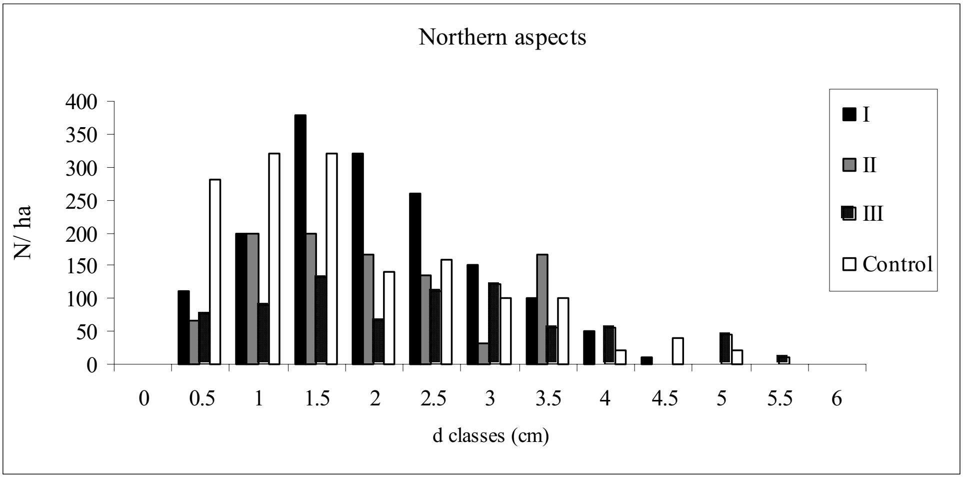

Figure 3. Distribution of tree diameter in the three treatments and Control plot

The distributions of height and diameter among the different treatments can be seen in the Figures 2, 3 for the northern aspects and in the Figures 4, 5 for the southern aspects. These distributions follow the normal pattern with the greatest concentration of seedlings in the height class 60 - 80 cm. and the diameter class 1 – 2. 5 cm. in all treatments on both aspects.

The vitality and the developmental tendency fluctuated to satisfactory levels in all treatments in the northern aspects with average values 20 and 2.0 respectively, because of the better growth conditions. In the southern aspects the values of the vitality and the developmental tendency were smaller in all treatments (18 and 1.8 respectively) than in northern aspects.

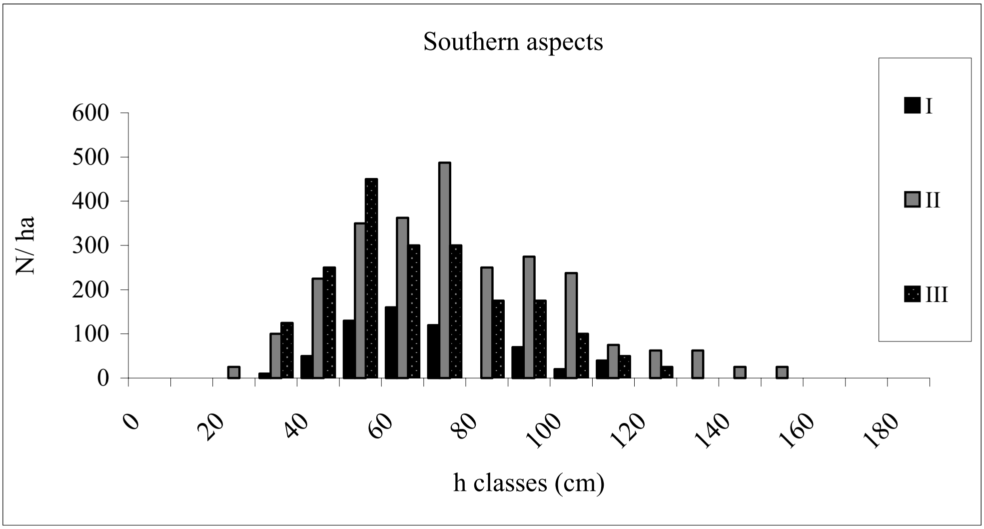

Figure 4. Distribution of tree height in the three treatments

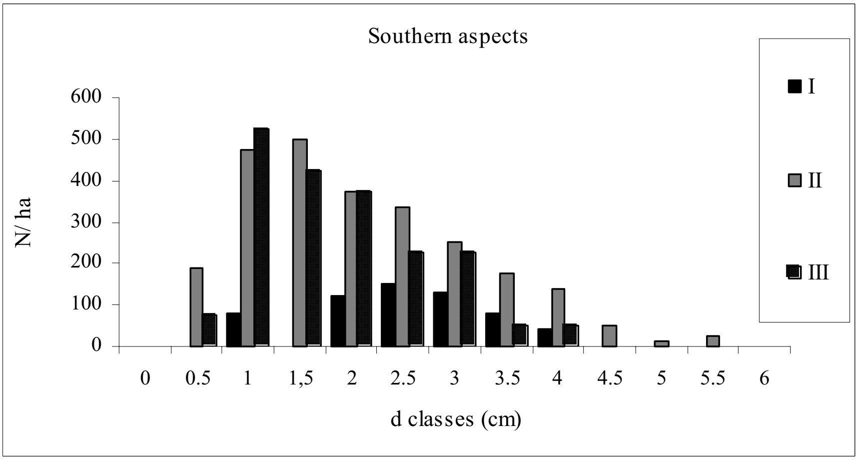

Figure 5. Distribution of tree diameter in the three treatments

4 DISCUSSION & CONCLUSIONS

Despite human intervention on the study area aiming at the artificial re-establishment of the vegetation, mainly of broadleaved trees, an average to satisfactory natural regeneration of *P. brutia* occurred. This took place during the first years after the fire. Simultaneously much of the existent undergrowth (mainly of *Quercus coccifera* and less of *Phillyrea latifolia* and *Paliurus spina-cristi*) with high re-sprouting ability covered the surface particularly on the northern aspects. This negatively affected the natural regeneration of *P. brutia*. On the other hand human intervention had a beneficial effect on natural regeneration on the southern aspects, where (Schiller et al. 1998) a major problem was the lack of soil moisture and the shallow ground depth.

The favourable re-sprouting of the undergrowth and reforestation of the seedlings on the northern aspects limited the natural regeneration of *P. brutia* (Spanos et al. 2000). The survival of the replanted seedlings on the northern plots was noticeable in the same area (Spanos et al. 2003). Spanos et al. (2003) found that the density of the seedlings was better on the northern aspects where reforestation had not taken place.

From research after an earlier fire in the same area Tsitsoni et al (2004) found that the post fire regeneration of *P. brutia* was successful without human intervention. Felling and burnt wood removal did not significantly affect the natural regeneration of *P. brutia* as is mentioned also by Martinez-Sànchez et al (1999).

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