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The Effect of Aspect on Post-Fire Recovery of a Mixed Lebanon Cedar-Anatolian Black Pine Forest: After the First 5 Years

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Abstract: The aim of the study was to examine the effect of aspect on post-fire recovery of a mixed Lebanon cedar (*Cedrus libani* A. Rich.) -Anatolian black pine (*Pinus nigra* Arnold subsp. *pallasiana* [Lamb.] Holmboe) forest in Köprülü Kanyon National Park, southern Turkey. Study plots were randomly selected according to three main aspects within the burned area. Density and height of seedlings of both species were determined. Plant coverage, plant species diversity and maximum height of vegetation were also examined. Aspect had a significant effect on total plant coverage and multiple comparisons indicated that total plant coverage on N-facing slopes was significantly lower than that on both W-facing and S-facing slopes. However, aspect had no effect on plant species diversity or maximum height of vegetation. The densities of seedlings of *C. libani* and *P. nigra* were very low on slopes of all aspects and aspect had no significant effect on seedling density in either species. However, grazed *P. nigra* seedlings were significantly shorter than ungrazed ones, but such a difference was not observed in *C. libani* seedlings. Goat browsing may be a more important factor affecting the recovery of these mixed forests.

Key words: Aspect, *Cedrus libani*, *Pinus nigra* subsp. *pallasiana*, post-fire establishment

INTRODUCTION

Pure and mixed forests of *Pinus nigra* Arnold subsp. *pallasiana* (Lamb.) Holmboe (Anatolian black pine) and *Cedrus libani* A. Rich. (Lebanon cedar) are both of economic importance for wood production and of ecological significance. These forests have long been affected by human activities such as cutting and grazing (Boydak, 2003). Burning has also become an important human-based factor affecting these ecosystems in recent years (Espelta *et al.*, 2003).

Fire is known to be an ecological factor in Mediterranean environments (Trabaud, 1994). Most species have adaptations to fire in coastal and lower-altitude Mediterranean ecosystems (Lavorel, 1999). Thus, the post-fire recovery of these communities generally occurs rapidly (Arianoutsou-Faraggitaki, 1984; Spanos *et al.*, 2000). On the other hand, the role of fire in Mediterranean mountain forest ecosystems is basically different. Tree species dominating these ecosystems (e.g., *Pinus nigra*, *Cedrus libani*) do not have any fire-adapted trait such as serotiny, a well-known adaptation of low altitude Mediterranean pines (Daskalakou and Thanos, 1996). Consequently, post-fire recovery of these mountain tree species depends entirely on seed dispersal from seed bearing individuals located outside of the burned area (Retana *et al.*, 2002). This dependence, therefore, results in the recovery process of these forests being longer than that of lower-altitude Mediterranean forests.

Slope aspect is one of the factors affecting vegetation structure and plant community composition (Armesto and Martinez, 1978; Carmel and Kadmon, 1999; Guerrero-Campo *et al.*, 1999; Sternberg and Shoshany, 2001). The main difference between shaded and sunny slopes is the amount of solar radiation each receives. This affects availability of water as well, which is of critical importance for plant growth (Kutiel, 1992).

The aim of the present study was to examine the effect of aspect on post-fire recovery of a mixed *C. libani*-*P. nigra* subsp. *pallasiana* forest after the first 5 years under high grazing pressure in Köprülü Kanyon National Park, southern Turkey.

MATERIALS AND METHODS

Study area: The study was conducted in Köprülü Kanyon National Park, located in the Taurus Mountains, southern Turkey, from July to September 2003 (5 years after fire). The National Park area is between 100 m and nearly 2500 m height above sea level and is of great importance in terms of habitat diversity, including most of the Mediterranean habitat types, from maquis to high-mountain Mediterranean alpine zone (Ayaşlıgil and Duhme, 1993). The study area, which burned in July 1998, was a mixed Lebanon cedar (*Cedrus libani*) -Anatolian black pine (*Pinus nigra* subsp. *pallasiana*) forest in the northern part of the National Park area at approximately 1400-1500 m above sea level (37°21' N, 31°05' E). The area

is underlain by limestone, the most common bedrock type throughout the Taurus Mountains of Anatolia. In the study area, the burned trunks had not been removed after the fire and no other forestry practice had been applied either.

Although the closest meteorological station to the study area is in Antalya (60 km away), there is an elevational difference between the study area and this station (42 m a.s.l.). Therefore, to reflect the climate of the study area, data from Isparta Meteorological Station (997 m a.s.l.), 70 km away from the study area, were used (Turkish State Meteorological Service). The climate is Mediterranean, with cool, wet winters and hot, dry summers. Mean annual rainfall is 598 mm with a summer drought (38.3 mm of rainfall from July to September). Mean annual temperature is 12.1°C. Mean temperatures in the hottest (July) and the coldest (January) months are 23.1 and 1.7°C, respectively.

Goat and cattle grazing is one of the most important economic activities of the villages within and around the Köprülü Kanyon National Park area. It is estimated that there are approximately 22,000 domestic goats throughout the National Park area, covering 36,614 ha and especially in forest villages people keep a considerable number of goats due to a lack of economic alternatives (Ayaşlıgil and Duhme, 1993). Therefore, the study area has been under high grazing pressure by goats and cattle for decades.

Sampling design: Two replicates of plots nearly 1 ha in size were selected randomly for each of the main aspects [N-NW (afterwards N), W-SW (afterwards W) and S] of the burned area. Five 5×5 m (25 m²) subplots for counting and measuring *P. nigra* and *C. libani* seedlings and 15 1×1 m (1 m²) quadrats for measuring projected foliage coverage of vegetation were established randomly in each plot, through transects across the middle of the selected plots. In total, 30 5×5 m subplots and 90 1×1 m quadrats were used in the burned area during this study. In each subplot (25 m²), *P. nigra* and *C. libani* seedlings were counted, their heights were measured and their grazing situation was recorded as binary data (that is, as grazed or ungrazed). In each quadrat (1 m²), individuals of plant species were counted, their projected cover degrees were determined visually and maximum vegetation height was measured.

Data analysis: Densities of seedlings of *P. nigra* and *C. libani* were compared among slope aspects of the burned area using one-way analysis of variance (ANOVA). The two-year old seedlings were the only age group including a sampling size sufficient for statistical analysis for both *P. nigra* and *C. libani*. Therefore, when comparing the heights of grazed and ungrazed seedlings

of different ages, only two-year-old seedlings could be statistically analyzed using Student's t-test. The effect of aspect and growth form on plant coverage was analyzed by a model-I two-way ANOVA using aspect and growth form as fixed factors. Tukey's HSD test was used for multiple comparisons among groups.

Plant species diversity in each quadrat was estimated using the number of individuals of each species with Shannon's information-theoretic index of species diversity (Brower *et al.*, 1990). To examine the effect of aspect on plant species diversity and maximum vegetation height, one-way ANOVAs were performed.

Prior to parametric tests, Kolmogorov-Smirnov and Levene tests were conducted to check the data for normality and homoscedasticity, respectively. Data were transformed to log₁₀(x+1) prior to analysis if they did not meet the prerequisites of parametric tests.

RESULTS

Mean densities of *P. nigra* and *C. libani* seedlings in the study plots (n = 30) were 1.93 and 2.17 individuals/25 m², respectively; there was no significant difference between these values (t = -0.354, df = 58, p = 0.725). Although ANOVA results indicate no significant difference in terms of density of seedlings of either *P. nigra* (F = 3.195, df = 2, p = 0.057) or *C. libani* (F = 0.923, d.f. = 2, p = 0.410) among slope aspects, the higher densities of *P. nigra* seedlings on northern aspects than on the others might be biologically important (Table 2).

Mean heights of grazed seedlings of both species were generally lower than ungrazed ones (Table 3); the exceptions seem to be a result of lower sampling sizes within some age classes. There was no significant difference in mean height between two-year-old grazed and ungrazed seedlings in *C. libani* (t = -1.566, df = 44, p = 0.125), whereas a significant difference was found in those of *P. nigra* (t = -3.530, df = 42, p = 0.001). It was not possible to compare statistically other age classes because of the low sampling sizes.

Aspect had a significant effect on mean total coverage (%) by plant species (Table 1) and multiple comparisons indicated that N-facing slopes are significantly different from both W-facing and S-facing

Table 1: Summary of the two-way ANOVA table for the effects of aspect and growth form on plant coverage

Effect	df	MS	F	p-value
Aspect	2	0.940	4.490	0.0120
Growth form	1	0.001	0.007	0.9350
Aspect × growth form	2	2.010	9.630	0.0001
Error	174	0.210		

Values were tested after logarithmic transformation to obtain the normal distribution

Table 2: Mean (\pm SE) density (individuals/25 m²) of seedlings of *P. nigra* and *C. libani* on different aspects of the burned area

	Aspect			
	N	W	S	Total
<i>Pinus</i>	3.20 \pm 0.8	1.80 \pm 0.7	0.80 \pm 0.4	1.93 \pm 0.4
<i>Cedrus</i>	3.00 \pm 0.9	1.30 \pm 0.5	2.20 \pm 1.1	2.17 \pm 0.5

Table 3: Mean (\pm SE) height (cm) of grazed (g+) and ungrazed (g-) seedlings of *P. nigra* and *C. libani* at different ages

	Age		
	1	2	3
<i>Pinus</i>			
g (-)	6.06 \pm 0.5	10.90 \pm 0.6	13.8 \pm 2.3
g (+)	6.00 \pm 0.9	8.56 \pm 0.4	10.5 \pm 1.3
<i>Cedrus</i>			
g (-)	7.14 \pm 0.9	11.00 \pm 0.6	18.5 \pm 2.5
g (+)	9.50 \pm 0.5	9.80 \pm 0.4	14.1 \pm 0.2

Table 4: Mean (\pm SE) coverage (%) of plant species belonging to different growth forms on different aspects of the burned area

	Aspect			
	N	W	S	Total
Woody	10.3 \pm 3.4	17.9 \pm 2.7	27.9 \pm 3.6	18.7 \pm 2.0
Herbaceous	16.3 \pm 2.2	14.8 \pm 2.3	12.6 \pm 2.1	14.6 \pm 1.3

slopes (Table 4; Tukey's HSD test, $p < 0.05$). However, mean coverage (%) by woody and herbaceous species did not differ among aspects (Table 1). Neither Shannon diversity ($F = 0.238$, $p > 0.05$) nor maximum vegetation height ($F = 0.983$, $p > 0.05$) was significantly different among aspects.

DISCUSSION

Although post-fire recovery of *C. libani* and *P. nigra* forests have already been studied, little attention has given to the mixed forests of these species. The present study contributes to current literature with data on the effect of aspect on recovery of these mixed forests.

The results of the present study showed that aspect has little effect on densities of either *P. nigra* subsp. *pallasiana* or *C. libani* seedlings in post-fire environments. Species diversity of plant species did not vary among aspects either. However, aspect had an effect on total vegetation coverage. Since this study just reports the effect of aspect on post-fire recovery of a mixed *C. libani*-*P. nigra* subsp. *pallasiana* forest, even though there was evidence of a high grazing pressure over the study area the results are not discussed in terms of the effects of goat browsing on post-fire recovery.

P. nigra forests are well adapted to frequent low-intensity fires (Castellnou *et al.*, 2002) and did not evolve under conditions with frequent crown fires (Tapias *et al.*, 2004). Therefore, the establishment of *P. nigra* generally does not occur well after wildfires (Trabaud and Campant, 1991). Moreover, it was reported that *P. nigra* is the dominant species in an area before a fire, but it almost

disappears after the fire (Retana *et al.*, 2002). In the study area, mean total density of *P. nigra* seedlings was only 0.08 individuals m⁻² and this result supported the conclusions above on post-fire poor establishment of *P. nigra*. Contrary to *P. nigra*, prescribed fires increase the establishment of *C. libani* seedlings (Boydak *et al.*, 1998). Seedlings of *C. libani* establish well in prescribed-burned areas by the first post-fire year and thereafter in the second, third and fourth years (Boydak, 1986). Moreover, prescribed fire is a reliable silvicultural tool in the success of natural regeneration of Lebanon cedar in the karstic lands of Mediterranean Turkey (Boydak *et al.*, 1998). In the study area, however, mean total density of *C. libani* seedlings was just 0.09 individuals m⁻². This is much lower than the value found in the 5th year of a prescribed-fire experiment conducted in a pure forest of *C. libani* in the western Taurus Mountains (21 individuals m⁻², Boydak *et al.*, 1998).

Although the densities of seedlings of both species did not differ significantly among aspects, the density of seedlings of *P. nigra* was higher on N-facing aspects and decreased towards west-facing and south-facing ones. This result is not surprising since it is known that the establishment of *P. nigra* occurs quite early in mesic areas (N-facing plots in the present study), while pine recruitment is delayed several years in xeric areas (Gracia *et al.*, 2002).

Although the diversity of plant species did not vary among aspects, aspect had a significant effect on total vegetation coverage; N-facing slopes had lower vegetation coverage than W- and S-facing slopes. This may indicate that aspect has an effect on the growth of plant species, but not on their establishment. This result supported the current literature concerning the Mediterranean Basin (Sternberg and Shoshany, 2001; Bellot *et al.*, 2004), where S-facing slopes receive higher solar radiation than N-facing ones, resulting in higher evapotranspiration rates and higher maximum temperatures during summer drought conditions.

There was a difference between the two species in the mean height of two-year-old grazed and ungrazed seedlings. In *P. nigra*, there was a significant difference between the two grazing groups, but this was not the case for *C. libani*. A decrease in the heights of seedlings of *C. libani* exposed to goat grazing is expected, as in *P. nigra*. Therefore, the lack of difference between grazed and ungrazed seedlings of *C. libani* may show the resistance of this species to goat grazing. In fact, there is some evidence on the resistance of seedlings of *C. libani* to grazing (Boydak, 1986). Therefore, goat browsing may be a more important factor affecting the recovery of the mixed forests of *C. libani* and *P. nigra* subsp. *pallasiana* than fire.

Further research on post-fire recovery of and the effect of goat browsing on mixed and pure forests of *C. libani* and *P. nigra* subsp. *pallasiana* is needed to contribute to the current knowledge on the dynamics of these forests and is of importance in terms of management and conservation.

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