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The Effect of Prescribed Fire on The Natural Regeneration Success of Lebanon Cedar (*Cedrus libani A. Rich.*) at Antalya-Kaş Locality

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Abstract: With this study the effect of prescribed fire on the natural regeneration success of Lebanon Cedar (*Cedrus libani A. Rich.*) by shelterwood method was investigated at Antalya-Kaş localitiy. Split plot design with three replications was applied as experimental design. Prescribed fire was applied to slash pile at one of each main plot while the other was left as control. Main plots were divided into two subplots and equal number of seeds were used at each subplot for additional seeding by applying broadcast seeding (full seeding) or drill sowing methods. Seedling survival was recorded each year and the height growth of the seedlings was measured at the end of the fifth vegetation period. The results revealed that there were significant differences between the plots where prescribed fire was applied and the control plots for the seedling survival and height growth. Drill sowing method gave slightly better seedling survival than broadcast seeding method; however, enough seedlings were also obtained by broadcast seeding method. On the other hand, drill sowing is more expensive and difficult or sometimes even impossible to apply in karstic soils. According to the results of this and other related investigations, higher seedling survival, better development and more healthy seedlings were obtained at the areas where prescribed fire was applied, Therefore, the prescribed fire is a reliable silvicultural tool in the success of natural regeneration of Lebanon cedar at karstic lands of the Mediterranean Turkey.

Antalya-Kaş Yöresinde Denetimle Yakmanın Toros Sedirinin (*Cedrus libani A. Rich.*) Doğal Gençleştirme Başarısına Etkileri

Özet: Bu çalışma ile Antalya-Kaş yöresi Toros Sediri (*Cedrus libani A. Rich.*) ormanlarının büyük alan siper yöntemi ile gençleştirilmesinde, denetimli yakmanın başarı üzerine etkileri araştırılmıştır. Araştırmada üç yinelemeli bölünmüş parseller deneme deseni uygulanmıştır. Ana parsellerden birisinde öbekler halinde yığılan kesim artıklarında denetimli yakma uygulanmış, diğer ana parsel kontrol parseli olarak bırakılmıştır. Ana parseller alt parsellere ayrılarak, bu alt parsellerde tam alan serpme ekimi veya çizgi ekimi yöntemleriyle eşit sayıda tohum takviyesi yapılmıştır. Parsellerde yaşayan fidan sayıları her yıl vejetasyon periyodu sonunda belirlenmiş, beşinci vejetasyon peryodu sonunda ise fidan boyları ölçülmüştür. Araştırma sonuçlarına göre; denetimli yakma uygulanan parsellerle kontrol parselleri arasında, yaşayan fidan sayıları ve boy gelişmeleri bakımından önemli farklılıklar ortaya çıkmıştır. Çalışmada denetimli yakma uygulanan parsellerdeki çizgi ekimlerinde tam alan serpme ekimlerine oranla az farkla daha fazla yaşayan fidan sayısı saptanmıştır. Ancak tam alan serpme ekimlerine oranla az farkla daha fazla yaşayan fidan sayısı saptanmıştır. Ancak tam alan serpme ekimleriyle de yeterli gençlik elde edilmiştir. Öte yandan çizgi ekimlerinin karstik alanlarda uygulanması daha pahalı ve güç olmakta, hatta uygulanamayabilmektedir. Bu ve diğer ilgili araştırmaların sonuçlarına göre; denetimli yakma uygulanan alanlarda daha fazla yaşayan fidan, daha iyi gelişme ve daha sağlıklı fidanlar elde edilmektedir. Bu nedenle Türkiye'nin Akdeniz Bölgesi'ndeki karstik alanlarda, Sedir doğal gençleştirme çalışmalarının başarısı için, denetimli yakmalar, güvenilir bir silvikültürel araçtır.

Introduction

Lebanon cedar (*Cedrus libani A. Rich.*) is presently found primarily in the Mediterranean Region of Turkey. Historical records indicate that extensive and magnificent forests of Lebanon cedar also occured in Syria and Lebanon (1, 2); however, human impact for the past 5000 years have left only small populations in Syria and Lebanon (3, 4). Lebanon cedar is generally found on the Taurus Mauntains between 800 and 1200 meter elevations, but can be found at lower (500-600m) and higher (2400m) elevations as small populations or individuals. There are also some scattered populations in other parts of Anatolia (1, 5, 6, 7). Presently pure natural Lebanon cedar forests cover 99.325 ha area either in normal (67.850 ha) or degreaded constitution (31.475 ha). In addition to this, there are mixed forests of Lebanon cedar with other species in large areas, too (8). Moreover between 1983-1989 alone, the Turkish Forest Service has regenerated an additional 61.611 ha of Lebanon cedar by planting (9).

Lebanon cedar forests are found on different geological formations and parent materials of sedimentary, metamorphic and volcanic origins (7, 10). But it is primarily found on calcerous (karstic) formations of the Mesozoic, Eocene, Miocene, Upper Cretaceae, Permocarboniferous etc. (1, 11). The largest and the most important karst region in Turkey lies in the Taurus Mountains (12). The genetic soil types on the calcerous areas where Lebanon cedar occures are rendsina, terra fusca and terra rosa (13, 10). The soil texture is sandy loam, clayey loam, and loam; and the structure is granular at the top soil and blocky and coarse at the subsoil. The soil is generally shallow, medium, or medium-deep (14). However, the soil's fertility is not attributable only to the 20-30 cm depth of surface soil on karstic lands as many cracks between limestone blocks contain fine soil and create physiologically deep soil (15). Roots of Lebanon cedar and other species easily develop and penetrate along the cracks. The formation of karstic areas allows good drainage. But the water holding capacity of the fine soil between the cracks is high. The absence of deep soils on the rugged terrain of this calcerous areas is not releated to soil erosion (16). Surface soil formation is very slow because rainwater and snow melt penetrate immediately into the rock crack system and into deep rock layers. In this terrain, soil is formed along the cracks and stratification surfaces of the limestone (16).

Some early studies revealed that, prescribed fire had positive effect on the natural regeneration success of Lebanon cedar (17, 18, 19). Concentration of mineral plant nutrients, available phosphorus and available nitrogen increased after fire (18). Cation exchange capacity also increased after fire on different parent materials (20, 21). However we still need more precise information about the mutual effects of different combinations of natural regeneration methods, additional seeding methods and prescribed fire on the higher survival and better seedling development of Lebanon cedar-especially in hot and dry karstic sites. With this study the effect of prescribed fire on the natural regeneration success of Lebanon cedar by shelterwood method was investigated at Antalya-Kaş locality. Moreover, the place of the prescribed fire in the natural regeneration success of Lebanon cedar was discussed considering the natural regeneration methods and different climatic conditions prevailing on the karstic lands.

Materials and Methods

The research area is located at 50 km north of Kaş (Figure 1); Gömbe-sarı Seki locality at 1300m elevation on western exposure with about 30 % slope gradient. Mean yearly precipitation is about 800-1000 mm with most of it occurring as snow (7). The parent material is limestone, and the soil is sandy loam and medium-deep.

The sample plots were taken in a Lebanon cedar forest where seeding cutting of shelterwood method had been applied in 1989. Split plot design with three replications was applied as experimental design. Each block (4x4 m) was divided into two main plots.

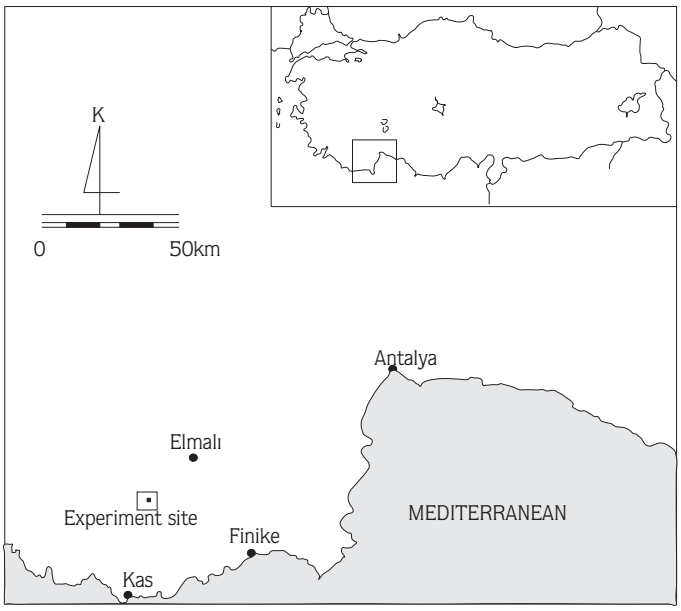

Figure 1. Location map of the research area.

Prescribed fire was applied to slash pile in late November of 1989 at one of each main plot (2x4m) while the other was left as control. Main plots were divided into two subplots (2x2m) and as additional seeding, equal number of seeds (100 seeds per sqm) from the same locality were used by applying broadcast seeding (full seeding) or drill sowing methods in early December of 1989.

Experimental design of split plots at random blocks with five replications was used in the present research. But two of the replications were damaged by wild animals and hence excluded from the experiment. As a general rule, the prescribed fire is applied to slash piles which usually have square shapes and about 5m dimensions in the natural regeneration activities of Lebanon cedar. Selection of the plot sizes based on the practical application of the natural regeneration method. Moreover, while deciding the numbers of the seeds for additional seeding (400 seeds per subplots) reliable results from the statistical analyses were considered.

Seedling survival was recorded at the end of 1990, 1991, 1992, 1993 and 1994 vegetation periods. Height growth of the seedlings was measured at the end of the fifth vegatation period (1994).

In order to reveal the differences between the treatments, analyses of variance were carried out by using the Minitap statistical package (22). The number of seedlings was transformed into square root before the analyses of variance, in order to convert the distributions into normal distributions.

Results

Mean numbers of the survived seedlings according to the treatments and years are given in Table 1. In addition to this, the trend in mean numbers of survived seedlings in the plots where prescribed fire was applied and control plots are presented in Figure 2. The results of the analyses of variance carried out for each of the five years are complied in Table 2.

Significant differences were found between the plots where prescribed fire was applied and control plots for seedling survived at the end of 1990, 1991, 1992, 1993 and 1994 vegetation periods. In the plots where prescribed fire was applied the number of the survived seedlings was appearently higher than the control plots at each year. The number of the survived seedlings highly decreased at the following vegetation periods in all plots. But the number of survived seedlings (mean of 4 sqm: 84.83 seedlings) in the plots where prescribed fire was applied came out as many times higher than the control plots (mean of 4 sqm: 4.33 seedlings) at the end of the fifth vegetation period (Table 1, Figure 2).

The analysis of variance did not reveal any significant differences between the seeding treatments for the first two years. But later, two seeding methods became significantly different at 0,05 level (Table 2). In the plots where prescribed fire was applied the number of the survived seedlings in subplots of drill sowing method have been slightly higher than the subplots of broadcast seeding while in control plots the situation was reverse, which indicates that the differences between seeding method can be neglected.

Table 1. Mean number of survived seedlings according to the years, and mean seedling heights at the age of five.

Years	Prescribed fire plots Number of survived seedlings at 4 sqm			Control plots Number of survived seedlings at 4 sqm		
	Broadcast Seeding	Drill Sowing	Mean	Broadcast Seeding	Drill Sowing	Mean
1990	164.33	200.00	182.16	55.67	31.33	43.50
1991	132.00	176.33	154.17	10.00	5.00	7.50
1992	108.67	128.67	118.67	5.67	4.67	5.17
1993	98.67	119.00	108.83	4.33	4.33	4.33
1994	75.33	94.33	84.83	4.33	4.33	4.33
Mean Heights (1994) (cm)	37.43	34.23	35.83	27.93	20.57	24.25

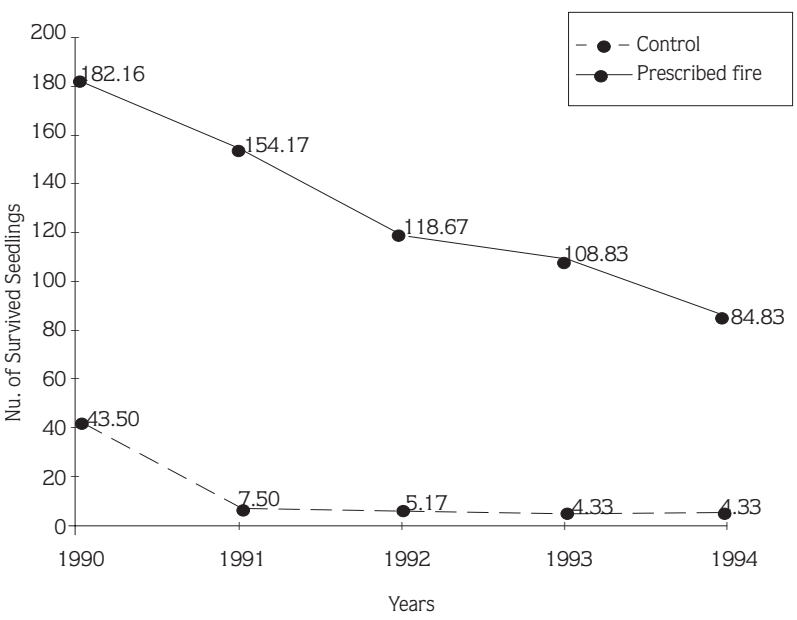

Figure 2. The trend in mean number of survived seedlings in the subplots (4 sqm) where prescribed fire was applied and the control plots.

Table 2. Analysis of variance for the number of survived seedlings, and the mean seedling heights.

Source of Variation	d.f.	Number of survived seedlings 1990	1991	1992	1993	1994	Mean heights 1994
Blocks	2	12.3 ns	9.0 ns	15.7*	18.3*	12.3*	614*
Burning	1	130.9**	265***	200.9***	181.6***	130.6***	402*
Burning*block	2	0.3 ns	0.08 ns	0.01 ns	0.2 ns	0.3 ns	84 ns
Seeding (broadcast-drill)	1	6.1 ns	22 ns	18.4*	16.4*	16.1*	163 ns
Error	5	1.5	3.8	2.3	1.5	1.5	55

ns: not significant, *, **, ***: Significant at 0.05, 0.01, 0.001 levels respectively. d.f: Degree of freedom.

Analysis of variance was also applied for sedling heights which was measured at the end of the fifth vegetation periods. The plots where prescribed fire was applied and control plots were found to be significantly different at 0.05 level. In addation to higher number of seedlings, in the plots of prescribed fire the mean height (35.83 cm) was 48% higher than that of seedlings of control plots (24.25 cm). Moreover, it is observed that in the plots of prescribed fire the seedlings were more vigorous, healthy, and the colour was clearly bluish green.

Discussion

According to the results of this investigation, many times higher seedling survival was obtained in the plots of prescribed fire (mean of 4 sqm: 84.83 seedlings) than the control plots (mean of 4 sqm: 4.33 seedlings) at the end of the fifth vegetation period. Moreover the mean height of the seedlings in the plots of prescribed fire (35.83 cm) was 48% higher than that of control plots (24.25 cm). In addition to these, the seedlings in the plots where the prescribed fire was applied were more vigorous, healthy

and the colour was clearly bluish green. These results are consistent with the results reported in previous investigations (17, 18, 19).

Fire allows rapid root penetration into the bedrock cracks, and vigorous, competition-free growth of stems, consequently, higher survival, especially in hot, dry karstic sites because treatment of prescribed fire can provide favourable seed bed for germination. Moreover, at karstic areas concentrations of mineral plant nutrients, available phosphorus and available nitrogen increased after fire, as well (18). In addition to these, cation exchange capacity (20, 21), soil reaction (pH), and exchangable potasium also increased after fire at karstic lands or other parent materials (18, 20, 21). On the other hand, organic matter decreased at first year, but increased at second year after burning (18, 20).

Although slightly more seedlings were obtained in drill sowing method in the plots of prescribed fire (in control plots, situation was reverse), differences in terms of average seedling numbers between broadcast seedling and drill sowing methods were insignificant for the first two years. But they were determined to be statistically significant from the third year onwards (Table 1 and 2), and drill sowing method produced slightly higher number of seedlings. This result is in good agreement with those reported by Boydak et. al. (18). Nevertheles, the number of seedlings produced by broadcast seeding method was proved to be highly sufficient from the regeneration point of view. On the other hand, drill sowing method is more expensive and difficult, or sometimes even impossible to apply due to the stony and unfavourable soil surface conditions of karstic lands. For this reason it is both appropriate and effective to use the broadcast seeding method as additional seeding to supplament the natural seeding. Furthermore, this method imitates the natural seeding process better.

Both the shelterwood and the strip clearcut methods could be applied as natural regeneration methos for Lebanon cedar (6, 23). Since the seed yield of Lebanon cedar is not fully investigated, additional seeding must be accepted as a rule to supplament the natural seeding, which increase the success of regeneration together with prescribed fire. Boydak (24) suggess that 15 to 20 kg/ha of additional seeds is suffecient for shelterwood areas, but more seeds (20 to 30 kg/ha) are necessary for strip clearcut areas.

In some years and places, natural regeneration of Lebanon cedar can be successful on karstik lands without fire (25, 26). There are years when good precipitation conditions and good seed yields coincide, creating exceptionally favourable years for natural regeneration. These favourable conditions differ according to locations and occur with a few or more years intervals. On the Taurus Mountains, for example, the year 1982 represents such a favourable year and at many localities the protected seedlings were survived from east to west (6, 24). These exceptional years allow Lebanon cedar to regenerate without prescribed fire. However, these exceptional years can not be relied on in managed forests. Therefore, prescribed fire will continue to be one of the most important silvicultural tools to ensure the success of the regeneration, especially on hot and dry sites which possibly occur several consecutive years.

Within the Lebanon cedar region, uncontrolled goat grazing is one of the foremost problems for the regeneration. Every effort should be made to develop a balanced solution between forestry and grazing.

Lebanon cedar is significant in the historical, aesthetic and scientific perspectives. There are only about 100.000 ha pure natural forest of this species. Therefore, a considerable proportion of Lebanon cedar forest should be conserved for future generations. Moreover, its rotation period should be prolonged and yearly natural regeneration sites must be reduced. Improvement of degraded Lebanon cedar forests and reforestation of vast bare karstic lands in the Taurus Mountains must be considered a major forestry challenge. In addition to these, afforestation with this species of high adaptability should be emphasized in plantation sites in Central and Eeastern Anatolia, out of its natural occurrence.

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