ISSN 1314-6246 Molla & Velizarova, 2016 *J. BioSci. Biotech.* **2016**, 5(3): 251-257

RESEARCH ARTICLE

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# Investigation of post-fire natural regeneration in forest plantations of *Pinus sylvestris* and *Larix decidua* on the Northern slopes of Rila mountain

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***Article info:***
*Received*: April 2016
*Accepted*: December 2016

## ABSTRACT

Wildfires alter both the vegetation and the soil properties, thus changing the conditions of their regeneration. Each year, forest fires impact significant areas within the lower forest zone, where the coniferous plantations, especially Scots pine plantations are deteriorated. The natural forest recovery processes in fire-affected areas are still insufficiently studied in Bulgaria. Therefore, the aim of the present study was to investigate the possibility of a natural post-fire regeneration of forest vegetation and the conditions, under which it was limited. The natural regeneration of coniferous plantations in the area of Dolna Banya (The Northern slopes of Rila Mt) with dominant tree species of Scots pine (*Pinus sylvestris* L.) (Object 1) and European larch (*Larix decidua* Mill.) (Object 2) was studied four years after fire and was found to depend on the slope aspect, the micro-relief and soil humidity. It was found that on the south-western slopes, the diversity of broadleaved tree species recovery (birch, oak, sallow, aspen) was higher in comparison with the coniferous (Scotch pine) ones. On the Eastern slope, the regeneration of coniferous prevailed over that of broadleaves. On the ridges, the regeneration was the lowest one, while on the foot of the slopes was higher.

**Key words:** Forest fire, regeneration, relief features, soil indexes, *Pinus sylvestris* L., *Larix decidua* Mill

## Introduction

Forest fires lead to changes in both the vegetation and the soil, which influences the conditions for vegetation regeneration (Parro et al., 2015). Although in some of the fire affected areas the amount of soil organic matter decreases after a fire, it was found that available forms of nutrients increases (Marion et al., 1991; Neary et al., 2005; Aref et al., 2011), which according to Brose et al. (1999) promotes regeneration of tree species. It is also considered that after burning the forest litter the access to seeds to the mineral soil surface is facilitated, which favors the regeneration of the trees, besides destroying a part of the competing plant species (Certini, 2005; Keeley et al., 2008; Ahn et al., 2013). On the other hand, it has been reported that the reduction of soil organic matter due to high-intensity fires may limit the regeneration of the affected fire areas because of changing the soil water regime (Buhk et al., 2007; Vacchiano et al., 2015). Other studies have shown that after forest fires in coniferous forests, in most cases, the all timber was harvested and removed from fire-affected area and, thus, the erosion processes were accelerated (Choung et al., 2004; Velizarova, 2008; Vallejo et al., 2012; Francos et al., 2016). In addition to some changes in soil, the vegetation regeneration in fire affected areas depends on the terrain characteristics (Martín-Alcón, Coll, 2016), the presence of mature trees yielding seed, and the duration of rainless periods, especially in zone with lower altitudes (Moser et al., 2010; Vacchiano et al., 2015), in which every year, forest fires affect significant areas of forest lands. , In these zones, the artificially established plantations of pine forests are currently found to be in poor conditions, especially in what concerns the Scots pine plantations (National Conference, Kyustendil). The processes of forest regeneration in fire- affected areas are insufficiently studied in Bulgaria. Therefore, the aim of this study is to examine the possibility of after fire natural regeneration of forest vegetation and to identify its limiting conditions.

DOI: 10.69085/jbb20163251

## Materials and Methods

### *Sampling sites characteristics*

The natural regeneration of coniferous forests with a predominant presence of *Pinus sylvestris* L. 70%, *Quercus frainetto* Ten. – 20% and *Quercus cerris* L. 10% in Object 1 was studied. The second object (Object 2) was afforested before forest fire area represented by European larch (Larix decidua Mill.) 80% and Scots pine (*Pinus sylvestris* L.) 20%. The experimental sites are located within the territory of village Dolna Banya (at lower altitudes on the northern slopes of Rila Mountain) and belong to the Thracian forest area (Zahariev et al., 1979). Observations were performed four years after the fire occurrence (Figure 1). The soils are Chromic Luvisols (LV-cr) (WRBSR, 2014). Within each object, three test areas were defined. In order to ensure representative conditions for regeneration comparison, an equal rectangular zone with an – area of 100 m$^2$ was investigated in all cases. At each test area, the trees and shrubs species were counted and their heights and diameters at the ground level were measured and documented. The main characteristics of the test areas – exposure, slope, altitude, forest composition, etc. are given in Table 1. Additionally, soil samples were collected from each test areas from 0 to 5 cm and from 5 to 20 cm soil depths. Control test areas were established in the forest, which was not affected by fires.

**Table 1.** *Characteristics of the sampling sites.*

| Objects | Variants | Aspect | Slope, degree (%) | Altitude, m. a.s.l. | Tree species composition in % |
|---|---|---|---|---|---|
| Object 1 - Scots pine (*Pinus sylvestris* L.) | 1 | Ridge | 2 (3,4) | 730 | *Pinus sylvestris* L.-70<br>*Quercus frainetto* Ten. - 20<br>*Quercus cerris* L. - 10 |
| | 2 | Southwest | 15 (26,7) | 723 | |
| | 3 | Southwest | 5 (8,7) | 725 | |
| | Control | Ridge | 2 (3,4) | 724 | *Quercus frainetto* Ten. - 60<br>*Pinus sylvestris* L.- 40 |
| Object 2 E. larch. (*Larix decidua* Mill.) | 1 | East | 10 (17.6) | 665 | *Larix decidua* Mill.- 80<br>*Pinus sylvestris* L.-20 |
| | 2 | Southeast | 8 (14,0) | 660 | |
| | 3 | Southwest | 12 (21,2) | 655 | |
| | control | Ridge | 2 (3,4) | 724 | *Quercus frainetto* Ten. - 60<br>*Pinus sylvestris* L.- 40 |

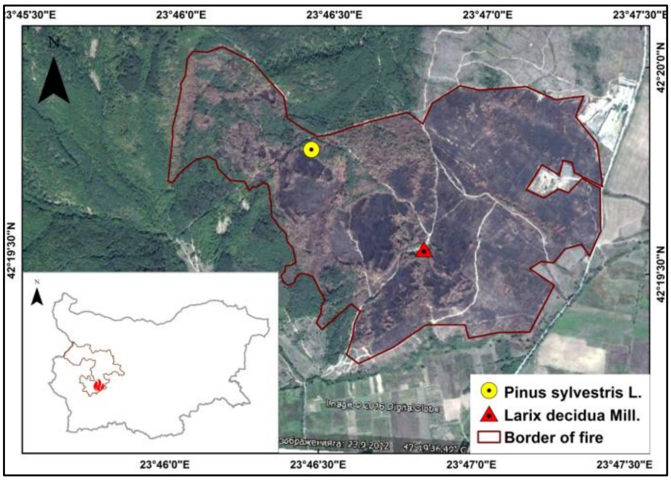

**Figure 1.** *Location of the studied region: Object 1 forest plantation of Scots pine (Pinus sylvestris L.), and Object 2 forest plantation of European larch (Larix decidua Mill.).*

### *Methods used*

The plots locations were selected randomly along the slope, according to the methodology presented in (Dakov, Vlasev, 1972). The degree of regeneration was divided into four categories as follows: very good (>75 %), good (50-75 %), weak (25-50%) and poor (<25 %), based on the requirements of the Ordinance 8 for logging.

## Results

The regeneration results obtained are presented as a number of the undergrowth per hectare (Figure 1) and as the percentage of each species to the total number (Table 2).

As can be seen, for all studied variants of Object 1, the regeneration of the dominant tree species of Scots pine (*P. sylvestris* L.) was poor (Table 1). In the fire-affected plantations, independently of the dominant species, spread before the fire influence, the pioneering species such as Silver birch (*Betula pendula* Roth.), Aspen (*Populus tremula* L.)

DOI: 10.69085/jbb20163251

**Table 2.** *Regeneration characteristics of the objects.*

| Objects | Variants | Degree of regeneration | Grass and shrubs vegetation, % - covering of the sampling area | Regenerated species after forest fire number/ha | Tree species, % - of total number of trees |
|---|---|---|---|---|---|
| Object 1 - Scots pine (*Pinus sylvestris* L.) | 1 | poor | 90–95 | 1200 | *Q. sp.* – 50<br>*P. sylvestris* – 33<br>*P. tremula* – 17 |
| | 2 | very good | 20–25 | 20600 | *B. pendula* – 77<br>*P. sylvestris* – 8<br>Q. sp. – 7<br>*S. caprea* – 5<br>*P. tremula* – 3 |
| | 3 | weak | 70–75 | 8000 | *P. Sylvestris* – 45<br>*Q. sp* – 40<br>*B. pendula* – 7.5<br>*P. tremula* – 5<br>*S. caprea* – 2.5 |
| Object 2 E. larch. (*Larix decidua* Mill.) | 1 | poor | 80–85 | 3500 | *P. sylvestris* – 80<br>*Q. sp.* – 14<br>*B. pendula* – 3<br>*Pr.communis* – 3 |
| | 2 | poor | 90–95 | 1500 | *Q. sp.* – 80<br>*P. sylvestris* – 7<br>*Pr.communis* – 7<br>*C. monogyna* – 6 |
| | 3 | poor | 90–95 | 1200 | *Q. sp.* – 58<br>*P. sylvestris* – 9<br>*R.pesudoacacia*-9<br>*Pr.communis* – 8<br>*C. monogyna* – 8<br>*B. pendula* – 8 |

and sallow (*Salix caprea* L.) were characterized by a high regeneration abundance in the post-fire plants communities (Table 1, Figure 2, 4). The data obtained show that the post-fire tree species composition in the test areas of Object 1 had changed significantly from 70% of *P. sylvestris* before fire to 20% in the post-fire test plots. The share of the Scots pine decreased in post-fire test plots, while the number of earlier-stage succession deciduous tree species increased. This clearly demonstrates the lower regeneration ability of the Scots pine in fire-affected areas, especially in those affected by crown fire. As can be seen, for all studied variants of Object 1, the regeneration of the dominant tree species of Scots pine (*P. sylvestris* L.) was poor (Table 1). In the fire affected plantations, independently of the dominant species, spread before the fire influence, the pioneering species such as Silver birch (*Betula pendula* Roth.), Aspen (*Populus tremula* L.) and sallow (*Salix caprea* L.) were characterized by a high regeneration abundance in the post-fire plant communities (Table 1, Figure 2, 4). The data obtained show that the post-fire tree species composition in the test areas of Object 1 had changed significantly – from 70% of *P. sylvestris* before fire to 20% in the post-fire test plots. The share of the Scots pine decreased in post-fire test plots, while the number of earlier-stage succession deciduous tree species increased. This clearly demonstrates the lower regeneration ability of the Scots pine in fire-affected areas, especially in those affected by crown fire.

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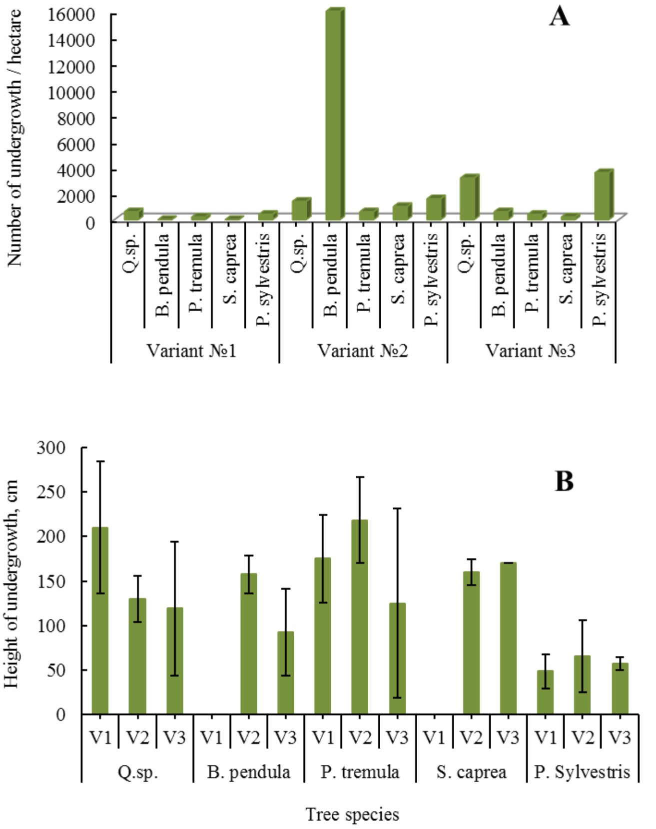

**Figure 2.** *Object 1. A – Post-fire regeneration abundance of undergrowth species, in number/ha; B – Height of undergrowth species, in cm (mean ±SD).*

**Figure 3.** *Regeneration in Object 1 (test plots – 1, 2 and 3) forest plantation of Scots pine (Pinus sylvestris L.).*

The tree species regeneration in Object 2 with pre-forest fire cover of European larch was found to be poor in all variants (Table 1). Besides the undergrowth of the Scots pine (*Pinus sylvestris* L.) with density of 1000 n/ha (48% of the total undergrowth number), and shoots of oak with density of 800 n/ha (39%), the regeneration was due to white birch (*Betula pendula* Roth.) with a density of 200 n/ha (3%), wild pear (*Pirus communis* L.) with a density of 300 n/ha (5%), common hawthorn (*Crataegus monogyna* Jacq.) with a density of 200 n/ha (3%), and white acacia (*Robinia pseudoacacia* L.) with a density of approximately 100 n/ha (2%). Regeneration of the European larch (*Larix decidua* Mill.), which is an introduced species was not observed. Probably, the high intensity crown fire has destroyed the existing seeds of the pre-fire European larch plantations.

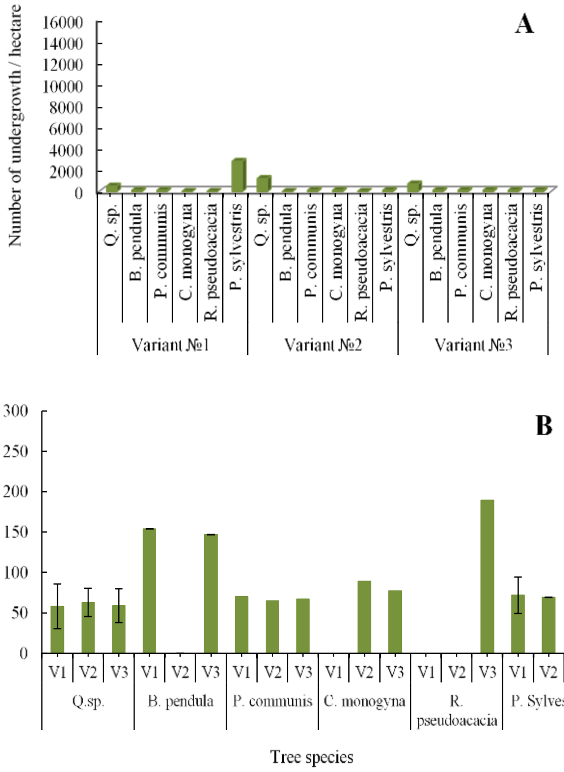

**Figure 4.** *Object 2 Pre-fire dominant tree species of Larix decidua Mill. A – Post-fire regeneration abundance of undergrowth species; B – Height of undergrowth species (mean±SD).*

**Figure 5.** *Regeneration in Object 2 (test plots – 1, 2 and 3) forest plantation of European larch (Larix decidua Mill.).*

## Discussion

The results of the presented study demonstrate that the tree species regeneration is weaker and less pronounced on the mountain slope with south and southeast exposures compared with that with southwest exposure. Slope related regeneration process dependencies have been found also by other authors (Martin-Alcon and Coll, 2016), according to whom the relief characteristics such, as slope and exposure, play a significant role in soil humidity and redistribution of nutrient elements such as carbon and nitrogen. According to Moser et al. (2010), the lack of sufficient soil humidity is one of the main factors limiting tree species regeneration in fire-affected areas,

DOI: 10.69085/jbb20163251

especially with such located at low above sea level altitudes. This is most probably the main reasons for the lower undergrowth heights of the tree species located in Object 2 in comparison with those from Object 1.

The *Querqus* species are less prone to fire influence, due to the specificity of their timber, having a thicker bark, leading to a vegetative after-fire propagation / growth through forming new cuttings. This is the most plausible explanation for the observed almost equal percentage representation of the dominant species *Pinus sylvestris* L. Compared to that of the *Querqus* species, with which a mixed plantation will be developed in future.

A similar trend has been found by Martin-Alcon and Coll, (2016), who have investigated a Black pine regeneration, 15 years after fire and have registered its weaker regrowth, although being the dominant species before the fire. In this way, in some cases, forest fires can favor conditions appropriate for the growth of fire-resistant/ tolerant species (Ivanauskas et al., 2003). The relatively small anemochorous seeds of Silver birch (*Betula pendula* Roth.), Aspen (*Populus tremula* L.) and sallow (*Salix caprea* L.) favor their easier dispersion on longer distances (Clark et al., 1998; McEuen, Curran, 2004). Furthermore, they are propagating intensively also via cuttings formation. On the other hand, the seeds of coniferous trees propagate to shorter distances and their growth depends on the presence of the trees, which have survived the fire, or their availability in the vicinity of the fire-affected territories (Franklin et al., 2002; Retana et al., 2012; Vallejo et al., 2012; Vacchiano et al., 2015).

## Conclusions

The post-fire natural regeneration processes in studied areas are related to the relief characteristics – slope and exposure. On the south and southeastern slopes, the regeneration is the lowest. On the foot of the slopes and in the micro-declines the regeneration was higher, due to increased soil humidity, while on the ridges, was the lowest one.

The diversity of broadleaves tree species recovery (birch, oak, sallow, aspen) was higher in comparison with the coniferous (Scotch pine) ones.

The share of the Scots pine decreased in post-fire test plots, while the number of earlier-stage succession deciduous tree species like white birch (*Betula pendula* Roth.), Aspen (*Populus tremula* Linn.) and *Salix caprea* (*Salix caprea* L.) are increased.

In test areas with pre-forest fire cover of European larch, the natural regeneration of earlier-stage succession was mainly with white birch (*Betula pendula* Roth.), wild pear (*Pirus communis* L.), common hawthorn (*Crataegus monogyna* Jacq.) and white acacia (*Robinia pseudoacacia* L.) Regeneration of the European larch (*Larix decidua* Mill.), which is an introduced species, was not observed.

## Acknowledgements

This research was supported by the BAS Program for Career Development of Young Scientists attributed to I. Molla.

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