ECOLOGICAL CONDITIONS AND NATURAL REGENERATION IN CONIFEROUS FORESTS DOMINATED BY SCOTs PINE (*PINUS SYLVESTRIS* L.) IN NORTHERN RILA MOUNTAIN, BULGARIA

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Abstract

Natural regeneration was studied in forests dominated by Scots pine (*Pinus sylvestris* L.) around the age of 100 years. Renewal is characterized by small species diversity of undergrowth. Predominantly involved in the composition of the undergrowth is *Picea abies* (L.) Karst. This is the result of favourable ecological conditions for the formation of mixed forests of Scots pine and Norway spruce in the research area - watershed of the Cherni Iskar River, at 1500-1550 m altitude, in the northern part of Rila Mountain. The spruce undergrowth is situated mostly in groups. In regeneration floor of studied ecosystems there are undergrowth of Norway spruce and young fir plants (*Abies alba* Mill.). Single specimens of undergrowth of beech (*Fagus sylvatica* L.) are found rarely. Height structure of the undergrowth varies in studied regeneration groups, as they are formed at different times. Indicator about that is an undergrowth age in each of them. The regeneration floor in some sectors of studied forest ecosystems by Scots pine has a terraced structure. It was found that there are young spruce trees with a height of fourteen feet on its top. The ecosystems by *Pinus sylvestris* (L.), that are studied, have natural origin.

Key words: ecology, regeneration, air temperature, undergrowth, structure, forest ecosystems

INTRODUCTION

In terms of phytogeography, Bulgaria belongs to the southeastern province of European middle floristic region (Alexandrov et al., 1988) and the coniferous species cover about one third of the forested area of the country. The history of distribution of Norway spruce in a mountain on the Balkan peninsula is rather complicated, connected with the climatic and ecological changes in the natural environment (Tonkov, Bozhilova, 2006) and the concurrence with other tree species.

Major of coniferous forests are overspread in the mountains of Southwestern Bulgaria, where there were studied regeneration processes in different mountain ecosystems (Kostov, 1989; Stoyanova, 1998, 2001, 2011; Velichkov, 2003; Velich-
kov, Popov, 2003; Popov et al., 2004; Tonkov et al., 2009). Mixed stands are more highly-productive than pure one-age stands and their formation leads to improved fertility of the natural environment. The climatic conditions of their growth and development were characterized by Raev (1983, 1994, 2006), Raev, Rossnev (2003), Dimitrov et al. (2010), Dimitrov et al. (2011), Stoyanova, Stoyanov (2012). An important contribution have the results of studying the components and processes in forest ecosystems, their structure, function and regeneration in forests of different regions of the country (Milanov, Stoyanova, 1980; Marinov et al., 1983; Zhelyazkov, Stoyanova, 1984; Stoyanova et al., 2006, 2007b, 2010a,b, etc.). Bulgaria is in border region of the spread of Norway spruce (*Picea abies* (L.) Karst.) and of beech (*Fagus sylvatica* L.) in Europe (Stefanov, 1943). Therefore scientific and practical interest of researches on the ecological conditions and the natural regeneration of these tree species is significant.

The **aim** of this study was to analyze the natural regeneration process in forests, dominated by Scots pine (*Pinus sylvestris* L.), for detecting different stages of mixed forests of pine and spruce formation, by determine quantitative and qualitative indicators of undergrowth conditions, and by characterizing some climatic indicators in relation to ecology of the undergrowth of the studied forest ecosystems.

**MATERIALS AND METHODS**

Scots pine forest ecosystems at above 100 years were studied. They are located on the northern slopes of Rila Mountain, at 1500-1550 m altitude, in the belt of the optimum Norway spruce distribution in this part of the mountain. Studied forest area belongs to Samokov State Forestry and is a part of the vegetation cover in the catchment area of Cherni Iskar River. Scots pine is one of main tree species, that form forest ecosystems in Rila. The investigated forests are situated in the Ecological Station ‘Govedartsi’ (FRI – BAS) – locality of ‘Ovnarsko’. Data on the location and forest characteristics were given by Raev (1989, 2006), Raev, Rossnev (2003), Raev, Miteva (2005).

Environmental conditions are favourable for pure and mixed coniferous forests formation in the belt of *P. abies*. The experimental areas are located near weather observation sites, provided by FRI - BAS in Station ‘Govedartsi’ (Raev, 1989, 1994). It was created in the second half of the last century for coniferous forests complex studying in Northern Rila. A brief summary, based on information from the climate station, is provided. Methods that carried out meteorological observations, are described by Raev (2006).

A study on structure and condition of natural regeneration through silvicultural methods of work was conducted (Stoyanova, 1998, 2001, 2006; Stoyanova, 2006). Undergrowth data were obtained from three experimental areas, each of which has a size of 100 m². Data analysis after assessment was performed. It was conducted as follows: establish the quantity of each undergrowth tree species; determine age
structure and height of the undergrowth. The sample plots were located in different forest sectors with regeneration groups differentiated by undergrowth age and height. They were chosen after observations on the natural regeneration of the dendrocoenoses dominated by Scots pine.

The forests are with natural origin and some of them are established to trend of plant succession. The data for the undergrowth quantity and age structure have been determined on the basis of three experimental areas. They were chosen to reflect different stages of the formation of young generation forest. Information relates to two age categories undergrowth: young and older strengthened. From the research carried out the species composition of the undergrowth and distribution, the age of the saplings have been determined. Height structure of the undergrowth varies in studied regeneration groups, as they were formed at different times. Indicator about that is an undergrowth age of the in each of them.

The natural regeneration was studied in Scots pine ecosystems, grass cover is torn at large spots in the illuminated areas. There are different size areas with dead forest underlay in more shade. The regeneration floor in some sectors was with specific structure. Studied forests of Scots pine occurred naturally. They have formed in place from the forests of *P. abies*. According to certain local information, they have occurred after anthropogenic impacts in the past for expanding grazing areas. There were carried out multiyear studies about the structure and dynamics of natural regeneration in conifer forests dominated by *P. abies*, in the Ecological Station on the northern slopes of Rila Mountain.

RESULTS AND DISCUSSION

Characteristics of ecological conditions

Climate and soil conditions on northern slopes of Rila Mountain are favourable for coniferous forests formation (Sokolovska et al., 2007; Stoyanova et al., 2007a). The investigation region is with comparatively cool mountain climate. In terms of habitats, the researched area falls in the middle-mountain sub-belt of beech, fir and spruce forests in southern border area. Soil cover in a vertical sequence is presented by two main types. These are shallow brown forest soils, saturated/unsaturated - Eutric/Distric Cambisols and ordinary dark coloured forest soils - Leptic-humic Umbbrisols, which occupy upper-mountain sub-belt of spruce forests. The brown-forest soils are well structured and the intensities of weathering, mineralization and humification are related to the high air and soil humidity, relatively high precipitation quantities and lower average annual temperatures.

Data about contemporary climate and microclimate representative coniferous forests of Rila were analyzed (Raev, 1983, 2006; Stoyanova et al., 2009; Dimitrov et al., 2011). For the northern slopes of this mountain was found that the potential duration of the vegetation period of spruce forests is about 3.5 months, but in some years, the duration varies (Raev, 2006). The climatic conditions are within the limits
of optimal values for providing constant and high bioproductivity. A good relationship was found between air temperature and duration of solar radiation; between precipitation and De Martonne index; between relative air humidity and temperatures. According to Raev, Rossnev (2003) the investigated coniferous forests grow in optimal conditions.

Table 1 shows data about average annual air temperature changing for the period 2005-2009. That climate index condition, based on outdoors and forest of Scots pine meteorological measurements in ‘Govedartsi’, is compared.

### Table 1. Average annual air temperature, at 1550 m, in the northern part of Rila Mountain for the period 2005-2009

<table>
<thead>
<tr>
<th>Location of meteorological measures</th>
<th>Average annual air temperature of the years</th>
<th>Average annual air temperature for 2005-2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>Open air</td>
<td>4.6</td>
<td>5.3</td>
</tr>
<tr>
<td>Under forest</td>
<td>4.9</td>
<td>5.2</td>
</tr>
</tbody>
</table>

According the data in Table 1, it is seen that under the canopy of Scots pine forest with Norway spruce, the average annual air temperature for the observed five-year period was 5.9 °C, and the outdoors is 5.8 °C.

The relatively large difference of the average annual air temperature measured at outdoors and in forest is established in 2005, respectively 4.9 °C and 4.6 °C. In the same year, the air temperature is the lowest than next four years.

It is noted that for the entire five-year period, the temperature ranges from 4.9 °C to 6.5 °C in the Scots pine forest, at outdoors - from 4.6 °C to 6.4 °C. In the cooler 2005, it was found at a relatively the largest amount of rainfalls (Raev, 1983, 2006; Stoyanova et al., 2009). Compared in aspect ‘in the forest and beyond’, temperature data in the coldest month of the year show their mitigation under the forest canopy.

According to data from meteorological observations in ‘Govedartsi’, at 1550 m and other Ecological Stations of FRI – BAS (Raev, Miteva, 2006), the air temperatures are above normal values in the years 1990, 1993, 1994, 1998, 2000, 2001, 2003. The maximum precipitations was observed in the spruce forests, to 1224.2 mm in 2005. It was found that the average annual air temperature and the annual rainfall. These data are averaged over an extended period of time from 1986. With increasing altitude, rainfall increases. Climatic elements are with very important ecological function for the regeneration and state of our forests.

**Natural regeneration in forests dominated by Pinus sylvestris**

Mixed pine and spruce forests in Rila are more common in its northern part. They are mostly transitional stage of succession process after burning or destruction
of spruce forests through windfalls, anthropogenic impact and others. Characteristically, these open spaces are occupied by communities of Scots pine and gradually conditions for reforestation of *P. abies* are created. Vegetation successions are related to forest biodiversity. They arise and run under the influence of different environmental factors.

The investigation is conducted on undergrowth in the tree regeneration groups. The results from observation show that the little precipitations during July and August except on the state of the saplings.

The following tables show results of natural regeneration of studied Scots pine forests. They have been formed in the belt of the optimum spread of *P. abies* in the northern slopes of Rila. Natural regeneration was studied in regeneration groups in Scots pine ecosystems, that has occurred in Norway spruce habitats.

Observations on undergrowth composition show that Norway spruce undergrowth is dominating. The undergrowth of Silver fir is significantly less involved. The results show that the composition of the undergrowth involved single individuals and beech.

Studies on the undergrowth are made in different regeneration groups (Table 2). The information relates to two age categories undergrowth: young and strengthened, which is older. According to the definition of some researchers, young undergrowth include specimens with a height of 20-30 cm. These are one-year and several-year saplings. Observations show that many of them have dried and died. This is the initial phase of origination and placement of young forest, when a root system of undergrowth is developed. At that time, young tree plants compete with grass species for moisture and nutrients needed for growth and development. Strengthened undergrowth is composed of sapling trees, that tower above the grass layer. This is the undergrowth, which has not reached a height of 1.30 m. At that height the older trees diameter is measured at the forests dendrobiometric measurements.

**Table 2.** Comparison of distribution of young and strengthened undergrowth in the different regeneration groups

<table>
<thead>
<tr>
<th>Investigated regeneration groups</th>
<th>Categories of undergrowth</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Strengthened</td>
</tr>
<tr>
<td>RPs 1</td>
<td>60.81</td>
<td>39.19</td>
</tr>
<tr>
<td>RPs 2</td>
<td>48.57</td>
<td>51.43</td>
</tr>
<tr>
<td>RPs 3</td>
<td>17.30</td>
<td>82.70</td>
</tr>
</tbody>
</table>

In Table 2 are shown the data for the undergrowth quantity and age structure in the three experimental areas (RPs 1, RPs 2 and RPs 3). They were chosen to reflect different stages of the formation of young generation forest. The information relates to two age categories undergrowth: young and older strengthened.
The natural regeneration was studied in Scots pine ecosystems, grass cover is torn at large spots in the illuminated areas. There are different sized areas with dead forest underlay in more shade.

The quantity variation of researched undergrowth from three experimental areas is reflected in the present Fig. 1. They are located at various places under the Scots pineforest canopy. The experimental areas include separate age undergrowth groups. Measurement results are compared for the two undergrowth categories. This is done for each of the three experimental areas (RPs 1-3).

![Figure 1](image)

**Fig. 1.** Amendment to the undergrowth quantity depending on its age. Age structure of the undergrowth: 1 (for age groups 1-5 years); 2 (6-10); 3 (11-15); 4 (16-20); 5 (21-25); 6 (26-30) and 7 (> 30)

Age structure and quantity of the undergrowth varies in studied regeneration groups, as they are formed at different times. Indicator about that is an undergrowth age of each of them (Table 3). In the studied regeneration groups, individuals are assigned to different groups in height. Based on the data, it was found that the maximum saplings height of the three experimental areas respectively, in the optimum zone for *P. abies* distribution in North Rila Mountain.

As results shown, the resumption in RPs 1 is relatively more heterogeneous according to the undergrowth age. This also is related to its height. For researched undergrowth from regeneration groups, it is defined the central growth. Data analysis was performed after the calculations. The results are summarized and the relative number of shares in the undergrowth of the experimental areas are established. It was found that the undergrowth from studies regeneration groups form different height structures. Its age is not also the same in the experimental areas.

Mainly involved in RPs 1 is undergrowth within 10 years (45.94%), followed by 11 to 20 years (sum 40.54%), with equal little by little about following age groups (21-30 and more 30 years). In RPs 1 prevails younger undergrowth at age of 15. The participation of the undergrowth of the last two age groups declines sharply. Presence of undergrowth for the last age group is not found in the RPs 2.
Table 3. Distribution balance between the undergrowth of age and height, for investigated regeneration groups

<table>
<thead>
<tr>
<th>Height of the undergrowth, cm</th>
<th>Age groups of the undergrowth, years</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 – 10</td>
<td>11 – 20</td>
</tr>
<tr>
<td>Undergrowth of the first regeneration group RPs 1:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to 30 cm</td>
<td>45.94</td>
<td>14.87</td>
</tr>
<tr>
<td>from 30 to 130 cm</td>
<td>-</td>
<td>25.67</td>
</tr>
<tr>
<td>Total</td>
<td>45.94</td>
<td>40.54</td>
</tr>
<tr>
<td>Undergrowth of the second regeneration group RPs 2:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to 30 cm</td>
<td>22.86</td>
<td>25.71</td>
</tr>
<tr>
<td>from 30 to 130 cm</td>
<td>8.57</td>
<td>22.86</td>
</tr>
<tr>
<td>Total</td>
<td>31.43</td>
<td>48.57</td>
</tr>
<tr>
<td>Undergrowth of the third regeneration group RPs 3:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to 30 cm</td>
<td>-</td>
<td>17.30</td>
</tr>
<tr>
<td>From 30 to 130 cm</td>
<td>-</td>
<td>40.39</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>57.69</td>
</tr>
</tbody>
</table>

For the regeneration group RPs 1 it was established that the undergrowth up to 30 cm is nearly twice more than the one with height 30 - 130 cm. The differences in the height for the other two investigated groups are: for RPs 2 the results show that the undergrowth up to 30 cm is relatively near the number of the higher one in the biogroup; for RPs 3 the data from Table 3 show that the undergrowth up to 30 cm is significantly less than the one with height 30 - 130 cm.

The results of undergrowth state in RPs 3 prove that this age group has occurred before the others. The highest number of saplings are at 11-20 years old (57.69%), followed by those aged 21-30 years old. In RPs 1 prevails younger undergrowth at age of 10 years. Presence of undergrowth for the first age group is not found RPs 3.

Data on the undergrowth age structure from the experimental areas is shown in Table 3. As the results show, the resumption in RPs1 is relatively more heterogeneous according to the undergrowth age. This also applies in relation to its height.

For studied undergrowth of regeneration groups, the growth of central stem was defined. The results obtained are summarized and the relative number of shares in the undergrowth of experimental areas was established. Manifestation of the interrelations of heliophilous as *P. sylvestris*, with species tolerant to shade as *P. abies*, are revealed in the study of the appearance of a mixed forest composed of these species.

The results show that natural regeneration dynamics in Scots pine ecosystems are characterized by pronounced unevenness. This is determined by the spatial structure of the undergrowth and the factors of its existence. On the other hand these are biology features and ecological requirements at a young age for the tree species.
CONCLUSION

Studying the characteristics of natural regeneration in forests of Scots pine allows to reveal characteristics (patterns) in the structure and dynamics of mixed forest ecosystems of Scots pine and Norway spruce. The most commonly used indicator is the quantity of undergrowth.

This study determined the structure of the undergrowth in regeneration groups. They have arisen in different periods of time, as evidenced by the age of undergrowth in them. It provides information on the ongoing stages in the dynamics of regeneration process. In Table 3, undergrowth quantity distribution in categories in various experienced areas young and strengthened are shown.

From observations made on the undergrowth composition, it is shown that Norway spruce is predominant. Silver fir undergrowth is significantly less involved. The results show that in the undergrowth composition beech is involved, but single individuals. This is the result of favourable ecological conditions for the formation of mixed forests of Scots pine and Norway spruce in the research area of the watershed of Cherni Iskar River, in the northern part of the Rila.

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