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# Natural regeneration of Norway Spruce (*Picea abies* (L.) Karst.) stands on northern Velebit

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## Abstract

***Background and Purpose***: *Natural regeneration is a natural phenomenon that depends on numerous factors. Regeneration of virgin forests is successful even without any human interference. For the regeneration of economic forests we do not have that much time and thus try to speed up the process. The study of factors involved in natural regeneration as the most perfect system of forest ecosystem regeneration requires long lasting research.*

***Material and Methods:*** *Numbers and heights of seedlings and new growths, as well as the species participating in natural regeneration were measured on four test plots over the period of four years (1995, 1998, 1999, 2000). The plots were located at different elevations and contained different plant communities. The Norway spruce seed yield and its quality (germination) were also researched.*

***Results:*** *Very poor appearance of seedlings and new growth and even the decline in the numbers were observed on all test plots. This can be directly correlated to management in which single-tree selection management and piling of timber supply result in poor light conditions and gradual disappearance of Norway spruce. Seed germination ranging from 13% on plot I to 48% on plot II shows that the seed has very low natural germination and only abundant crops can lead to greater natural regeneration.*

***Conclusion***: *Norway spruce is a species whose natural regeneration in the above mentioned structural and site conditions is a difficult process. Natural regeneration of Norway spruce is affected by management, timber supply, condition of vegetation on the soil, as well as the intensity of light. The seed quality and its quantity did not affect regeneration on test plots.*

## INTRODUCTION

Norway spruce is a species covering a small area of only 16.760 ha with timber supply of around 3 mil.m$^3$, which amounts to 1% of all forests in the Republic of Croatia *(1)*. The present-day situation and way of managing Norway spruce stands on Northern Velebit are not completely satisfactory. At many places the Norway spruce is disappearing, the natural regeneration is failing, the stands are becoming weedy and there are many other problems that are slowly but steadily threatening the Norway spruce. Norway spruce has been drying lately due to the European spruce bark beetle (*Ips hypographus* L.) *(2)*. Interaction of several factors is of special importance. Regeneration measures for each separate case must be adjusted to special site conditions and local

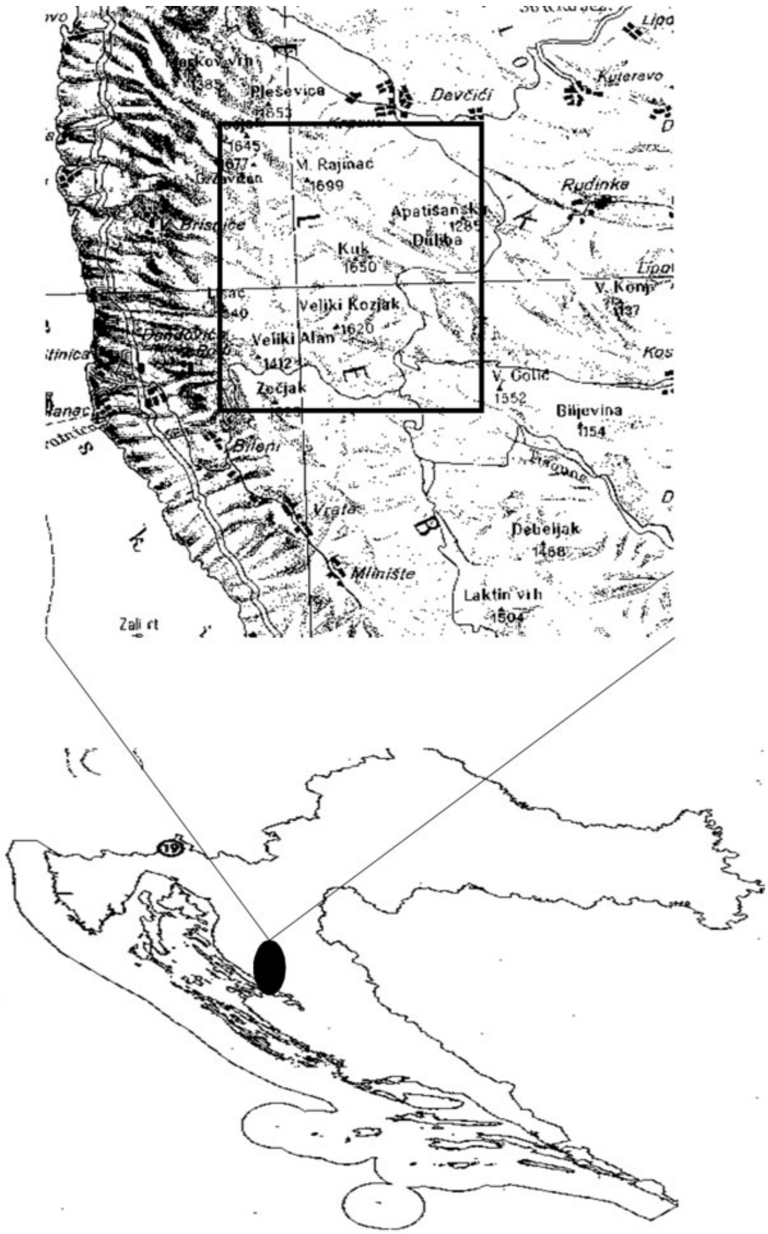


**Figure 1.** *Field of research*.

characteristics of forest communities. A measure which proved to work on northern expositions can be a complete failure at other locations.

## FIELD OF RESEARCH

Velebit is usually divided into northern, from Vratnik to Veliki Alan, central from Veliki Alan to Oštarije, southern from Oštarije to M. Halan and south-eastern part from M. Halan to Zrmanja. According to Poljak *(3)* northern Velebit is the part stretching between the roads Senj-Vratnik-Žuta Lokva and Stinica-Alan-Mrkvište. The field of research included mainly northern Velebit with the exception of Štirovača which belongs to central Velebit.

## MATERIALS AND METHODS

The research method was based on stationary research on test plots. When selecting test plots we tried to choose typical sites for the Norway spruce on Northern Velebit.

The plots were located at different elevations and site conditions. We determined the total of four test plots as we believe they include most site conditions on Velebit. The size of the test plots was 50m x 50m. We tried to select the plots in stands untouched by man for a prolonged period of time, such as virgin forests, protected objects, tree seed stands or unmanaged stands. The research was carried out over the period of four years.

In order to obtain basic structural data on every test plot we measured the tree circumference of every tree

**TABLE 1**

Seedlings and new growth structure on test plot I.

| Different stages | Norway spruce | | | | Silver fir | | | | Common beech+maple | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 |
| Seedlings | | 1 | | | 65 | 42 | 16 | 9 | 3 | | | |
| –25 | 1 | 1 | 2 | 2 | 121 | 157 | 163 | 167 | 20 | 15 | 9 | 9 |
| –50 | | | | | 4 | 4 | 4 | 4 | 15 | 17 | 17 | 14 |
| –75 | | | | | | | | | 10 | 8 | 9 | 9 |
| –100 | | | | | | | | | 13 | 12 | 12 | 12 |
| –125 | | | | | | | | | 3 | 3 | 3 | 3 |
| –150 | | | | | | | | | 2 | 2 | 2 | 2 |
| –175 | | | | | | | | | 1 | 1 | 1 | 1 |
| –200 | | | | | | | | | 1 | 1 | 1 | 1 |
| –225 | | | | | | | | | | | | |
| –250 | | | | | | | | | 3 | 3 | 3 | 3 |
| Total | 1 | 2 | 2 | 2 | 190 | 203 | 183 | 180 | 71 | 62 | 57 | 54 |
| **Per 1 ha** | **100** | **200** | **200** | **200** | **19000** | **20300** | **18300** | **18000** | **7100** | **6200** | **5700** | **5400** |

higher than 9 cm, as well as its height. On every test plot we measured regeneration elements on a 2 m wide profile, through the entire plot (100 $m^2$). On each plot and in its immediate vicinity we gathered cones in order to determine the quantity of crop and the elements of spruce seed quality.

The quality of forest seed was tested in the laboratory of the Department of Ecology and Silviculture, Faculty of Forestry, University of Zagreb in Krstić germinators and on the basis of ISTA Rules *(4)*. Seed extraction was performed in the seed extraction plant of a Forest Research Institute Jastrebarsko.

## RESEARCH RESULTS

### Test plot I

Test plot 1 was located in the secondary virgin forest Klepina Duliba in Štirovača. The data from table 1 show that the test plot contained only two spruce plants of which only one new plant appeared in the last three years. There were more silver fir plants. Every year we noticed an abundant appearance of new growths and their survival. It needs to be added that the test plot was located in the part of the stand with the Norway spruce prevalence. Average relative light intensity of 2.7% was measured on the entire plot.

The virgin forest was in optimal stage with several of its parts in the stage of decay. One part of the test plot was in the stage of decay. The stand was characterized by thick density, and light intensity was very poor. This could explain why silver fir seedlings prevailed. However, this does not account for the lack of spruce seedlings, as at this elevation light is not essential for germination, except as a source of heat (direct light). Beech and a few maples prevailed among broad leaved species.

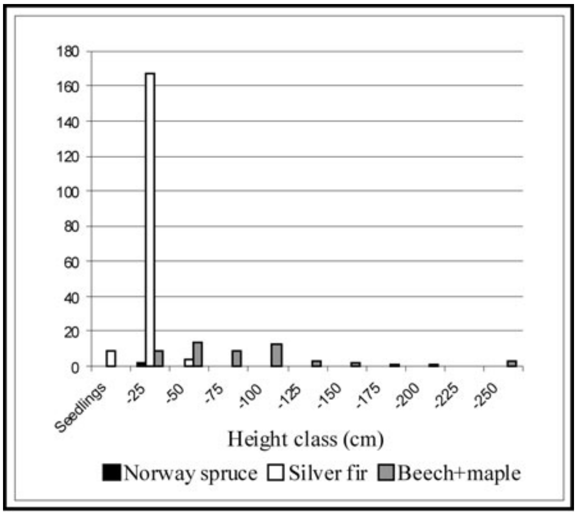


**Figure 2.** *Distribution of seedlings and new growth numbers on test plot I.*

These trees can be found at the edge of the stand, they are suppressed and in these conditions have little chance for survival.

### Test plot II

Table 2 clearly shows that fir prevailed on this test plot as well. There was almost no spruce with an exception of a few weak and suppressed plants among new growths. Beech and maple were more significantly represented at plot edges along the road due to better light conditions, while beech tended to appear in smaller depressions where snow stayed longer. Fir appeared abundantly, especially at slightly elevated places. Light conditions on the test plot were also weak due to the thick canopy, and

**TABLE 2**

Structure of seedlings and new growth on test plot II.

| Different stages | Norway spruce | | | | Silver fir | | | | Common beech+maple | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 |
| Seedlings | | | | 2 | 1 | 19 | 25 | 11 | | 1 | 1 | |
| –25 | 3 | 2 | 2 | 2 | 24 | 24 | 32 | 28 | 1 | 1 | 2 | 2 |
| –50 | 1 | 2 | 2 | 2 | 17 | 15 | 15 | 15 | 1 | 1 | 1 | 1 |
| –75 | | | | | 6 | 8 | 8 | 8 | 2 | 2 | 2 | 2 |
| –100 | | | | | | | | | | | | |
| –125 | 6 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 |
| –150 | 7 | 7 | 7 | 7 | | | | | | | | |
| –175 | | 1 | 1 | 1 | | | | | | | | |
| –200 | 2 | 1 | 1 | 1 | | | | | | | | |
| –225 | | | | | | | | | 1 | 1 | 1 | |
| –250 | | | | | 1 | 1 | 1 | | 2 | | | 1 |
| Total | 19 | 18 | 17 | 20 | 52 | 70 | 84 | 65 | 8 | 7 | 8 | 7 |
| **Per 1 ha** | **1900** | **1800** | **1700** | **2000** | **5200** | **7000** | **8400** | **6500** | **800** | **700** | **800** | **700** |

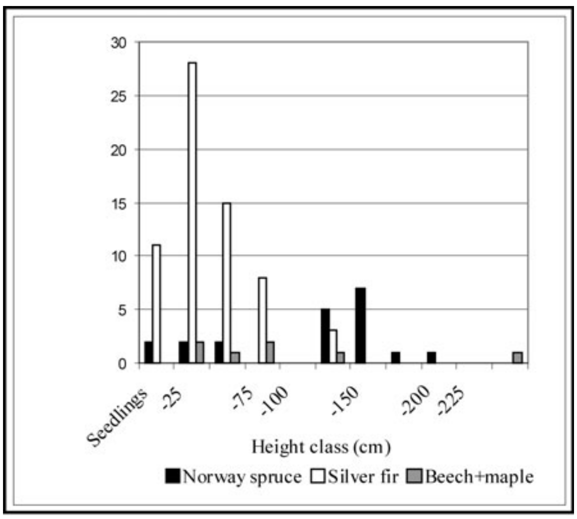


**Figure 3.** *Distribution of seedlings and new growth numbers on test plot II.*

the average measured light intensity was 2.9%. Mountain Ash (*Sorbus aucuparia* L.) was present in large numbers and silver fir appeared abundantly underneath.

## Test plot III

The data presented in Table 3 confirm the prevalence of silver fir on the test plot. It was widespread, very vital and looked good. There were few Norway spruce trees and, as shown in the table, their numbers were declining. This test plot was quite rocky with very little flat area and the soil contained between the rocks. Despite the unfavorable conditions the silver fir proved to be resistant and several seedlings were noticed to be alive in small quantities of soil in the rocks. The maple seemed to be developing very well in the upper parts of the rocks which had plenty of light. It is worth mentioning that silver fir seedlings developed on moss layers on the northern sides of the rocks. They will probably die later on due to lack of water. The average light intensity measured the whole plot amounted to 3.7%.

## Test plot IV

From the data presented in Table 4 it is evident that there was almost no natural regeneration on this test plot. The transects for measuring regeneration elements included only one Norway spruce plant through all the four years of measurement. The same was true of the entire plot where no Norway spruce plant was recorded. A similar thing happened with the silver fir whose seedlings and new growth did not appear in larger numbers. The situation in the stand outside the test plot was iden-

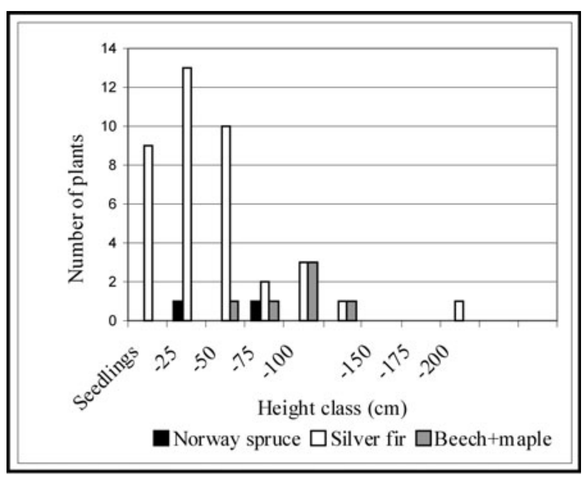


**Figure 4.** *Distribution of seedlings and new growth numbers on test plot III.*

**TABLE 3**

Seedlings and new growth structure on test plot III.

| Different stages | Norway spruce | | | | Silver fir | | | | Common beech+maple | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 |
| Seedlings | | | | | 1 | | 24 | 9 | | | | |
| –25 | 4 | 2 | 2 | 1 | 21 | 14 | 12 | 13 | 1 | | | |
| –50 | 3 | 2 | | | 6 | 9 | 9 | 10 | 6 | 1 | 1 | 1 |
| –75 | | 1 | 1 | 1 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| –100 | | | | | 2 | 2 | 3 | 3 | | 5 | 5 | 3 |
| –125 | | | | | 1 | 1 | 1 | 1 | 6 | 2 | 2 | 1 |
| –150 | | | | | | | | | | | | |
| –175 | | | | | | | | | | | | |
| –200 | | | | | 1 | 1 | 1 | 1 | 1 | | | |
| –225 | | | | | | | | | | | | |
| –250 | | | | | 1 | | | | 1 | | | |
| Total | 7 | 5 | 3 | 2 | 36 | 30 | 51 | 41 | 16 | 9 | 9 | 6 |
| **Per 1 ha** | **700** | **500** | **300** | **200** | **3600** | **3000** | **5100** | **4100** | **1600** | **900** | **900** | **600** |

**TABLE 4**

Seedlings and new growth structure on test plot IV.

| Different stages | Norway spruce | | | | Silver fir | | | | Common beech+maple | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 | 1995 | 1998 | 1999 | 2000 |
| Seedlings | | | | | | 11 | 3 | | | | | |
| –25 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | | | | |
| –50 | | | | | | | | | 3 | 2 | 2 | 2 |
| –75 | | | | | | | | | | | | |
| –100 | | | | | | | | | 1 | 1 | 1 | 1 |
| –125 | | | | | | | | | | | | |
| –150 | | | | | | | | | 6 | 4 | 3 | 3 |
| –175 | | | | | | | | | | | 1 | 1 |
| –200 | | | | | | | | | | | | |
| –225 | | | | | | | | | | | | |
| –250 | | | | | | | | | | | | |
| Total | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 10 | 7 | 7 | 7 |
| **Per 1 ha** | **100** | **100** | **100** | **100** | **200** | **200** | **300** | **300** | **1000** | **700** | **700** | **700** |

tical. We believe that a very dense vegetation, in several places up to 1 meter high, was the main cause of the problem. Grass cover was so dense that it prevented contact of the seed with soil. The seed that managed to germinate was destroyed when high snow pressed grass vegetation on young plants. Competition due to shortage of water in this area was another decisive element for the failure of natural regeneration. As this is an economic forest, the test plot did not contain (high) rootstocks nor uprooted trees on which seedlings could develop. Average relative light intensity on the test plot amounted to 11.2%.

## Seed germination

The main prerequisite for natural regeneration of every stand is the seed of good quality and sufficient quantity, and the soil which is ready to receive the seed and enable its germination. Besides abundant crops, the seed must be of adequate germination capacity. For this reason we gathered Norway spruce cones, extracted the seed and tested its germination.

In Sweden the seed in cones matures in September and in Poland and Byelorussia in October. Seed dispersal starts at the beginning of September and most of it falls

**TABLE 5**

Seed germination of Norway spruce.

| Plot number | Number of seeds | Germination after (days) | | | Total | Ungerminated |
|---|---|---|---|---|---|---|
| | | 7 | 14 | 21 | (%) | (%) |
| I | 100 | 12 | 0,5 | 0 | 13 | 87 |
| II | 100 | 45 | 3,5 | 0 | 48 | 52 |
| III | 100 | 12 | 2 | 0 | 14 | 86 |
| IV | 100 | 23 | 1 | 0 | 24 | 76 |

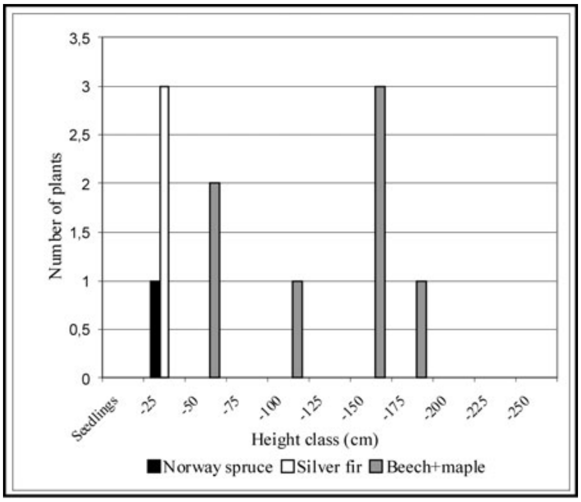


**Figure 5.** *Distribution of seedlings and new growth on test plot IV*

during winter when seed moisture is lower than 18%. When we started gathering cones at the end of August no cone was open. Good yield which can be expected every 3 to 5 years depends on geographical position *(5)*. At higher latitudes and elevations, the period can be even longer. Our results of laboratory germination tests ranged from 13 to 48% but in natural conditions they must be much lower. Only abundant yields can result in a large appearance of seedlings.

## DISCUSSION AND CONCLUSION

When discussing regeneration of Norway spruce stands on high mountain elevations (1.200 – 1.400 m) we must consider the following *(6)*:

- there are no rules for regeneration of mountain forests
- lack of heat
- movement of snow masses
- vegetation competition
- shortage of seed with germination capacity
- unfavorable soil for germination and nutrition (layers of leaves, decay and raw humus)
- frost and frost droughts.

Complex interaction of individual factors is of special importance. Measures for regeneration must be adapted to special site conditions and local characteristics of forest communities *(7, 8)*. A method which proved to work at northern expositions can fail at other locations. We must take this into account when analyzing our measurements.

As far as the regeneration of Norway spruce is concerned, the situation is alarming. Its regeneration is poor and completely absent on some plots. The research lasted six years and the seedlings and new growth were measured throughout this period. However, on two plots no new plants could be recorded. There are many reasons for this. Either excessive weeding or intensive felling were recorded on north-western expositions, which resulted in soil drying, decay of Norway spruce seedlings and entrance of beech. The phenomenon is particularly evident at high elevations closer to sub-alpine beech forest belt. Let us remind of Ott *(6)* and human impatience with regeneration of high mountain stands. Despite poor or no regeneration, the forests were »managed« and the basic mass was reduced. In this way the forest got plenty of light, which led to weeding and wind downtimber. Of course, the method of management was irregular selection cut. Due to thick canopy cover, rare seedlings and new growth could not survive. Deep valleys rich in nutrients and snow have strong vegetation competition. Such conditions are unfavorable for the growth of Norway spruce *(9)*. Nature itself took care of its successful regeneration in these conditions by enabling regeneration on fallen and decayed rootstock and trunks. However, the present-day situation, when the entire tree is used, does not allow for such regeneration. Therefore, it is recommended to leave a few trees of lower value, especially at the bottom of funnel-shaped holes where vegetation competition is the strongest. According to Hilgarter *(10)* the seedlings that develop in soil survive in larger numbers than those grown on decayed rootstock. The appearance of seedlings on decayed trees is higher than on mineral soil.

The yield and the quality of seed are very poor. In the researched period we did not record high yield of cones and the results of test seed collecting proved its low quality. Laboratory germination ranged from 13 to 48%. At higher elevations we observed even lower germination. If the seed is bad and the soil that should receive it is not favorable, then regeneration results should not be surprising.

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