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# FIVE-YEAR HEIGHT GROWTH OF NORWAY SPRUCE ADVANCE REGENERATION FOLLOWING CUTTING OF SMALL CANOPY OPENINGS IN A SPRUCE MIRE

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## SUMMARY

We studied the early height growth of Norway spruce advance regeneration in one experimental stand in northern Finland where canopy openings were cut with three different diameters (10 m, 15 m and 20 m). The experimental design included four blocks in which the cuttings were made with 2 – 4 replicates. Altogether 386 advance growth trees were measured for total height in spring 2005 and spring 2010. Average five-year height growths were 13.7, 14.6, and 12.9 cm, in the 10, 15, and 20 m openings, respectively. The opening size was non-significant but the interaction between size and tree height in 2005 was significantly explaining growth.

KEYWORDS: canopy opening, height growth, spruce mire, *Picea abies*

## INTRODUCTION

Large areas of drained spruce mires are approaching regeneration maturity in Finland (Hökkä *et al*. 2002). Currently, artificial regeneration with clear-cutting and planting of Norway spruce (*Picea abies* (L.) Karst.) seedlings is the most commonly used method and it has been shown to produce good regeneration results (Moilanen *et al*., 1995). Costly early age investments and the potential for leaching of nitrogen and phosphorus and suspended solids into the receiving water bodies are the problems of artificial regeneration in fertile drained peatland sites (Nieminen, 2004).

In a recent study, cutting of small canopy openings as an alternative to clear-cutting has proven to result in good regeneration density in spruce mires (Hökkä *et al*., 2012). In a mature Norway spruce stand, the number of advance growth after cutting varied from 670 to over 37 000 seedlings per hectare (Hökkä *et al*., 2011). During five years after cutting, also a considerable number of additional new seedlings were established. Conifer seedlings have been shown to germinate easily on peat (Sarasto and Seppälä, 1964) which may explain the good results of studies on natural regeneration of spruce mires (e.g., Holgén and Hånell, 2000).

In mineral soil sites the development of spruce advance growth after over-story removal has been shown to be rather slow, only 20-30 cm during the first five years (Koistinen and Valkonen, 1993). This is because spruce seedlings need several years to adapt to the changed environmental conditions followed by cutting. On the other hand, Niemistö and Poutiainen

(2004) found that spruce height growth on drained peatlands responded to birch overstory removal already within the first five-year period.

The objective of this study was to investigate the height growth response of Norway spruce advance growth seedlings to the cutting of small canopy openings of different size in fertile drained spruce mire in northern Finland.

## MATERIALS AND METHODS

The study site was located in southern Lapland (N = 7341008, E = 440177) and was classified as a eutrophic, shallow-peat spruce swamp (Vasander and Laine, 2008) with peat thickness varying from 10 – 50 cm. The average annual temperature sum (with 5 $^{o}$C threshold) during the years 2000–2010 was 1076 dd ˚C. The site was drained first time in the 1960s, and the present tree stand was composed of mature Norway spruce with variable admixture of pubescent birch (*Betula pubescens* Ehrh.). Stand dominant height varied from 17 to 18 m, and stand volume from 170 to 227 $m^3$ $ha^{-1}$.

The experiment was established in autumn 2004. The cuttings were done in winter 2004-2005. Three opening diameters were used: 10, 15, and 20 m. The experimental design was composed of altogether 4 randomized blocks, each including the three different opening sizes replicated 2 – 4 times.

The regeneration result and seedling characteristics were inventoried as follows: a circular sample plot of 10 $m^2$ in size (radius = 1.79 m) was located in the middle of each opening and 5 $m^2$ (radius = 1.26 m) plots were established in each cardinal direction (N, E, S, W) at a 1.5 m distance from the edge of the opening. For this height growth study, 386 advance growth trees (height after cutting > 10cm and < 2m) from 23 openings were measured for total height in two surveys carried out in spring 2005 and spring 2010.

Statistical analysis was performed to test the effect of opening size on seedling 5-year height growth. The following mixed ANOVA model was used to analyze the block-level average seedling densities:

$$ih_{ki} = bx_{ki} + u_k + e_{ki} \qquad (1)$$

where

$ih_{kt}$ = height growth of seedling i (cm) in block $k$
$x_{kt}$ = independent variables (opening size, height in 2005)
$b$ = fixed parameters
$u_k$ = random effect for the $k$th block
$e_{ki}$ = random effect of tree i on plot k

## RESULTS

Average heights of the seedlings after cutting in 2005 were 39.3 cm, 37.3 cm and 34.0 cm, in the 10 m, 15 m, and 20 m diameter openings, respectively. Highest average 5-year height growth was 14.6 cm in the 15 m openings and lowest growth 12.9 cm in the 20 m openings (Fig 1). In 10 m openings, height growth was 13.7 cm. According to ANOVA model the main effect of opening size was non-significant but the interaction between opening size and tree height in 2005 was a significant explanatory variable (Table 1). In mid-sized openings, better height growth was observed with increasing tree height in 2005, while there was no such trend in the large and small openings (Table 1).

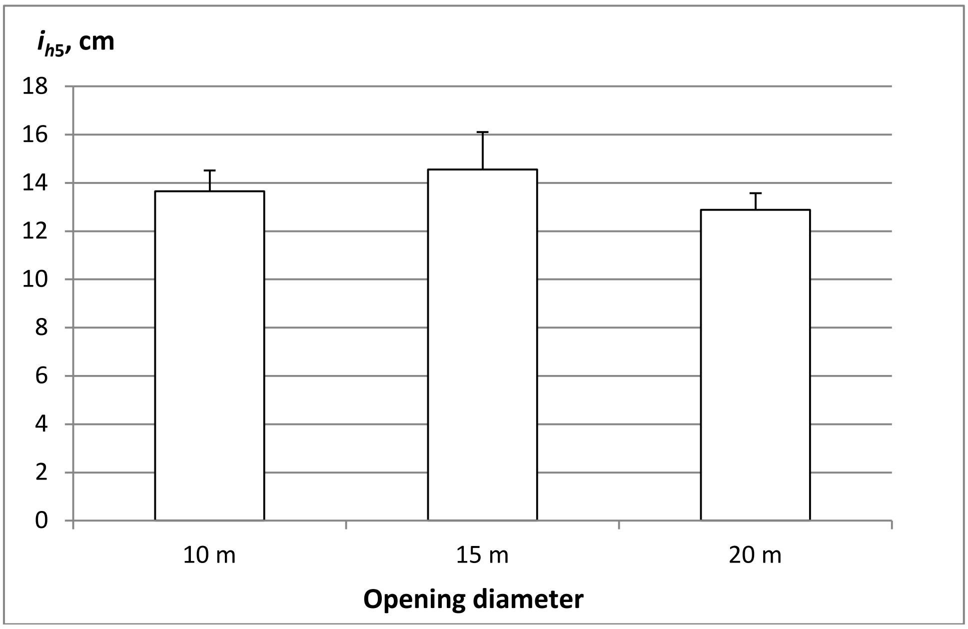


Fig. 1. Average five-year height growth of Norway spruce advance growth seedlings in different size canopy openings. Bars indicate standard error of mean (N=386).

Table 1. The parameter estimates and their standard errors and t-values of model (1)

| Effect | Estimate | Standard Error | t-value |
|---|---|---|---|
| Intercept | 13.294 | 2.460 | 5.40 |
| 10 m | 2.780 | 3.192 | 0.87 |
| 15 m | -6.152 | 3.517 | -1.75 |
| 20 m | 0 | . | . |
| 10 m*$h$ | -0.054 | 0.034 | -1.62 |
| 15 m*$h$ | 0.189 | 0.046 | 4.10 |
| 20 m*$h$ | -0.023 | 0.036 | -0.66 |

$h$ = tree height in 2005, cm

DISCUSSION

In general, the average five-year height growth of advance growth spruce seedlings after opening cutting was relatively low. However, the first five-year height growth of released spruce seedlings in mineral soil sites in study of Koistinen and Valkonen (1993) was of the same magnitude if the geographical differences are taken into consideration. The results of this study showed that during the first five years differences among the openings in height growth were not observed.

In the mid-sized opening tree height in the beginning of the growth period showed positive correlation with height growth, i.e., trees of greater initial height showed better 5- year growth. This is in accord with result of Koistinen and Valkonen (1993), who concluded that initial tree height explained height growth of released Norway spruce seedlings. The result was, however, non-consistent for all cutting treatments and the reasons could not be explained by the present data.

Valkonen (2000) has described the release growth pattern of Norway spruce after over-story removal to be composed of several phases. According to Valkonen (2000), it will take ten years before the height growth of released seedlings deviates from that of the non-released seedlings in mineral soil sites in southern Finland. The total length of the recovery period was on average 14 years after which the seedling height growth became equal to the growth of non-suppressed seedlings of a spruce plantation (Valkonen, 2000). Contrary to this, Mielikäinen and Valkonen (1995) found that spruce height growth responded to removal of silver birch (*Betula pendula* Roth.) overstory in 4-7 years in a mineral soil site. Similarly, Niemistö and Poutiainen (2004) showed that the recovery period lasted 5-10 years after removal of a pubescent birch overstory in a drained peatland site. Probable reason for the different result is that initial light conditions are more favorable for seedlings growth under birch overstory than under spruce overstory. Because the seedlings of this study originate from a mature spruce-dominated stand it is likely that differences in growth may be expected in ten years after cutting.

Because of significant differences in the sizes of the openings and subsequent differences in light and available energy, seedling height growth should also differ among the openings. On the other hand, better growing conditions in the largest openings may partly be compensated for by the emerging ground vegetation, which is more abundant in the largest openings.

On the basis of the recent studies, cutting of small canopy openings appears to be a cheap method to regenerate spruce mires, because of the abundant advance growth and establishment of new spruce seedlings (Hökkä *et al*., 2011). However, the usability of the method also depends on the ability of the natural seedlings to eventually attain growth rate that is comparable to that of planted seedlings. Future inventories of seedling development are necessary to give answer to that issue.

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