Available online at www.sciencedirect.com
ScienceDirect
Forest Ecology and Management 255 (2008) 1186–1195
Forest Ecology and Management
www.elsevier.com/locate/foreco

Establishment of direct seeded seedlings of Norway spruce and Scots pine: Effects of stand conditions, orientation and distance with respect to shelter tree, and fertilisation

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Received 17 January 2007; received in revised form 13 September 2007; accepted 13 October 2007

Abstract

The objectives of this work were to quantify the effects of stand stem density (SSD), orientation and distance with respect to shelter tree, and fertilisation on the establishment of *Pinus sylvestris* L. and *Picea abies* (L.) Karst. regenerated by direct seeding on different soil preparations. The field experiment was performed on South (64°14′N, 19°46′E, 225 m a.s.l.) and North (64°09′N, 19°36′E, 274 m a.s.l.) slopes in boreal Sweden. Regeneration and height growth in three SSDs with different light regimes, i.e. uncut forest (~500 stems/ha), shelterwood (~150 stems/ha), and clear-cut, were compared. Sowing was done in 2001, after using two soil preparations (mineral soil and a mixture of mineral soil and humus layer ground to a fine texture), at six distances to shelter trees (0.5, 1, 1.5, 2, 4 and 6 m). Half of the seedlings were also irrigated with fertiliser (10 mM N) from the second to the fourth growing season after seeding, i.e. until final inventories were made. The light environment did not differ significantly between different orientations and distances with respect to trees, but it was clearly different between SSDs. The establishment and growth of direct seeded seedlings depended on species and SSD as well as on soil preparation. On the North slope, the emergence was highest (50 seedlings in percent of germinable seeds for *P. sylvestris* and 44% for *P. abies*) in SSD 150. On the other hand, on the South slope the conditions in SSD 0 favoured the high emergence of *P. sylvestris* (41%), whereas for *P. abies* there was no difference between SSD 0 and SSD 150 (28% versus 30%, respectively). The soil preparation that created a mixture of mineral soil and humus layer generally favoured seedling emergence. Only for *P. abies* on the North slope, fertilised seedlings were taller (ca. 20%) than non-fertilised seedlings. After four years, *P. abies* on the North slope was most successful with nine seedlings in percent of germinable seeds remaining out of 24% emerged. The main conclusion is that for plant establishment from seed, the general conditions of the stand matter more than the orientation and distance with respect to the nearest tree and the light environment is more important than the nutritional status, i.e. light requirements cannot be moderated by nutrient supply.

Keywords: Frost heaving; Height growth; Light; Predation; Shelterwood; Soil preparation; Clear-cut; Dense forest

1. Introduction

During the latter part of the 20th century, Fennoscandian forests have been harvested mainly by creating clear-cuts. This method has the advantage of being effective, but it is questioned. There is a growing interest in forestry-related amenity and recreation together with a debate on forest decline and certification, which both favour more environmentally friendly approaches to forest management (Pommerening, 2006). Furthermore, regeneration following clear-cutting is not always successful as the local climate changes along with soil flora and soil nutrient and water contents (Ottosson Löfvenius, 1993; Marshall, 2000; Langvall and Örlander, 2001). At least in small-scale forestry, other methods than clear-cutting, e.g. different types of continuous cover forestry systems (CCFS), are of interest.

In areas that are difficult to regenerate, for example in wetlands, in areas with high risk of frost, or in stands where competition from the surrounding vegetation is severe, the use of shelterwoods, i.e. a form of CCFS, when regenerating forests can be advantageous. Shelter trees not only provide seeds for natural regeneration, but they also create a favourable environment for seedlings. The ground temperature in a day is more stable in a shelterwood than on a clear-cut since the

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0378-1127/$ – see front matter
doi:10.1016/j.foreco.2007.10.024

overstorey trees to some extent prevent the long-wave radiation from leaving to the atmosphere. This will give less frequent summer frosts and less frost heaving but also less incoming radiation (Hannerz and Gemmel, 1994; Orlander and Langvall, 1997; Orlander and Karlsson, 2000). Other effects of shelter trees are that the seedlings will benefit from less wind exposure, more stable soil water content (on a clear-cut there can easily be an excess of water when the mature stand is removed, but also droughts as a result of more extreme temperatures), and less vegetation competition for seedlings (Holgen and Hånell, 2000).

However, leaving shelter trees when harvested may also bring disadvantages for the following regeneration. A high shelter tree density together with the location of seedlings compared to the surrounding trees may create a microclimate with competition for light, water, and nutrition (Malcolm and Ibrahim, 1993; Ottosson Löfvenius, 1993; de Chantal et al., 2003b). Depending on growing site, mechanical disturbances due to snow and rain (Goulet, 1995; Winsa, 1995a) and predation (Nystrand and Granström, 1997b,a, 2000) will also affect seedlings. It is thus necessary to fully understand the complex picture of competition both between seedlings and between seedlings and mature trees. For optimum regeneration with a sufficient number of seedlings and good growth in an uncut forest the tree canopy has to be layered in a way that favours development of a forest stand with a gap structure close to that of a natural forest (Linder et al., 1997; Okland et al., 2003).

In this work focus was on regeneration from seed. In a separate paper focus is on regeneration from plants (Erefur et al., in preparation). The overall aim of this work and the parallel work on plants is to understand how the environment could be moderated in combination with the selection of plant material to get a cost-effective regeneration in CCFSs. This research aims at optimizing silvicultural methods and at answering the following questions. Is it possible to say how sparse a forest stand has to be in order for individual distance to shelter tree to matter for seedling growth? At what distance will competition between shelter trees and seedlings then occur, and what type of competition will take place? Can fertilisation outweigh inadequate light conditions? The specific objectives of this study were to quantify the effects of stand stem density (SSD), orientation and distance with respect to shelter tree on seedling emergence, mortality, and height growth at two sites on slopes of opposite aspects. On height growth, the effect of fertilisation was also evaluated. Shade-tolerant *P. abies* (*Picea abies* L. Karst.) and shade-intolerant *P. sylvestris* (*Pinus sylvestris* L.) growing on two different soil preparations were compared, based on their light demands. Hypothesising that light was the main competitive factor, one further objective was to characterise the light environment in the different SSDs.

2. Materials and methods

2.1. Study site and experimental design

The experiment was performed on a South slope (64°14′N, 19°46′E, 225 m a.s.l., 7.5% declination) and a North slope (64°09′N, 19°36′E, 274 m a.s.l., 12% declination) in Vindeln Experimental Forests, 60 km NW of Umeå in northern Sweden. Both slopes are spruce-dominated with a vegetation cover dominated by *Vaccinium myrtillus* L. on a moist podzolic soil with a texture of loamy sandy till (Hägglund and Lundmark, 1982). Further information on the site characteristics is presented in Table 1. Three different types of stands were selected or created in May 2001 at each site, that is SSD 500 (~500 stems/ha, i.e. dense forest), SSD 150 (~150 stems/ha, i.e. thinned forest or shelterwood) and SSD 0 (clear-cut; created about 10 years before the thinned forest/shelterwood). All three experimental areas were ca. 50 m^2, but whereas SSD 150 was thinned as a circle in the forest of SSD 500, both SSD 500 and SSD 0 were delimited within a larger area of SSD 500 and SSD 0, respectively. The climate in northern Sweden is temperate with a rather limited growing season mainly in June, July, and August. The weather conditions during the years of the experiment are listed in Table 2, showing that the summer of 2001 was wet whereas 2002 was dry and warm. The summers of 2003 and 2004 were closer to last decade normals in temperature and precipitation.

Table 1
Stand characteristics

	Site index[a]	Age	Volume (m^3 sk/ha)	Basal area (m^2/ha)
South slope	G22	144	340	37
North slope	G20	111	182	27

The inventory was done in 1989 except for basal area that was measured in 2002.
[a] Top height (m) in even-aged stands at 100 years of total age for Norway spruce.

Table 2
Weather conditions on the South slope (S) and North slope (N)

Condition	Growing season[a]							
	2001		2002		2003		2004	
	S	N	S	N	S	N	S	N
Number of days	169	169	150	150	139	139	160	162
Temperature sum[b] (day °C)	995	1038	1228	1298	1062	1081	914	954
Precipitation[c] (mm)	561	585	216	251	392	340	394	421

[a] Period of the year when the daily mean temperature is above +5 °C.
[b] The sum of the mean temperature for all days with daily mean temperature above +5 °C.
[c] Measured 1.6 m above ground.