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Sustainable forest management in northern Fennoscandia (NORFOR)

Seminar on forest regeneration and management in Salla, Finland, 29–30 September, 2009

Mikko Hyppönen and Sirkka Tapaninen (eds.)

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Abstract

Forests are extremely important for regional development and welfare in northern Fennoscandia, and the problems and questions related to forest management and forest research are very similar in all the countries in the area. Forest management in the severe northern conditions is based on scientific knowledge produced by the national forest research institutes and universities. However, there has so far been relatively little cooperation in research on forest management between the countries. Since 2007, the NORFOR network of sustainable forest management in northern Fennoscandia has initiated a number of cooperative projects and arranged meetings, workshops and excursions focused on forest management in the of the harsh climatic conditions of northern Fennoscandia. The main topics have been natural regeneration and direct seeding of Scots pine, damage by pathogens and pests, the interplay between forestry and reindeer husbandry, and the risk management and profitability of different silvicultural regimes.

The overall aim of the NORFOR network is to establish a borderless platform in the field of research and higher education of forest management, and to create an action plan for the platform for the next few years. The objectives of the seminars, workshops and other events are, with the focus on the above topics (i) to present ongoing research in the different countries, (ii) to draw up concrete plans for co-operative research and researcher exchange between the relevant organizations, (iii) to prepare plans providing opportunities for students to carry out thesis or diploma work at universities and universities of applied science within the platform, and (iv) to perform benchmarking for sustainable forest management practices, especially forest regeneration.

This issue of Metla's Working Papers is a compilation of the extended abstracts of the NORFOR seminar on forest regeneration and management held in Salla, Finland, 29–30 September, 2009. The main goal of the seminar was to discuss the main topics of NORFOR cooperation.

Keywords

NORFOR, sustainable forest management, forest regeneration

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Other information

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Preface

Forests are extremely important for regional development and welfare in the northern parts of the Fennoscandian countries, especially in Finland and Sweden. Forest management in the harsh northern conditions is based on scientific knowledge produced by national forest research institutes and universities. In the northern parts of Fennoscandia there are a number of research and higher educational organisations. In addition, large forest companies that have R&D activities are also operating in the region. For one reason or another, there has so far been relatively little cooperation between the forest R&D organisations. This is rather surprising because the problems and questions related to forest research, forest management, and forest education are very similar in the all of the northern parts of Fennoscandia.

In order to initiate cooperation between the countries an excursion and a meeting of forest regeneration researchers were arranged in Norrbotten in autumn 2007. Representatives from SLU, Sveaskog, Skogforsk and Metla participated in the event. The participants of the meeting concluded that the best way to start continuous cooperation would be to establish common R&D projects in connection with a network of forest researchers, professionals from the forestry sector, and students (NORFOR).

Therefore, since 2007, the NORFOR network of sustainable forest management in northern Fennoscandia has initiated cooperative projects and arranged meetings and excursions focusing on the unique conditions related to the harsh climate of northern Fennoscandia. The topics include natural regeneration and direct seeding of Scots pine, damage by pathogens and pests, the interplay between forestry and reindeer husbandry, and the risk management and profitability of different silvicultural regimes.

The overall aim of the NORFOR network is to establish a borderless platform in the field of research and higher education of forest management, and to create an action plan for the platform for the next few years. The objectives of the workshops are, with the focus on the above topics, (i) to present ongoing research in the different countries, (ii) to draw up concrete plans for cooperative research and researcher exchange between the relevant organizations, (iii) to prepare plans providing opportunities for students to carry out thesis or diploma work at universities and universities of applied sciences within the platform, and (iv) to perform benchmarking for sustainable forest management practices, especially forest regeneration.

Up until now NORFOR cooperation has been limited to Finland and Sweden but it should also be expanded to include Norway. I hope that a concrete step in this direction will occur at the next workshop in Haparanda, Sweden, in autumn 2010.

This issue of Metla's Working Papers is a compilation of the extended abstracts of the presentations made at the NORFOR seminar on sustainable forest regeneration and management held in Salla, Finland, 29–30 September, 2009.

Mikko Hyppönen

Presentations on the seminar day 29.9.2009

08.30-	Coffee
09.00-09.15	Welcome and opening – **Mikko Hyppönen, Metla**
09.15-09.45	New approaches on forest management systems – **Charlotta Erefur, Sveaskog**
09.45-10.15	Causal damage agents on regeneration areas – **Risto Jalkanen, Metla**
10.15-10.45	Snow, lichen and trees: Sami herders' representation of reindeer winter pastures – **Samuel Roturier, SLU**
10.45-11.00	Break, refreshments
11.00-11.30	Temperature response of Scots pine seed germination as affected by cone collection date and subsequent seed storage – **Markku Nygren, Metla**
11.30-12.00	Establishment and height development of naturally regenerated Scots pine near the timberline – **Ville Hallikainen, Metla**
12.00-13.00	Lunch
13.00-13.30	Separate effects of reindeer pasturing and forestry on the lichen biomass – **Anu Akujärvi, University of Helsinki**
13.30-14.00	Direct seeding of pine seeds with a water back-pack: A laboratory study – **Carolina Sundin and Urban Bergsten, SLU**
14.00-14.30	Direct seeding of Scots pine in the autumn – results from state forests in Finnish Lapland – **Mikko Hyppönen, Metla**
14.30-15.00	Coffee
15.00-15.30	Presentation of a direct seeding trial plan in Norrbotten – **Hans Winsa, Sveaskog**
15.30-16.00	Huminmix site preparation in Kivesvaara northern Finland – experiences and research results – **Eero Kubin, Metla**
16.00-16.30	Discussion

Excursion 30.9.2009

Excursion area: Naruska Salla, 70 km from Sallatunturi (see the map).

Departure from Salla 8.15 a.m.

1 Suoltijoki

Themes: Direct seeding in the autumn – **Mikko Hyppönen**

Forestry history: old forest logging cabin – **Olli Lipponen, Metsähallitus**

2 Koivuselkä, frontier zone

Theme: Separate effects of reindeer pasturing and forestry on the lichen biomass **Anu Akujärvi**

Lunch

3 Tuntsan pubi

Themes: Natural regeneration of Scots pine under harsh circumstances in North-East Lapland, heath phenomenon – **Ville Hallikainen**

4 Sätsivaara

Themes: Preparatory cutting in natural regeneration of Scots pine – **Mikko Hyppönen**

Long-term variation of Scots pine seed crop – **Anu Hilli**

5 Rikkilehto

Theme: Forest damage – **Risto Jalkanen**

Return: Salla 3.45 p.m., Rovaniemi airport 5.30 p.m. and Rovaniemi Research Unit 6.00 p.m.

Chequered-Gap-Shelterwood-System

Charlotta Erefur[1)] and Urban Bergsten[2)]

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For different plant material and phases of seed/seedling development, stand type and site conditions, together with the location of the seedlings in relation to the surrounding trees, create different light, water and nutritional regimes. Shelter trees not only provide seeds for natural regeneration, but they can also create a favourable environment for seedlings. Important components of the response of plants to canopy closure and gap creation are the physiological and allocation responses to fluctuating light environments. One important factor influencing the choice of a silvicultural regime is the light requirements of the species to be regenerated. Studies in northern Sweden have shown that, for seedling establishment, stand density is of greater importance than the orientation and distance with respect to the nearest shelter tree, and that light requirements could not be compensated for by an adequate nutrient supply. Successful forest management strategies must be based on an understanding of the interactions among shelter, the vegetation, the physical environment, and the response of the regenerating tree species.

One way to regenerate forests by using the benefits of shelter trees and, at the same time create the favourable conditions of a clear-cut, could be a system in which forest gaps are formed within the shelterwood. The optimum light and moisture conditions for the species in question, i.e. tree species as well as perhaps lichen species, can be achieved through optimum selection of the shelterwood density, gap size, and within-gap position. This could ensure better regeneration success, without necessarily reducing regeneration growth compared to that in a clear-cut. In Sweden, a sustainable yield of lichens is important for the grazing of reindeer and, therefore, for reindeer husbandry. This kind of system could possibly be created in ways applicable to conventional forestry, with gap dimensions (e.g. 20–40 × 30–60 m) that ensure effective cutting costs for a conventional harvester working diagonally through a chequered pattern. The use of seeding or planting provides the possibility of not having to rely on natural regeneration, and also of being able to introduce the required species and genotypes (not always present in the stand). Shade-tolerant species could be regenerated in those parts of the gaps with comparably low light levels, while shade-intolerant species could be regenerated in those areas with comparably high light levels.

A Chequered-Gap-Shelterwood-System (CGSS) has been established at Kulbäcksliden in the Vindeln Experimental Forests, 60 km NW of Umeå, Sweden. The felling design creates a two dimensional stand with clear-cuts (gaps) and intact areas in a chequered pattern of rectangles. This geometrical pattern is designed for conventional harvesting with a gap size of 30 × 45 m. The aim of the experiment is to study establishment, survival and growth of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) planted in gaps in pine forest. There are two main questions to be answered: (1) how big should the openings be to achieve satisfactory establishment at a certain stand density and light level within the shelter, and (2) when is the proper time for the release of regeneration by cutting the shelterwood? The expected outcome of the experiment are estimates of the establishment capacity for different tree species in relation to the distance to the edge and the light environment, as well as estimates of the growth and yield of the shelter trees.

Damage agents in pine regeneration areas

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Forest damage due to different causal agents is traditionally classified into three groups: fungal damage, insect and mammal damage, and abiotic damage. In a long northern country at high latitudes, such as Finland, the relationships between the damage types clearly vary due to the differences in climatic conditions in the south–north direction. While insect and fungal damage dominate in the warmer southern part of Finland, abiotic damage together with fungal agents plays a decisive role in Lapland. This does not, however, mean that animal/insect damage is absent in Lapland because, for instance, the geometric moth (*Epirrita autumnata* Borkh.) caused damage to mountain birch over a 5000-km^2-wide area in the mid 1960s. In any case, the short summers and harsh winters are ideal conditions to promote direct abiotic injuries to trees and trigger the harmful effects of biotic agents in the continuously changing environment. Lapland is known for its special abiotic phenomena, many of which are related to low temperatures and the winter-time resistance of the trees.

The role of damage groups may vary also within Lapland, primarily due to stand age and its origin. In general, some causal agents occur only in seedlings or saplings, and others only in older trees. Furthermore, there are also differences between naturally and artificially regenerated stands. Susceptibility also varies by provenance or seed source.

In recent decades forest damage has been recorded in a number of silvicultural surveys. However, the principal purpose of these surveys has not been to focus on damaging agents. This often results in a high percentage for the class ‘causal agent not identified’. In addition, these are often only one-season surveys. Thus, a representative sample of causal agents may not be obtained in cases where the causal agent occurs periodically or appears just at the end of the growing season. With these marginal notes in mind we carried out a so-called Lapin laki (Lapland’s Law) survey in the summer of 2001 in plantations established with the help of a special governmental funding programme in 1984–1995. The main aim of the survey was to investigate the silvicultural status of the privately-owned, cultivated pine (*Pinus sylvestris* L.) and spruce (*Picea abies* (L.) H. Karst.) plantations in Lapland and Kuusamo (Hyppönen et al. 2003, Hallikainen et al. 2004).

As a part of the survey we also assessed damage on all cultivated and naturally regenerated saplings to be developed further. Two old causal agents and one new (appeared in 2001) were possible to record. Additionally, defects and abnormalities and the vitality of the saplings were also assessed. The material was collected in 208 forest compartments with 10 432 pine saplings as sample trees. Here we report the damage on cultivated saplings only.

Of all the damage records, 52.0% were caused by pathogens, 20.9% by mammals and insects, 19.8% by abiotic agents, vegetation etc., and 7.3% could not be identified. The most important causal agent was moose (*Alces alces* L.), which had damaged 16.4% of all the pine saplings (Jalkanen et al. 2005). In 92.5% of the moose-browsed saplings, moose was the most serious causal agent. Most of the damage was concentrated in the municipalities of SW Lapland, with over 30%

of saplings browsed, while the least damage occurred in eastern and northern central Lapland (Nikula et al. 2008). In some stands all the pine saplings were browsed. The most abundant species among insects were the pine resin gall moth (*Retinia resinella* L.) and the pine woolly aphid (*Pineus pini* M. Koch.), with 12.2 and 4.5% of the forest compartments and 0.4 and 0.5% of the saplings affected, respectively.

The most common disease was snow blight (*Phacidium infestans* L.), with 89.1 and 23.2% of the forest compartments and saplings affected, respectively. Typically, this disease was more common on sites with a northern and higher elevation than on those with a southern and lower elevation. In contrast, the second most common disease (*Melampsora pinitorqua* (Braun) Rostr.) was concentrated in SW and W Lapland, where the alternate host of the pathogen, aspen (*Populus tremula* L.), is common on fertile sites; the proportions of affected saplings in SW–W Lapland were 10 to 30%, and in the entire province 10.2% (Jalkanen et al. 2003). Lophodermella needle cast (*Lophodermella sulcigena* (Rostr.) v. Höhn.) and pine shoot disease (*Gremmeniella abietina* (Lagerb.) Morelet) occurred in 3.7 and 3.8% of saplings, respectively. All the three last-named diseases were present in 39 to 45% of the forest compartments. In this survey, Lophodermella needle cast was found only in southern and central Lapland, although it has been very common in treeline pines in recent years. In contrast, pine shoot disease was found only in N Lapland. We also recorded the so-called aggressive Scots pine blister rust caused by *Cronartium flaccidum* (Alb. et Schw.) Wint. in municipalities adjoining Sweden; at the highest 1.0% of saplings were infected in Kolari. We did not record pine canker (*Lachnellula pini* (Brunch.) Dennis) because our sites were too moist and artificially established for this fungus to occur. Further, we recorded neither pine sawfly (*Neodiprion* sp., *Diprion* sp.) outbreaks nor vole damage, and no *Heterobasidion* sp. or *Armillaria* sp. infections at all.

As regards other damage agents, sprouts, snow and adjacent saplings affected pine to some extent. Additionally, we also recorded abundant defects and growth disturbances in saplings which did not have any moose damage. This is the first time that such a high number of pine saplings were considered to have growth disturbances due to mineral imbalances on mineral soil sites in Lapland.

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Managing reindeer lichen during forest regeneration procedures

Samuel Roturier

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In northern Sweden, the conventional forest regeneration procedures applied in modern commercial forestry can disturb terricolous lichen (*Cladina* spp.) pastures. This has become a source of conflict with Sámi reindeer herders. The overall aim of this thesis was to investigate forest regeneration strategies that may minimize the disturbance to, and promote the regeneration of, reindeer lichen pastures. The practices and knowledge of Sámi herders related to lichen resources were also analysed.

The effects of relatively light soil preparation methods on re-establishment of the lichen cover, reindeer grazing and establishment of Pinus sylvestris planted seedlings were studied in a field experiment. Using the HuMinMix technique, which involves mixing the lichen mat with humus and mineral soil (humix substrate), was found to promote lichen mat recovery more effectively than conventional scarification. Seedling establishment was the highest for mounding and tracks with mineral soil. The proportion of seedlings mechanically damaged, possibly due to reindeer trampling in winter, indicates that planting on densely grazed areas should be avoided in order to minimize sources of conflict and to favour either direct seeding or natural regeneration. According to a survey, complete re-establishment of the lichen mat after soil preparation was estimated to take about one decade on the humix substrate, compared to probably more than five decades following conventional harrowing.

Possibilities for the artificial dispersal of reindeer lichen, e.g. in areas disturbed by conventional soil preparation, were also studied. The substrate was identified as a key factor for lichen establishment. In this respect, mineral soil was identified as a poor substrate for reindeer lichen immobilization, while milled organic materials, such as moss, were suitable substrates for lichen immobilization and growth. All the dispersal methods tested resulted in lichen establishment, but transplanted lichen cushions were heavily depleted by reindeer grazing, while fragmented lichen thalli were much less affected.

A study based on ethnolinguistics demonstrated that, whereas the Western use of the word 'pasture' is often associated with a specific plant community, the Sámi herders' understanding of the word (guohtun in Sámi) also incorporates the effect of snow on grazing. Sámi herders use their knowledge of the effects of forest trees and other vegetation on snow conditions to strategically plan reindeer grazing during winter. Sámi herders' knowledge of the winter pastures should therefore be integrated with information on the effects of forest regeneration procedures on stand development

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Temperature response of Scots pine seed germination as affected by cone collection date

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The temperature climate plays a dominant role in determining tree seed development and maturation in boreal Scandinavian forests. For example, at the polar timber line the probability of achieving a mature, germinable Scots pine seed crop is very low, approximately 0.02–0.03. The relationship between seed maturation and temperature climate was established already in the early 1900's by the works of Hagem in Norway, Wibeck in Sweden and Heikinheimo and Kujala in Finland. The emphasis since has been on the anatomical development of seeds, i.e. the growth and development of the embryo and the megagametophyte. Simak established the relationship between anatomical embryo development and the germinability of the seeds in laboratory conditions.

After completion of anatomical embryo development in the autumn, Scots pine seeds overwinter in the trees and are shed the following spring. The overwintering period appears to be critical in terms of maintaining germinability. Studies carried out Sweden, Finland and Norway have all reported occasional declines in germination capacity during the winter months. On the other hand, the chilling and frost temperatures during overwintering may also have beneficial effects on germination, as suggested by Vegis in Sweden and Mork in Norway. They both reported that, after adequate chilling, seeds germinate in a wider environmental conditions in terms of light and temperature requirements as compared to non-chilled seeds, which have a more narrow 'window' for germination temperature, for example.

In this extended abstract, I report some preliminary results of a study on the effects of collection date on the germination characteristics of Scots pine seeds. When planning the study, I wanted to see whether the temperature requirements for Scots pine seed germination would change during overwintering in the trees in natural conditions.

Cones were collected from a managed Scots pine stand in the vicinity of the Suonenjoki Research Station on two occasions in autumn/winter during the years 2007–2008 and 2008–2009. Seeds from the same 10 to 12 individual trees were collected in both years. At each collection, 1–2 litre of cones were randomly picked from each tree. Cone and seed water content were measured and fresh cones were extracted in a ventilated oven at a temperature of +38 °C for 3–5 days. The seeds were dewinged by hand and empty seeds were removed with a Dakota type seed blower. The seed yield per tree was approximately 10 g of full seeds, corresponding to approximately 2000 seeds, per tree at each collection.

Randomly chosen samples of full seeds were germinated on an individual tree basis on a thermogradient plate at constant temperatures ranging from +14 to +28 °C (Fig. 1). The phoperiod was constant: cool-white fluorescent light for 18 hrs. per day. 35 seeds from each tree were germinated in each temperature. Samples were x-rayed before the test in order to remove damaged and empty seeds. The seeds were counted daily and were considered germinated when the radicle was the same size as the seed itself. The germination percentages were calculated as proportions out of the full seeds in the test.

The results indicate that, during the overwintering, the germination of Scots pine seeds is enhanced, especially at low temperatures. Their rate of germination (measured as percentage of germinated seeds after one week's incubation) was especially higher when collected in mid-winter when compared with autumn-collected material. On the other hand, the average final germination (measured as percentage of germinated seeds after two weeks' incubation) was lower in mid-winter than in the autumn (Figs. 2 and 3). Furthermore, the winter-collected material in both years was more variable (in terms of germination capacity) at temperatures between +17 – +26 °C than the autumn-collected material.

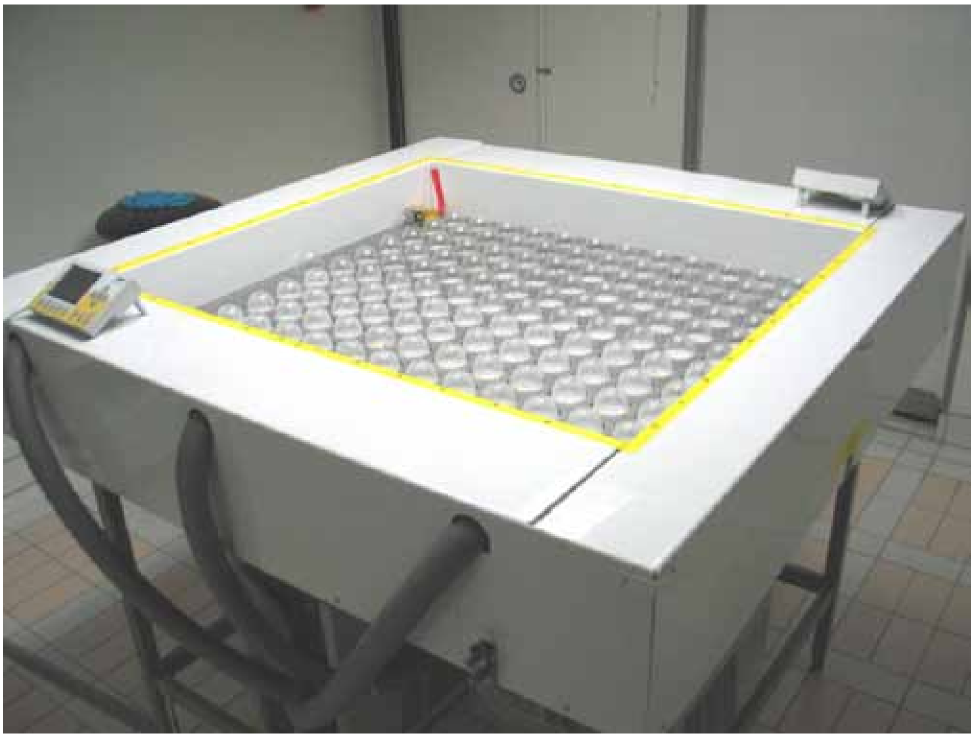

Figure 1. Thermogradient plate used in the germinations tests at constant temperatures ranging between +14 – +28. The germination papers were kept moist with a filter paper wick dipped into the water reservoir below the plate.

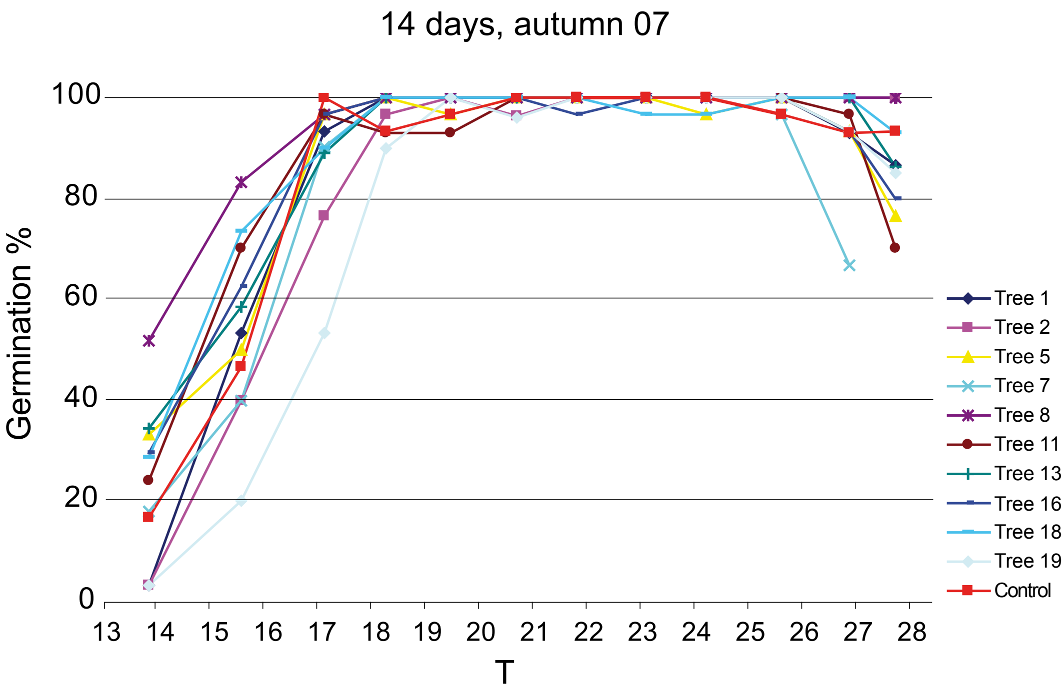

Figure 2a. Germination of autumn-collected Scots pine seeds from ten individual trees at constant temperatures ranging between +14 – 28 ºC. Germination percentage measured after 14 days incubation. Collection date: Nov 1, 2007.

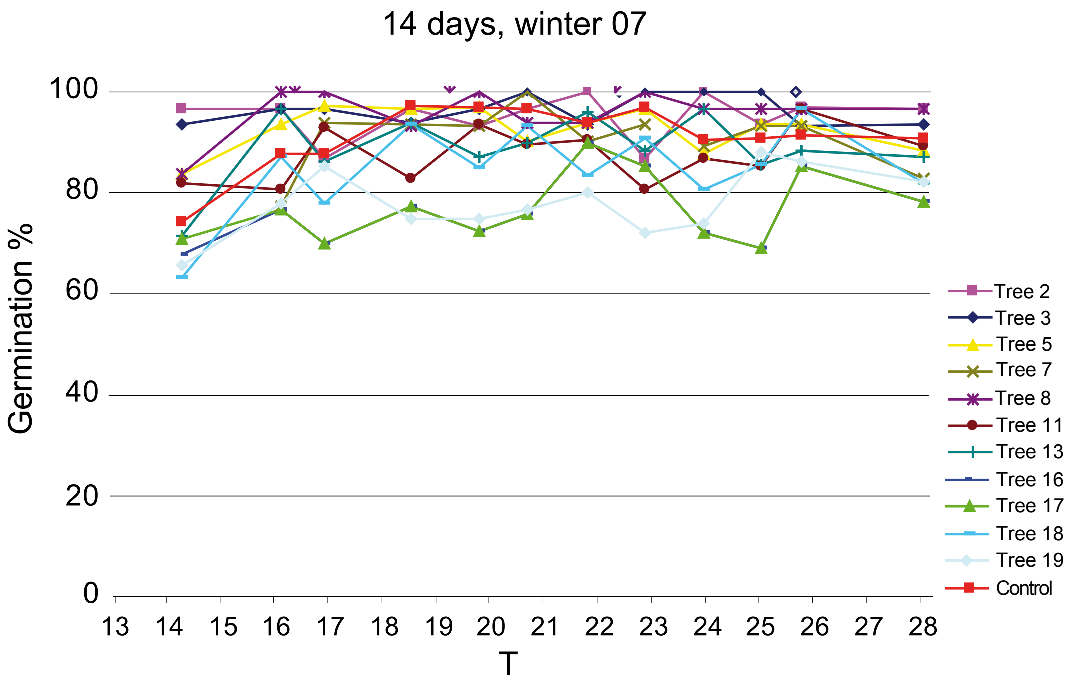

Figure 2b. Germination of winter-collected Scots pine seeds from ten individual trees at constant temperatures ranging between +14 – 28 ºC. Germination percentage measured after 14 days incubation. Collection date: March 23, 2008.

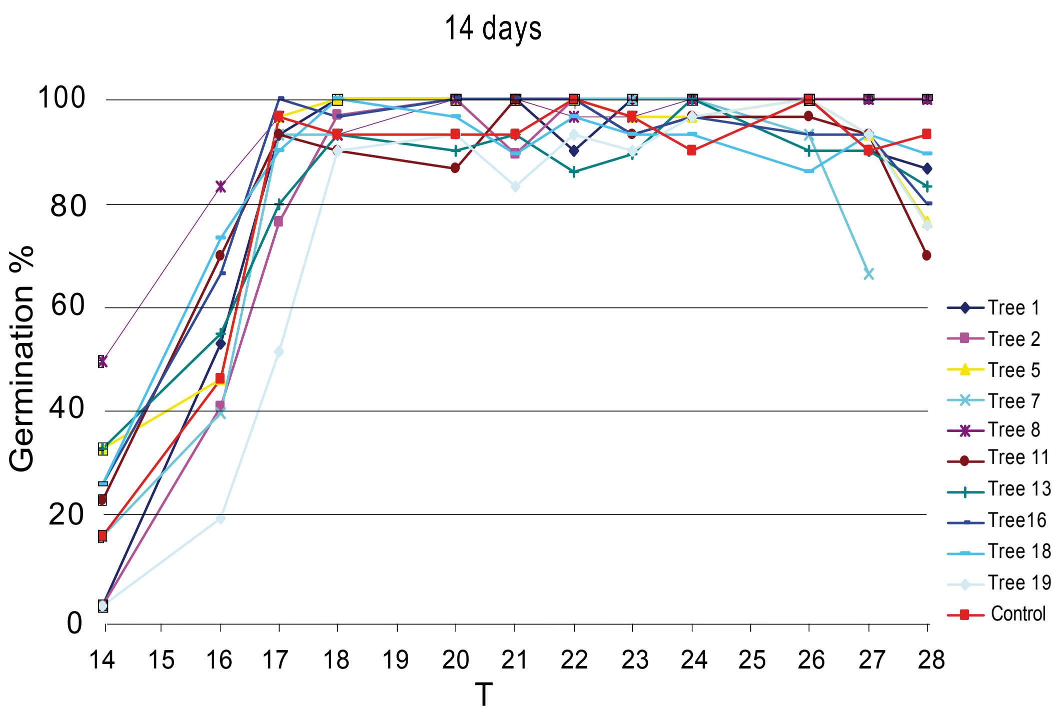

Figure 3a. Germination of autumn-collected Scots pine seeds from ten individual trees at constant temperatures ranging between +14 – 28 °C. Germination percentage measured after 14 days incubation. Collection date: Nov 20, 2008.

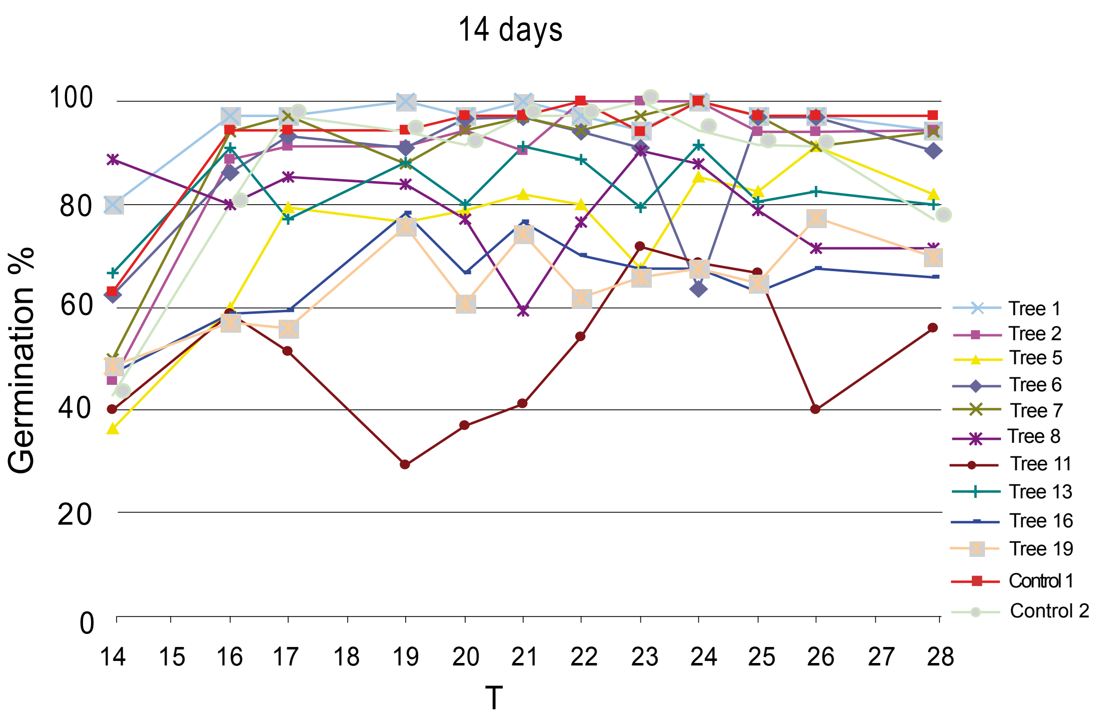

Figure 3b. Germination of winter-collected Scots pine seeds from ten individual trees at constant temperatures ranging between +14 – 28 °C. Germination percentage measured after 14 days incubation. Collection date: March 18, 2009.

Models for the establishment and height development of naturally regenerated *Pinus sylvestris* near the timberline in North-East Finnish Lapland

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Researchers and professionals in practical forestry have encountered difficulties in the regeneration success of Scots pine in natural regeneration near the timberline in North-East Lapland. The aim of the study was to analyze seedling establishment and seedling height development of Scots pine in the seed-tree stands located in the area. Harsh climatic conditions and also certain soil properties, reflected by the ground vegetation, have been assumed to be the main cause of these problems. Especially the coverage of heather (*Calluna vulgaris*) has been found to be connected with the problem, but some other allelopathic species such as crowberry (*Empetrum nigrum,* E. *hermaphroditum*) may have a negative effect on regeneration.

The inventory data for the modelling were collected from state-owned forests. The total number of randomly sampled stands was 62. The time since seed-tree cutting varied from 2 to 17 years, the average being 7 years. From 2 to 13 circular sample plots (area 50 m^2) were measured in each of the stands in order to determine seedling recruitment. In addition, a random sample of 15 stands was sampled from the 62 stands, including 25 randomly located sample plots of 10 m^2. Detailed measurements were made on the ground vegetation on these sample plots as they were the explanatory variables for the recruitment models. The regeneration success, i.e. seedling density, was modelled using multinomial logistic regression procedures with a random factor. Both nominal and ordered multinomial models were used. The models were computed using MlwiN statistical software. The seedling height was modelled using the linear mixed model procedure.

The average number of living pine seedlings in the study stands was about 1000 ha^{-1}, but there was considerable variation between the stands. The median was slightly less than 600 ha^{-1}. About one half of the stands had regenerated very poorly, the number of seedlings being about 500 ha^{-1} or less.

Site type and number of years since seed-tree cutting were the most significant predictors in the model, but effective temperature sum (threshold +5 °C), exposition, number of residual trees, and number of intermediate trees were also significant. The age of a seedling with maximum height was the most effective predictor in the height development model. Other significant explanatory variables were the time since seed-tree cutting, paludification, number of so called intermediate admixed birches, and distance between the seedling and the nearest seed tree.

The ground vegetation affected seedling recruitment. Increasing thickness of the moss layer inhibited recruitment, but the probability of finding a seedling was, contrary to expectations, higher on the patches covered with heather. According to the results for the sub-dataset of 15 stands, the coverage of exposed mineral soil had a positive effect on recruitment, in addition to the time since seed-tree cutting.

The study suggests that, in North-East Lapland, the regeneration success of Scots pine is worse than generally in northern Lapland near the timberline. The role of ground vegetation, especially heather, in seedling recruitment requires further study.

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Separate effects of reindeer pasturing and forestry on the lichen biomass

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Reindeer husbandry is an important livelihood in northern Fennoscandia. In the winter, reindeer live mainly on reindeer lichens (*Cladina* sp.) that grow in the northern coniferous forests. Since the forests are also used for wood production, there are conflicts between reindeer husbandry and forestry. According to the national forest inventories made in Finland, the lichen biomass has decreased dramatically since the 1970's (Hyppönen 2008). The lichen biomass has decreased in the southern and middle parts of the reindeer management area, and also in the Inari region in northern Lapland (Mattila 2006a, 2006b). So far, the inventories have only been carried out inside the reindeer management area where reindeer husbandry and forestry are practised together (Hyppönen 2008). There is a lack of knowledge about the separate effects of reindeer pasturing and forestry on the lichen biomass. The aim of this study is to determine the separate effects and to obtain information that would help to find a consensus concerning the land use.

Reindeer lichens grow in dry, oligotrophic sites (Reinikainen et al. 2001). The amount of light affects the growth of lichens. The largest lichen mats can be found in the open, late successional state forests. Lichens interact with trees and other plants. Tree litterfall and canopy rainfall affect the chemical properties of the soil. Lichens compete with dwarf shrubs and mosses. Some lichens may have allelopathic effects on other plants, which makes the vegetation cover patchy (Reinikainen et al. 2001).

Human impact on the northern forests has a long history (Reinikainen et al. 2001). Both reindeer husbandry and forestry have an effect on the lichen biomass. The reindeer are directed by the herders and the amount and pressure of grazing varies regionally and yearly. Forestry affects the lichens strongly especially in the forest regeneration phase (Hyppönen 2008). In young, dense stands the lichen biomass is decreased as a result of shading. Clear-cuttings and thinnings increase the amount of light in the forest, which may improve the growth of the lichens. Heavy machinery and soil preparation damage the lichens mechanically. Logging residues prevent the reindeer from cratering the lichens below the snow. Fragmentation of the forests increases the reindeer herding costs (Hyppönen 2008).

The following hypotheses were tested in this study: 1. Reindeer pasturing has a direct effect on the lichen biomass, 2. forestry affects the lichen biomass by changing the forest structure, 3. forestry has direct effects on the lichen biomass, and 4. the history of land use has an effect on the lichen biomass. The data were collected in a total of 50 grazed and ungrazed forest stands in Lapland. The stands were situated near the Russian border and in other fenced areas. The stands were pine dominated and the site types were dry and sub-dry. All the forest developmental stages were covered in the study. The sample plots were loacted on grazed and ungrazed sides of the reindeer fence. Three types of sample plot were used in the study. The tree stand properties, logging residue coverage and the amount of arboreal lichens were measured on five large sample plots in each stand. The properties of the saplings and the amount of reindeer faeces were measured on five smaller sample plots. The coverage, height and species composition of the lichens (*Cladina,* *Cladonia* and *Stereocaulon* sp.) and the coverage of dwarf shrubs and mosses were measured in 0.5 m * 0.5 m squares.

The separate effects of forestry and reindeer pasturing on the lichen biomass will be modelled using the general and generalized mixed models. Mixed models will be used because the data are hierarchic. We now have some preliminary results. The average lichen coverage was ca 15% in the grazed areas, and in the ungrazed areas ca 40%. The average height of the lichen was 28 mm in the grazed areas and 59 mm in the ungrazed areas. The average biomass of the lichen was 360 kg ha^{-1} in the grazed areas and 2650 kg ha^{-1} in the ungrazed areas. The results have been moisture calibrated.

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Direct seeding of pine seeds with a water back-pack: A laboratory study

Master thesis by Carolina Sundin, supervised by Urban Bergsten

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As the regeneration of forests is a necessary but somewhat expensive measure, it is important to find regeneration methods that are both cost effective and give satisfactory regeneration results. In a successful direct seeding, the large number of seedlings contributes to achieving stems in the future with suitable wood properties. These seedlings may have better root development and stability than planted seedlings. The utilization of direct seeding is limited by the seed supply, site conditions and the short sowing season. Therefore it is important to find ways to prolong the sowing season and to reduce seed consumption and also reduce the impact of the site on seedling emergence. The primary limiting factor in direct seeding as regards germination is a satisfactory water supply. Therefore it is important that the seeds have full access to water, and adequate gas exchange, when the germination starts.

The overall aim of this study was to collect information for developing a regeneration-based system for the sowing of "seed packages with a water backpack". The overall hypothesis was: if you include the water required for germination in the right packaging, germination will be fast and seedling establishment high even though the external environment does not provide optimal moisture conditions. Four experiments were carried out with different treatments. All the experiments were conducted indoors without any external water supply. The seed packages were placed on a table. The effects of different substrates (H_20 + peat + polymer and H_20 + peat), substrate volume, water volume, different packaging (plastic film or plastic tubes with a lid) and different of gas exchange levels (0, 2, or 10 holes in the plastic film or in the lid; diameter of the holes 1 mm) were studied. The first two experiments included the polymer Ac-Di-Sol® in all the treatments. The last two experiments were divided into two, half of the samples including the polymer and the other half not. The first three experiments used orchard seeds from Skaholma, while the fourth experiment used stand seed from Karesuando, half of which were invigorated and the other half acted as a control.

Seedling establishment on the substrates containing the polymer differed significantly (Fisher Exact ≤ 0.05) from those without the polymer. The substrates that contained peat, water and polymer had no seedlings at all. The polymer seemed to have an inhibiting effect on germination and seedling establishment. However, in the samples that only contained peat and water there was a high proportion of seedlings. The samples in experiment 3 with a substrate volume of 4.2 cm^3, water content 80.2% and gas exchange "10 holes" in the plastic lid, resulted in 100% seedlings independent of the tube size. Seedlings were able to grow without any hole in the plastic lid, although the results were better when there were holes in the lid, due to the improved gas exchange. The invigorated seeds resulted in more seedlings and better development compared to the control seeds, which is in agreement with earlier research. The substrate volume did not seem to have any impact on the results, and this could be interpreted to mean that relatively small seed packages can be used for direct seeding. The study shows, as expected, that you can obtain high seedling emergence if the seeds can be provided with water even though the external environment does not support sufficient water availability. If the "back-pack" is further developed, then the method could be applied in the field in order to improve the success of direct seeding techniques.

The success of autumn direct seeding of *Pinus sylvestris* in Finnish Lapland

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Direct seeding is a commonly used method in the regeneration of Scots pine (*Pinus sylvestris* L.) in Fennoscandia, especially in the northern parts of the region. Spring and early summer have proved to be the biologically best seeding times for Scots pine. In the case of mechanical seeding, the best time for direct seeding is relatively short. Site preparation and seeding machines cannot be taken to a regeneration area until the soil frost has melted, and the soil has drained and its carrying capacity has improved. Different alternatives have been considered for extending the seeding season. One alternative is to move to a seeding period in the late autumn. According to some studies, autumn seeding is more successful in the North than in the South (Wibeck 1927). The reasons for this are the relatively drier autumn and the faster freezing of the soil surface in the North, in which case the seeds do not absorb water before the onset of winter and withstand freezing during the winter. The seeds do not germinate, freeze, and are no longer subjected to melting/freezing cycles before the start of the growing season: they survive on the ground until the next spring.

Some research results suggest that, especially in the North, the seeds can remain viable for several years (Lassila 1920, Wibeck 1927). Post germination seems to be connected to the weather conditions during the the growing season: during unfavourable summers part of the seeds fail to germinate, and the worse the seed has ripened the higher proportion of seed that germinates in the coming years (Sarvas 1937). Post germination of the seeds is significant particularly in harsh climatic conditions (Sirén 1952, Tillman-Sutela 1995). As a result, it is possible that autumn direct seeding is better suited for northern than for southern conditions. This would offer direct seeding another season that would be dated to the late autumn (Nygren and Leinonen 1992). Indications of this kind of research results have been achieved (Hedemann-Gade 1927, Kinnunen 1982).

In Finnish Lapland, Metsähallitus has in small-scale practical forestry, carried out direct seeding of Scots pine in the late autumn (October) for about a decade. The aim of this study is to investigate the success of the trials. The focus of the study is on regeneration success and on modelling the establishment and seedling height development of seeded, young seedling Scots pine stands.

The data consist of a sample of the seedling stands established by direct sowing by Metsähallitus in the municipalities of Kittilä, Rovaniemi, and Salla in Western and Eastern Lapland. A total of 50 randomly sampled seedling stands directly seeded in late autumn during the period 1997–2005 were included in the sample. The sowing time was October. The field survey and measurements were carried out in summer 2008. The seedling stands were surveyed using systematic plot (r = 1.78 m, A = 10 m2) sampling. The data were hierarchically structured at the stand, circular plot, and seedling levels. Overall, the data consisted of 50 seedling stands and 908 sample plots. The main parameters of the data are given in Table 1.

Table I. Parameters of the study stands (n = 50).

Variable	Average	Median	SD	Minimum	Maximum
Temperature sum, d.d.	735	746	68	616	913
Elevation, m a.s.l.	249	247	49	96	330
Area, ha	6.1	4.5	6.1	0.4	29.0
Number of seed trees ha^{-1}	16	6	23	0	95
Number of retained trees ha^{-1}	32	26	28	0	127
Time since direct seeding, growing seasons	5	5	1	3	11
Humus layer, mm	19.8	18.3	6.4	8.9	35.3
Sink of iron stick, cm	18.0	17.6	6.6	5.3	39.1
Total number of seedlings ha^{-1}	27 327	21 633	21 342	3 160	127 200
Scots pine	14 023	9 980	16 569	1 200	109 733
Norway spruce	475	287	534	0	2 867
Birch	12 828	9 700	12 741	0	69 450
Number of main crop seedlings ha^{-1}	3 158	3 317	955	1 120	5 000
Scots pine	3 040	3 133	1 006	760	5 000
Norway spruce	118	67	141	0	600
Age of main crop pine seedlings, years	3	3	1	2	6
Height of main crop pine seedlings, cm	10.0	7.8	10.0	2.7	69.9
Proportion of empty sample plots, %	8.1	4.9	11.2	0.0	48.0

In contrast to the recommendations and the results of most studies, autumn direct seeding has been relatively successful. The total number of Scots pine seedlings averaged 14 000 ha^{-1} (median 9 000 ha^{-1}), and the number of Scots pine main crop seedlings averaged 3 000 ha^{-1}. These numbers are equal or more than those earlier reported in studies on direct seeding in the spring in northern Finland (e.g. Hyppönen 1998, Wall and Kubin 2000, Hallikainen et al. 2004).

The same set of explanatory variables was found to be the most significant in both seedling establishment models (total of pine seedlings and number of pine main crop seedlings): temperature sum, layer thickness, stoniness index (penetration of a steel rod into the soil), distance of the plot from the forest edge, proportion of exposed mineral soil, and seeding year. Temperature sum, stoniness index, and the proportion of exposed mineral soil positively affected the seedling density and humus layer thickness and distance from the forest edge negatively.

In autumn seeding it is important that the seeds are not subjected to a freezing/thawing cycle. The seeds must not developed already into germlings that are sensitive to frost and other winter damage. According to numerous studies, frost and ice are the most important factors affecting the destruction of seeds and germlings (e.g. Bergsten et al. 2001, de Chantal et al. 2002, Winsa and Bergsten 1994, Wennström et al. 1999, 2007). As seeding had been carried out late in the autumn (October) in this study, the most critical weather conditions were probably avoided.

The results suggest that late autumn is a viable seeding alternative, at least in Lapland, compared to spring and early summer. Additional research is still needed.

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An autumn seeding trial with *Pinus contorta* and *Pinus sylvestris*

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A direct seeding trial was established during 1997 to 1999 on two different sites in Norrbotten (Tallberget and Kukasjärvi), northern Sweden. The trial was initiated by the author of this paper, established, measured and reported by ForeCare AB. This is a summary of the last report (Höstsåddsförsök AssiDomän Kalix, ISRN Forecare-R-2001/008).

The aim of the study was to compare the results of mechanised spring and autumn seeding of Scots and contorta pine. The effect of microsite preparation was also studied in a manually seeded part of the trial. Both sites were mesic (subdry) with *Vaccinium myrtillus* vegetation. The mineral soil was a sandy-silty till.

Scarification was performed with a disc trencher (Donaren 280) equipped with a wheel for microsite preparation and a seeding device (Top 100). For each date, site and tree species, site preparation and mechanised seeding were carried out on twenty, 20 m long tracks randomly located on the site. Manual seeding was performed with and without microsite preparation on ten plots for each tree species, site and date.

Table 1. Treatments and dates for site preparation and seeding.

Date	Site	Mechanised seeding Scots pine Seeds/meter*	Contorta pine Seeds/meter*	Manual seeding Scots pine and Contorta pine
19971002	Kukasjärvi	15.5	14	For each pine species
19971001	Tallberget	15.5	14	10 plots with microsite
19980609	Kukasjärvi	19	18	preparation and 10 without
19980610	Tallberget	19	18	were seeded at the same
19981001	Kukasjärvi	18	16	dates and with the same seed
19981001	Tallberget	18	16	lots as the ones used for
19990609	Kukasjärvi	13	15	mechanised seeding.
19990610	Tallberget	13	15	

*Number of germinable seeds, germination percentage for Scots pine 95% and for contorta pine 85.5%

Results

The number of germinated and established seedlings were counted in autumn 1998, 1999 and 2000 on each of the manually seeded plots, and on 21 m long sections of each mechanically seeded lot of twenty tracks. The results were calculated as percentage (G% in table 2) by dividing the number of established seedlings by the number of germinable seeds that were sown. The seedling establishment percentage was used to calculate the number of seedlings per hectare (Senr in table 2) if scarification and mechanised seeding had been made with 18 germinable seeds per m on 4400 m/ha.

Table 2. Average seedling establishment for both sites (Kukasjärvi and Tallberget), autumn 2000.

	Mechanised seeding				Manual seeding			
	Scots pine		Contorta pine		Scots pine		Contorta pine	
Date	G%	Senr*	G%	Senr	Mp*	Nomp*	Mp	Nomp
1997 Autumn	3.0	2400	9.2	7300	-	-	3.6	6.8
1998 Spring	5.1	4000	9.6	7600	21.6	12.6	33.8	22.5
1998 Autumn	1.8	1400	4.0	3200	1.5	1.5	10.2	14.5
1999 Spring	8.2	6500	8.2	6500	41.0	11.5	33.9	21.7

*Seedling number per hectare, rounded to the closest 100. Mp = microsite preparation,
Nomp = No microsite preparation

Findings

- Spring and autumn seeding appear to be promising for contorta pine.
- Scots pine had poor results for autumn seeding
- Microsite preparation improved the seeding results for both pine species in spring seeding but had no effect in autumn seeding.
- Manual precision seeding improves the seeding results compared to mechanised "precision" seeding.

Comments

Contorta pine is adapted to seed dispersal after a forest fire when the heat of the fire opens the serotinous cones. However, it has to be a fast moving crown fire because, if the cones are directly subjected to flames for more than sixty seconds, the temperature inside the cones will become so high that the seeds are killed. Some cones open even without fire and disperse their seeds late in the summer. When contorta pine is directly seeded in the spring or in the nursery, the seeds first have to be subjected to cold-wet treatment before they can germinate. In this trial, cold-wet treated seeds were used for spring seeding and untreated seeds were used for autumn seeding. Our hypothesis that the difference between Scots and contorta pine seeds and the time for seed dispersal, should make it possible to use contorta in late autumn seeding seems to be correct. Since the contorta seeds require a cold-wet treatment we can expect that they will not start to germinate before the next spring until they have been subjected to the cold-wet treatment during the winter.

If we combine the seeding of Scots pine in spring with the seeding of contorta pine in the autumn it should be possible to use scarifiers equipped for mechanised seeding more efficiently throughout the growing season.

The main difference between mechanised and manual seeding in seedling establishment is both a problem and an opportunity. The possibility to continuously achieve a result that is two to three times better with manual seeding is a challenge for the development of mechanised seeding. Since seeds represent a major part of the costs in direct seeding, an improvement of at least 20% in seedling establishment should lower the costs by about one third.

However, more research is needed on both the possibility to use Scots pine and contorta pine in autumn seeding in relation to seed treatments (cold-wet and coating), and for the development of better mechanised seeding methods.

Long-term variation of Scots pine seed crop

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In northern Finland natural regeneration is commonly used in forestry for Scots pine (*Pinus sylvestris*). For this regeneration method, densities of 50–150 seed trees/ha are usually recommended. Seed production and quality in Scots pine stands vary between years, stands and individual trees. The variation between years is mainly due to variation in the weather conditions, while the variation between stands and individual trees depends on microclimatic conditions, site conditions, and genetic characteristics. According to Parviainen and Seppänen (1994), at least 100 seeds/m2 is needed to form a sufficiently dense seedling stand in northern Finland. Information about variation in the seed crop size and quality is important for reforestation: forest owners can select the best method for regenerating a cut area in any specific year. The main objective of this study was to analyse the long-term variation in the size and quality of Scots pine seed crops in northern Finland.

Material and methods

The size of the seed crop was studied in four natural stands, located in in Rovaniemi and in Kittilä, northern Finland. During the measuring period (1960–2004) there were 10–15 funnel-shaped seed fall traps in the stands. The seed fall traps were emptied five times at regular intervals between May and September. After collection, the total number of seeds was counted. In the study stands the number of stems/ha varied from 172 to 384 trees and the age of the stands from 133 years to 242 years (Hilli et al. 2008). The study sites were of the moist EMT type (Cajander 1925). The field layer was dominated by *Empetrum nigrum* and *Vaccinium myrtillus.* The altitude of the stands ranged from 160 m to 340 m a.s.l. (Hilli et al. 2008).

The expected germination percentage represents the probability with which fresh seeds will germinate. The expected germination percentage of the pine seed crop in the Kittilä pine stands was analysed. The cone samples were collected between the years 1986 and 2004, excluding the years 1987 and 1998 because of the low annual temperature sum during these years. The cone samples collected between the end of August and mid-September were removed from the database because the expected germination percentage of seeds changes considerably in August and at the beginning of September (Sahlén and Bergsten 1994). The cones were collected from 10 trees per stand, and 10 cones from every tree were randomly combined to form one sample. The number and location of the stands from which the cone samples were collected varied annually. The expected germination percentage of the pine seeds was determined by x-ray radiography on the basis of 300 seeds, and the total number of seed samples was 359. The percentage was calculated on the basis of all the seeds and of filled seeds only. The calculation was based on seed maturation analyses made on the proportion between embryos and embryo cavities (Simak 1980).

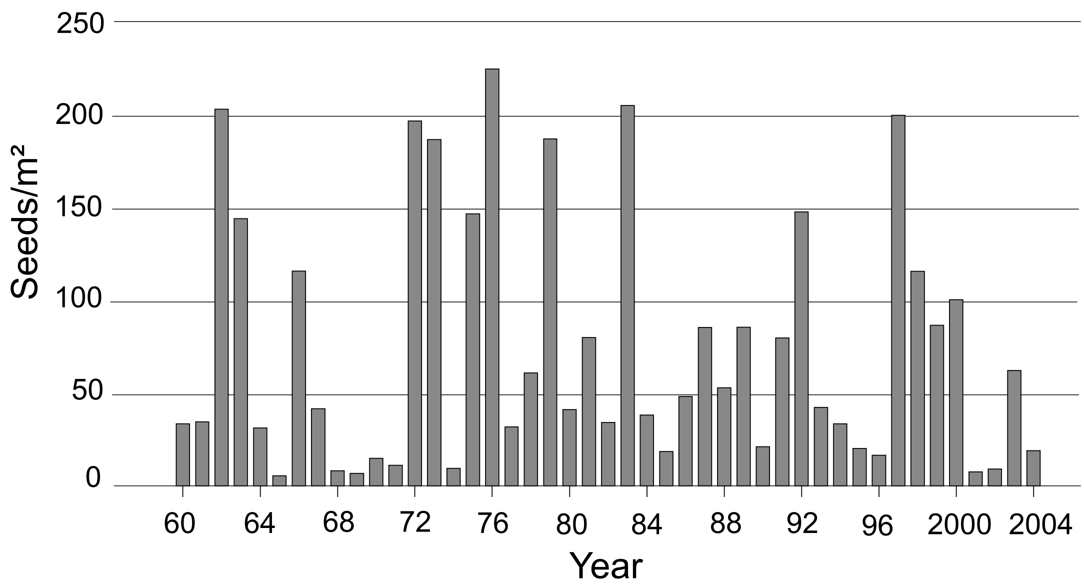

Figure 1. The mean size of the seed crop (seeds/m^2) in northern Finland in the years 1960–2004 (Hilli et al. 2008).

Results

The long-term average of the pine seed crop was 77 seeds/m^2 during the 1960–2004 measuring period in northern Finland. The best seed years were 1976, 1962 and 1983, with an average seed crop of 225, 203 and 205 seeds/m^2, respectively (Fig. 1). The maximum size of the seed crops in the Rovaniemi stands were 302 and 359 seeds/m^2 and in the Kittilä study stands of 247 and 251 seeds/m^2. The seed crop was the lowest in 1965, only 5 seeds/m^2. On the average, the minimum number of seeds needed to ensure natural regeneration in northern Finland occurs in three out of ten years, assuming that 100 seeds/m^2 is needed to form a sufficiently dense seedling stand (Hilli et al. 2008).

In the Kittilä pine stands the long-term, average expected germination percentage was 51% in all seeds and 61% in filled seeds. The expected germination percentage varied greatly between the years (Fig. 2) and between the stands within the same year. The long-term average of empty seeds was 17%, and the annual average of empty seeds also varied greatly among the stands. An annual temperature sum of 800 d.d. was needed to achieve an expected germination percentage of 50% (Hilli et al. 2008).

The results confirm the widely held assumption that the natural regeneration of Scots pine is difficult in most years in northern Finland because of the low seed quality and quantity. According to our results, the years when both the seed yield and the expected seed germination percentage were high did not coincide. In the future, it is important to study whether the quantity and quality are simultaneously high in the same stand (Hilli et al. 2008).

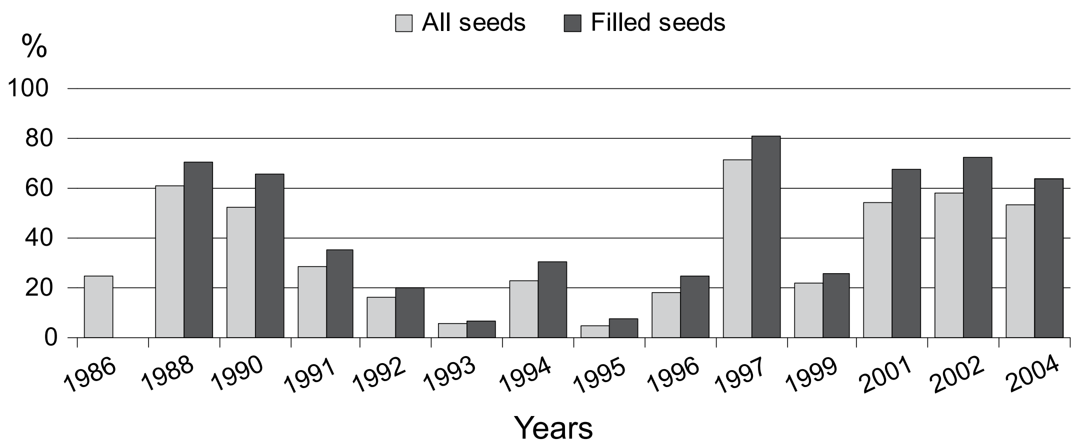

Figure 2. The annual means of the expected germination percentage (%) of all seeds and filled seeds in the stands in Kittilä during 1986–2004 (Hilli et al. 2008).

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Gremmeniella abietina in the Rikkilehto Scots pine stand

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In the late 1980s a strong debate on the role of air pollution in forests of Finnish Lapland divided opinions among scientists, the media and the public. Prior to 1987 Lapland was considered as a very clean area far from emission sources and the long-range transport of pollutants. The first large-scale forest decline phenomenon where air pollution was thought to play a marked role, was the so-called Lapland needle loss in summer 1987 (Jalkanen 1988, 1990, Jalkanen et al. 1990). One of the main claims, subsequently however never proved, was that increased ozone concentrations in the lower atmosphere caused the severe needle loss. However, this decline was experimentally shown to have been caused by frost damage to roots in the soil, which did not have the normal snow cover during the exceptionally cold December in 1987 (Ritari 1990). Signs of this phenomenon, which was concentrated on Scots pine (*Pinus sylvestris* L.), disappeared at the latest after 4 to 6 years, and the trees recovered to their normal growth level (Tuovinen et al. 2005), thereby finally ruling out the role of ozone underlying the decline event. These studies also revealed the role played by the lack of a reindeer lichen layer due to severe overgrazing.

In connection with the Lapland needle loss debate, alarming news appeared about the high emissions of SO2 and heavy metals from the Cu-Ni smelters in Monchegorsk, on the Kola Peninsula, Russia, located only 160 km from the Finnish Lapland border. Soon after, damaged Scots pine shoots and lower canopies of undetermined origin came to light in Salla in April 1988. Later in the same year, large areas of declined forests were reported; the size of the declined area next to the Russian border rose to 1000 ha. Some of the stands were so severely declined that they were judged to be renewed via clear-cutting. One of these so-called 'destroyed' sites was Rikkilehto located in the Salla jointly owned forest area, about 180 km from Monchegorsk.

Many of the comprehensive studies and published articles on the Salla forest damage clearly showed that the causal agent of the Salla forest damage was a pathogen *Gremmeniella abietina* (Lagerb.) Morelet. This fungus has two forms, the so-called small-tree type (STT) and the large-tree type (LTT), the latter form being responsible for the Salla forest damage. Again, Scots pine was the only species exhibiting damage symptoms, thus suggesting that anthropogenic factors played only a minor role underlying the decline.

In Rikkilehto, too, the causal primary factor was the pathogen *G. abietina*, killing branches from the lower canopy towards the top, and finally causing tree death. In the stand survey and subsequent shoot and branch analyses carried out in the laboratory it was found that *G. abietina* had started to infect the pines parallel to the establishment of the smelter in Monchegorsk (Kaitera and Jalkanen 1992, 1993, 1994). Furthermore, no signs of increased levels of air pollution were reported in the area (Kaitera and Jalkanen 1995). Secondary attacks by *Tomicus* spp. followed primary infections of the pathogen (Kaitera and Jalkanen 1993, 1995).

In the 1990 stand survey, the stem number in Rikkilehto was over 2500 stems per hectare, of which 1740 were Scots pine; 59.1% and 9.3% of the pines were either dead or expected to die, respectively (Kaitera and Jalkanen 1993). The major reason for tree mortality was *G. abietina.* In the 2005 survey, only 1.9% of the pines were assessed to be healthy; *G. abietina* symptoms were present in 97% of the living trees. There were 1007 dead pines per hectare; two thirds of them had already fallen. Although about 40% and 69% of the total number of trees and pines, respectively, were dead, resulting in natural stand thinning, it was concluded that even this 'fully destroyed' stand can be developed further. The decline of the pine trees in the stand was due to *G. abietina* infections which finally ended in 1988; since then there has been a temporary, minor outbreak of shoot damage in 1994. A cold pocket in the terrain in the Rikkilehto stand has been free of *G. abietina* infections, thus allowing the surviving pine trees to recover.

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