

# Effect of macroclimate on the development of Scots pine seedling stands on drained oligotrophic pine mires

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TIIVISTELMÄ: SUURILMASTON VAIKUTUS OJITETTUIJEN KARUJEN RÄMEIDEN MÄNTYTAIMIKOIDEN KEHITYKSEEN

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The influence of different fertilization treatments and ditch spacings on the height growth of young Scots pine (*Pinus sylvestris*) seedling stands growing under various climatic regimes were determined. Comparisons were made between naturally regenerated and planted seedling stands. The effective temperature sum had a stronger effect on the height growth of planted seedlings, and in North Finland the planted seedlings seemed to be influenced to a greater degree by the adverse climatic conditions. The heavier the dose of fertilizer that had been applied, the greater the differences in growth caused by macroclimate. A considerably larger proportion of natural seedlings were located on hummocks compared with that of planted seedlings, irrespective of the region. On plots with wider ditch spacings, seedlings growing on hummocks were superior in height growth to those on flat surfaces.

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Tutkimuksessa selvitettiin suurilmaston sekä hajalannoituksen ja sarkaleveyden yhteisvaikutusta ojitettujen karujen rämeiden mäntytaimikoiden pituuskasvuun. Koekentät perustettiin vuosina 1965-66 eri puolille maata. Lämpösumman vaikutus pituuskasvuun oli selvempi istutus- kuin luonnontaimilla. Pohjois-Suomessa istutus-taimet kasvoivat selvästi luonnontaimia heikommin. Lannoitus lisäsi kasvueroja etelästä pohjoiseen. Istutustaimiin verrattuna selvästi suurempi osa luonnontaimista kasvaa koekenttien sijainnista riippumatta mättäillä. Erityisesti leveämmillä saroilla taimet kasvoivat merkitsevästi paremmin mättäillä kuin tasapinoilla.

Keywords: *Pinus sylvestris*, plantations, regeneration, effective temperature sum, fertilization, ditch spacings, microtopography, peatlands.  
ODC 174.7 *Pinus sylvestris* + 232.4 + 236.4 + 181.2

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## 1. Introduction

Macroclimate affects the development of tree stands. In Finland temperature conditions have been shown to be the decisive factor explaining the decline in stand growth with increasing latitude (e.g. Heikurainen and Seppälä 1965, Koivisto 1971, Laine and Starr 1979, Keltikangas et al. 1986). The accumulated daily mean temperature above a threshold value of 5 °C, the so-called effective temperature sum, has been found to be a suitable expression for the annual effects of temperature (Heikurainen and Seppälä 1965) and has been extensively used in many studies.

Humidity conditions and regional water balances are also important for forest growth (Solantie 1974). Humidity conditions are especially important in the case of drained peatland forests which, in many instances, only exist when supported by artificial drainage.

The Department of Peatland Forestry, University of Helsinki, established a series of 25 experiments in different parts of Finland in 1965-66 with the aim of determining the optimal fertilization and ditch spacing treatments for the growth of natural and planted Scots pine seedling stands on nutrient

poor pine mires.

In addition to fertilization and ditch spacing effects, these experiments have also been used to assess the effect of macroclimate on the early development of planted and natural pine seedling stands (Heikurainen and Laine 1976).

The aim of the present study is to determine the relationship between height growth of naturally regenerated and planted seedling stands, 15 years after establishment, and macroclimate (effective temperature sum). Attention is particularly paid to the interactions between the effects of macroclimate and fertilization and ditch spacing treatments.

The experiment was established under the guidance of late Professor Leo Heikurainen. The authors prepared this paper jointly, although Lic. Toyohiro Miyazawa was largely responsible for preparing the first draft of the manuscript.

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## 2. Experimental sites

The location of the experimental sites and experimental design has been presented in detail earlier (e.g. Heikurainen et al. 1983).

The experiments were established and the treatments carried out in 1965 and 1966. They are distributed rather evenly from south to north between the limits for 1328 and 865 dd °C averages for period 1941-70. The original site type of the experimental sites ranged from dwarf-shrub pine bog to cottongrass pine bog having a peat layer generally exceeding one meter in thickness. Some of the sites exhibited features of tall-sedge pine fens or spruce pine swamps (see Heikurainen and Pakarinen 1982 and Laine et

al. 1986 for site type descriptions).

Each experimental site includes the following treatments: 10, 20 and 30 m ditch spacings; 0, 500, 1000 and 1500 kg/ha NPK fertilizer (N 14-P 7.9-K 8.3 %) doses. The fertilizer was applied broadcast immediately after planting.

Half of the sample plots were naturally regenerated by clear cutting the mature trees and using the existing seedlings less than 0.5 m in height to form the regeneration stock (Heikurainen 1954). In some cases seed trees were left outside the sample plots to complete the regeneration where the seedlings were unevenly distributed. On the other half of the

plots, the existing pine stands were completely removed when the experiments were established and the plots subsequently planted with 2 + 1 pine transplants of local provenance.

The experimental design is a blocked factorial type, in which a strip between

ditches forms a block (ditch spacing treatment with two replications). The fertilization and seedling type treatments were randomly allocated within ditch spacing blocks. Each experiment consists of 48 plots and there is thus a total of 1056 plots in all.

## 3. Field measurements

In each plot the height of trees in autumn 1981 and the annual height growth for years 1974-81 of three to ten sample trees were measured. Selection of the sample trees was according to the following criteria: healthy appearance, no leader changes during the measurement period (1974-81) (Heikurainen et al. 1983). In cases where there were less than 3 such trees fulfilling the above criteria, the plot was not used in the analyses. After this limitation was applied there were 1011 remaining plots.

For the purposes of this paper the fertilization and ditch spacing treatments were combined into fewer treatments as

follows: unfertilized (0) and fertilized (1000 + 1500 kg/ha) fertilizer treatments, and 10 m and 20 + 30 m ditch spacing treatments. This simplification of the treatments was done in order to make interpretation of the results more easy.

In some of the experimental sites, microtopography surrounding the sample tree to a radius of 40 cm was classified as follows: 1) hummock, 2) *Sphagnum fuscum* hummock, 3) lawn level, 4) hollow and 5) ditch spoil. The microtopography classification was carried out in 1981, when the ditch depths were also measured.

## 4. Results

### 4.1. Effective temperature sum, fertilization and ditch spacing

Height growth declined with decreasing temperature sum but the decline was steeper in the case of the planted regeneration treatment compared to natural regeneration treatment. The natural regeneration gave better growth in North Finland, while planted stands grew better in the south (Fig. 1). For both regeneration treatments the regression of growth on temperature sum was steeper in the case of the fertilized treatment.

The partial correlation coefficients, between temperature sum and height growth, calculated to eliminate the multicollinear

effects of site fertility (fertility index) and microtopography (proportion of seedlings growing on hummocks), are significant only in the case of the fertilized treatment (Table 1).

Both natural and planted regeneration treatments on plots with 10 m ditch spacing have grown faster than those on plots with wider ditch spacings. Planted seedlings appear to be more sensitive to regional macroclimate than naturally regenerated seedlings, especially in the case of the wider ditch spacing treatments. This is clearly indicated by the steeper slopes of the regression lines for the planted seedlings in Figure 2.

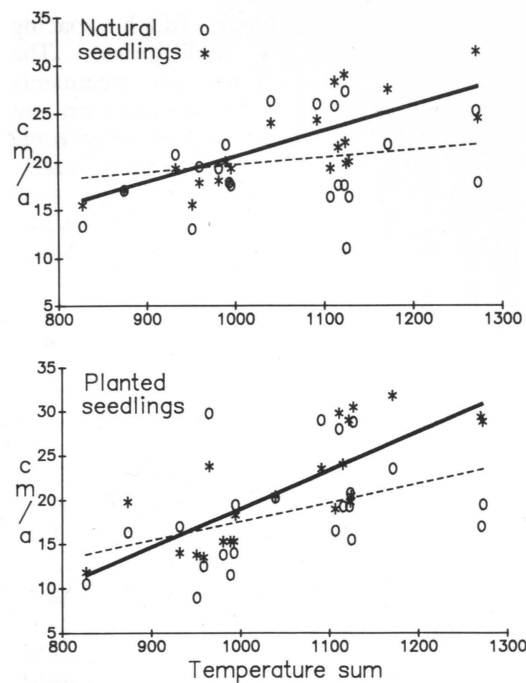


Fig. 1. Relationship between effective temperature sum (period 1977–80) and height growth (period 1978–81) of fertilized (solid line) and unfertilized (broken line) seedling stands, averaged over ditch spacing treatments.

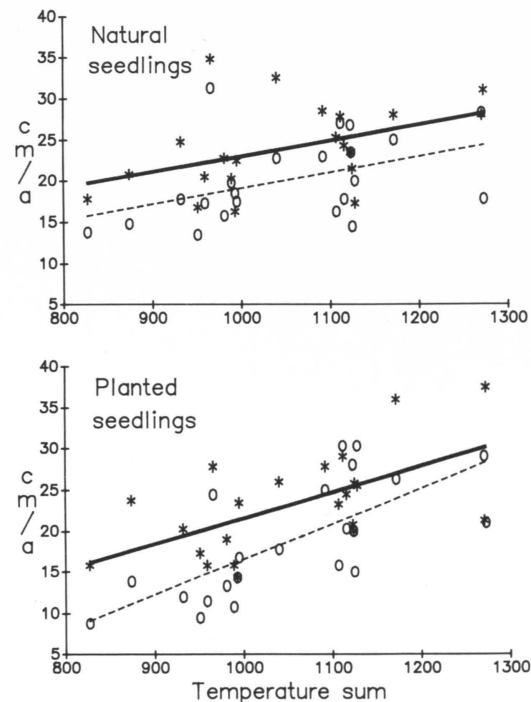


Fig. 2. Relationship between effective temperature sum (period 1977–80) and height growth (period 1978–81) of seedling stands in 10 m (solid line) and in 20/30 m (broken line) ditch spacings, averaged over fertilization treatments.

Table 1. Simple and partial correlation coefficients between height growth and some selected variables. Partial coefficients are given after elimination of linear effects of microtopography and fertility index.

Treatment	Temperature sum		Micro-topography	Fertility index
	Simple	Partial	Simple	Simple
Natural seedlings,				
control	0.450	0.346	-0.247	-0.231
fertilized	0.823**	0.779**	-0.461**	0.012
Planted seedlings,				
control	0.549*	0.377	-0.502*	0.199
fertilized	0.836**	0.791**	-0.527*	0.147

## 42. Influence of microtopography

There is a negative correlation between the effective temperature sum and the proportion of seedlings growing on hummocks (Fig. 3). In the northernmost experiments almost 90 % of the naturally regenerated seedlings were located on hummocks, while only ca. 60 % of the surviving planted seedlings were growing on hummocks. The proportion of seedlings growing on hummocks decreased with

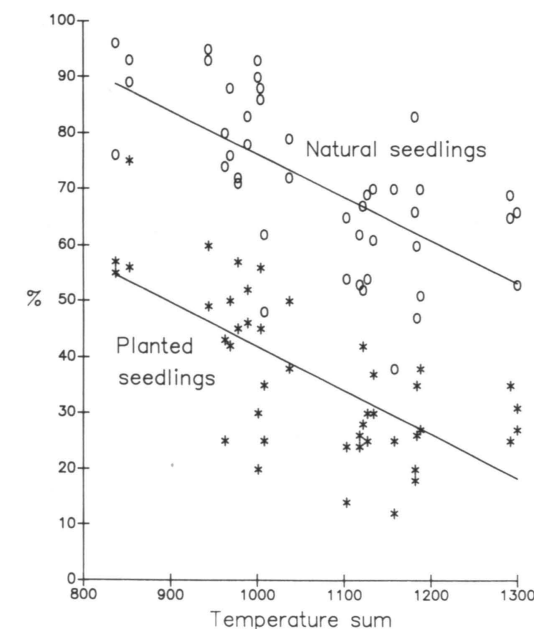


Fig. 3. Relationship between effective temperature sum (period 1941–70) and proportion of seedlings growing on hummocks.

increasing effective temperature sum, and the decrease was the same (ca. 7.0 %/100 dd °C) regardless of the regeneration treatment.

The seedlings on hummocks grew significantly better than those on lawn level surfaces in the wider ditch spacing treatments (20 + 30 m), whereas in the 10 m spacing no difference was found (Fig. 4). The results for both regeneration treatments were quite similar.

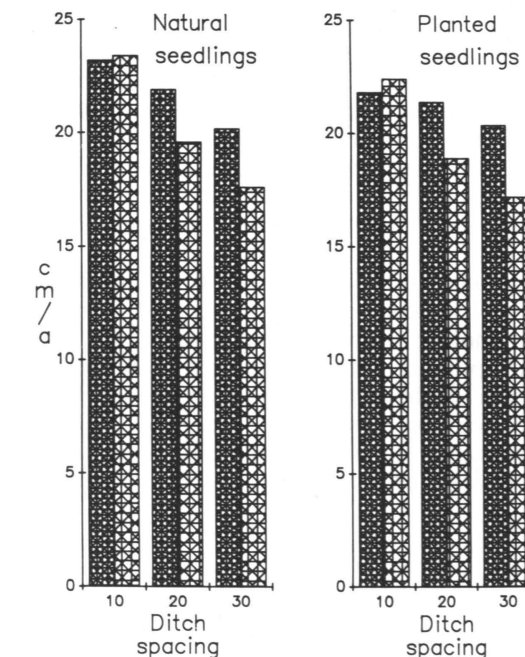


Fig. 4. Height growth (period 1978–81) of seedlings growing on hummocks (darker shading) and of those on lawn level surfaces (lighter shading) in different ditch spacing treatments.

## 5. Discussion and conclusions

The more adverse climatic conditions (i.e. lower temperature sum) in North Finland seem to influence the growth of fertilized seedling stands to a greater degree than unfertilized seedlings. This trend is especially clear in the case of planted

seedlings. This feature was already observed by Heikurainen and Laine (1976) for the growth period 1971–73, and it may be partially attributed to the much shorter duration of the fertilization effect on growth in the north (Heikurainen and Laine 1985).

The results for the naturally regenerated and planted seedlings differ in several respects. In particular, the effective temperature sum has a stronger effect on the height growth of planted seedlings than on that of naturally regenerated seedlings. Similar trends were observed in data collected earlier from the same experimental sites (Heikurainen and Laine 1976).

This regional difference in naturally regenerated and planted seedlings may be partly attributed to the marked increase in the mortality of planted seedlings caused by high doses of fertilizer in combination with decreased temperature sum, as indicated by Heikurainen and Laine (1976). A strong negative correlation has been found between the tree mortality and stand growth rates in planted seedling stands (e.g. Päivänen 1975). In the experiments, the broadcast fertilization treatments were carried out in conjunction with afforestation, which was not the common practice at the time of stand establishment.

Another factor contributing to the suboptimum growth of planted stands in the north is the small proportion of seedlings located on hummocks (ca. 60 %) as compared to that of naturally regenerated seedlings (ca. 90 %) (Fig. 3). This means that

a higher proportion of planted seedlings grows on surfaces with inferior drainage.

The better hydrology of hummocks was indicated in this study by the higher growth level of seedlings on hummocks in wider ditch spacing treatments (20 + 30 m), whereas in 10 m spacing no difference was found between hummock and lawn level surfaces (Fig. 4). Location on a hummock has apparently compensated for the generally insufficient drainage of the wider ditch spacings. Selection of an elevated level (hummock) as a planting site is thus recommendable, especially in the more humid climatic conditions of North Finland.

From the results of this experiment, the following practical recommendations can be drawn:

- use of natural regeneration on nutrient poor pine mires immediately after drainage, particularly in North Finland. Existing seedlings seem to be capable of forming the regeneration stock without delay after drainage and fertilization (cf. Heikurainen 1954).
- selection of such microtopographic sites that are hydrologically favorable for the development of seedlings, i.e. on hummocks (cf. Mannerkoski 1975).

## References

- Heikurainen, L. 1954. Rämemänniköiden uudistamisesta paljaaksihakkausta käyttäen. Referat: Über natürliche Verjüngung von Reisermoor-kiefernbeständen unter Anwendung von Kahlschlag. Acta For. Fenn. 61. 21 p.
- & Laine, J. 1976. Lannoituksen, kuivatuksen ja lämpöolojen vaikutus istutus- ja luonnontaimistojen kehitykseen rämeillä. Summary: Effect of fertilization, drainage, and temperature conditions on the development of planted and natural seedlings on pine swamps. Acta For. Fenn. 150. 38 p. ISBN 951-651-025-6.
- & Laine, J. 1985. Duration of the height growth response of young pine stands to NPK-fertilization on oligotrophic pine bogs in Finland. Seloste: NPK-lannoitusvaikutuksen kesto aika karujen rämeiden taimikoissa. Silva Fenn. 19(2): 155–167. ISSN 0037-5330.
- & Pakarinen, P. 1982. Mire vegetation and site types. In: Laine, J.(ed.). Peatlands and their utilization in Finland. Finnish Peatland Society, Finnish National Committee of the International Peat Society, Helsinki. p. 14–23. ISBN 951-99402-9-4.
- & Seppälä, K. 1965. Regionality in stand increment and its dependence on the temperature factor on drained swamps. Acta For. Fenn. 78. 14 p.
- , Laine, J. & Lepola, J. 1983. Lannoitus- ja sarkaleveyskokeita karujen rämeiden uudistamisessa ja taimikoiden kasvatuksessa. Summary: Fertilization and ditch spacing experiments concerned with regeneration and growing of young Scots pine stands on nutrient poor pine bogs. Silva Fenn. 17(4): 359–379. ISSN 0037-5330.
- Keltikangas, M., Laine, J., Puttonen, P. & Seppälä, K. 1986. Metsäojitetut suot vuosina 1930–1978: Ojitusalueiden inventoinnin tuloksia. Summary: Peatlands drained for forestry in 1930–1978: Results from field surveys of drained areas. Acta For. Fenn. 193. 94 p. ISBN 951-651-070-1.

- Koivisto, P. 1971. Regionality of forest growth in Finland. Seloste: Metsän kasvun alueellisuus Suomessa. Commun. Inst. For. Fenn. 71(2). 76 p.
- Laine, J., Päivänen, J., Schneider, H. & Vasander, H. 1986. Site types at Lakkasuo mire complex. Field guide. Publ. from the Dept. of Peatland Forestry, Univ. of Helsinki 8. 35 p.
- & Starr, M.R. 1979. An analysis of the post-drainage stand increment in relation to the peatland site type classification in Finland. Proc. of the International Symposium on Classification of Peat and Peatlands, Hyytiälä, Finland, September 17–21, 1979. International Peat Society. p. 147–159.
- Mannerkoski, H. 1975. Vanhan ojitusalueen uudistamismätästysmenetelmällä. Summary: Hummock-building method in reforestation of an old drainage area. Suo 26(3–4): 65–68. ISSN

0039-5471.

- Päivänen, J. 1975. Männyn istutuksen ajankohta ojiteilla avosoilla. Pääteinventoinnin tuloksia. Summary: Planting date of Scots pine on drained open peatlands. Results from final inventories. Suo 26(5): 95–100. ISSN 0039-5471.
- Solantie, R. 1974. Kesän vesitaseen vaikutus metsä- ja suokasvillisuuteen ja linnustoon sekä lämpöolojen välityksellä maatalouden toimintaedellytyksiin Suomessa. Summary: The influence of water balance in summer on forest and peatland vegetation and bird fauna and through the temperature on agricultural conditions in Finland. Silva Fenn. 8(3): 160–184. ISSN 0037-5330.

Total of 13 references