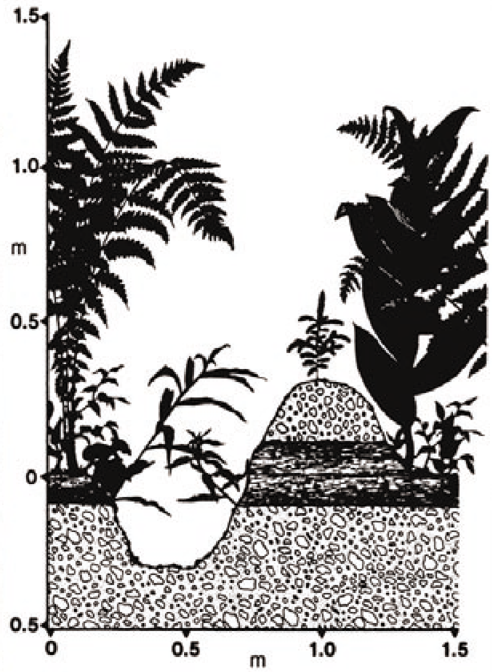
# The effects of soil temperature and site preparation on subalpine and boreal tree species: a bibliography




*L.M. McKinnon, A.K. Mitchell, and A. Vyse*

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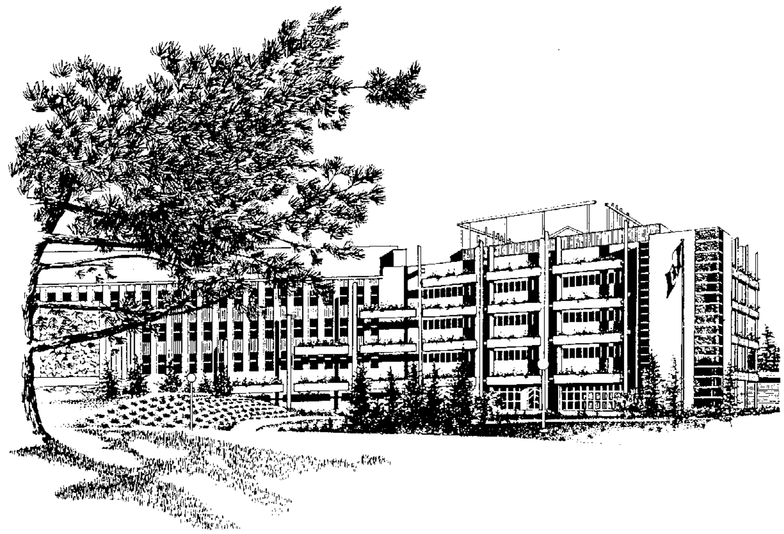

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# The effects of soil temperature and site preparation on subalpine and boreal tree species: a bibliography


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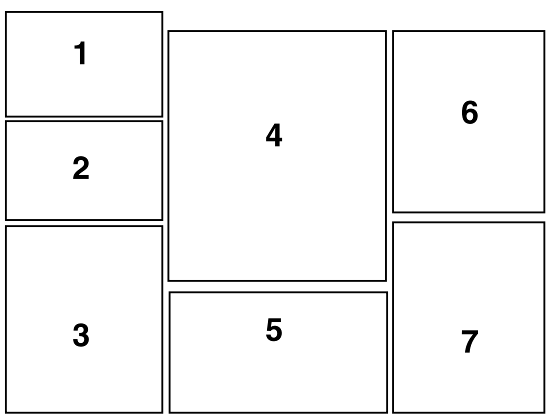


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2. Mechanical site preparation: mounding (Photo: A. Vyse).
3. Regenerating seedling on a mound (Photo: A. Vyse).
4. Schematic of a mound showing soil layers and the seedling and vegetation in year 1 (Spittlehouse *et al.* 1990).
5. Measuring seedling moisture stress in response to site preparation in the field (Photo: A. Vyse).
6. Measuring light levels around seedlings in a site preparation trial (Photo: A. Vyse).
7. Laboratory experiment measuring the effects of low root temperature on seedling growth and physiology (Photo: T. Bown).

# Abstract

In forestry, the purpose of site preparation is to ameliorate environmental conditions which limit tree seedling survival and growth. In subalpine and boreal forests, low soil temperature in particular is widely held to be a major limiting factor and frequently cited as rationale for the widespread use of site preparation prior to planting. However, the literature suggests that under field conditions higher soil temperatures and/or site preparation are not always associated with improvements in tree seedling performance. The purpose of this bibliography is to compile studies that may help to clarify the effects of soil temperature and site preparation on subalpine and boreal species. The bibliography contains more than 300 references and emphasizes North American experience, but has been supplemented with related studies from Fennosandia.

# Résumé

En foresterie, la préparation du terrain vise à améliorer les conditions environnementales qui limitent la survie et la croissance des semis. Dans les forêts subalpines et boréales, la basse température du sol en particulier est largement reconnue comme étant un important facteur limitant et est souvent invoquée pour justifier la pratique généralisée de la préparation du terrain avant la plantation. Cependant, il ressort des publications sur le sujet que, dans des conditions naturelles, une température du sol plus élevée conjuguée ou non à la préparation du terrain ne contribue pas toujours à améliorer le rendement des semis. La présente bibliographie est une compilation des études qui peuvent aider à clarifier les effets de la température du sol et de la préparation du terrain sur les essences subalpines et boréales. Les 300 références qu'elle contient sont surtout tirées de l'expérience nord-américaine, mais elles ont été complétées par des études connexes de la Fennoscandie.

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# 1 Introduction

In forestry, 'site preparation' is the treatment of harvested sites to remove or disturb logging slash, vegetation, forest floor materials, or soil prior to tree seedling regeneration. Methods commonly used include controlled burning, machine-based disturbances such as scarification, trenching, or the creation of mineral soil mounds, and the removal of vegetation using herbicides, manual brushing, or steam treatment. Regardless of the method used, the purpose of site preparation is to overcome limitations to the survival and growth of tree seedlings by creating a sufficient number of suitable, well-spaced growing sites. Thus, the use of site preparation implies that the factors limiting the survival and growth of a given tree species on a given site are understood and require amelioration to achieve acceptable seedling performance. Depending on the site and the method of site preparation employed, factors which may be modified by site preparation include soil temperature, soil water, soil aeration, soil nutrient availability, vegetation competition (for light, nutrients, water, or space), and the susceptibility of tree seedlings to vegetation press, pests, or frost.

Low soil temperature in particular is widely held to be a major limiting factor to the performance of tree species in subalpine and boreal forests, and therefore frequently cited as rationale for the widespread use of site preparation before planting. However, although controlled studies have shown that soil temperature can be a potentially important factor in the performance of subalpine and boreal tree species, under field conditions higher soil temperatures or site preparation are not always associated with improvements in tree seedling performance. Although the reasons for this are not known, this situation might arise because: i) site preparation may not always result in a difference in soil temperature between site-prepared and control areas that is large enough, long enough in duration, or in the range to be physiologically important; or ii) tree species responses to soil temperature typically observed in the laboratory under otherwise generally favourable conditions may not always be realized in the field because of acclimation effects or because other factors such as high vapour pressure deficits (which restrict photosynthesis) may limit the response to improved soil temperatures.

The purpose of this bibliography is to compile studies that may help to i) clarify the effects of soil temperature on subalpine and boreal species under controlled conditions and in the field, and ii) aid in the identification of sites and conditions in which site preparation may not be particularly effective in improving the performance of planted seedlings in subalpine or boreal climates. Section 2 comprises studies focusing on the effects of soil temperature on tree species in the absence of site preparation, and includes both controlled laboratory and nursery studies (Section 2.1)[1] and field studies conducted in subalpine and boreal climates (Section 2.2). Because inherent mechanistic responses to soil temperature are explored, studies of all life stages, from first-year to maturity, have been included. Section 3 represents the operational field perspective, and consists of studies of the effects of site preparation on the performance of planted seedlings in subalpine and boreal climates. Soil temperature was measured in some but not all of the site preparation studies presented. Section 4 contains a list of recommended reading of review articles and other literature describing important principles of tree seedling establishment, soil temperature, and site preparation. Citations are listed alphabetically by author within Sections 2, 3, and 4, and then indexed by species in Section 5.

The site preparation portion of the bibliography (Section 3) emphasizes North American experience, but this data base has been supplemented with related studies from Fennosandia where readily accessible and where at least an abstract was available in English. Additional relevant titles are available in the reference or literature cited sections of those Fennosandian studies which have been included. Although we have borrowed heavily from Fennosandian experience in the development of site preparation practices for planted stock in North America, research and communication of the effects of site preparation on subalpine and boreal species has increased markedly in North America in the last 15-years (Figure 1).

[1] Controlled studies are generally only included where soil temperature was manipulated independently of air temperature.

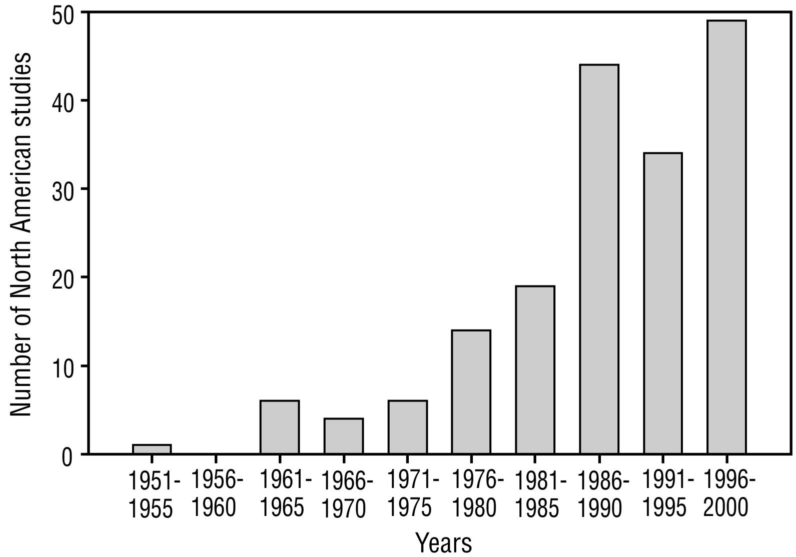


Figure 1. Chronology of the number of North American studies available regarding the effects of site preparation on planted stock in subalpine and boreal climates (source: Section 3).

Criteria used for inclusion or exclusion of field studies in the bibliography were as follows. Field studies were generally considered subalpine or boreal and therefore included if carried out in the Dfc region defined by the Köppen-Geiger global system of climate classification[2]. However, because the boundaries for the Dfc region are somewhat coarsely resolved, inclusion or exclusion of studies from Canada and Fennosandia was based more specifically on the climatic divisions of Rowe (1972)[3] for Canada and Ahti *et al.* (1968)[4] for Fennosandia. The exception in Canada was the province of British Columbia where, due to the complex distribution of forest types, a more detailed provincial ecosystem classification system was used (Meidinger and Pojar 1991)[5].

2 Refer to: Strahler, A., and Strahler, A. 1997. Physical geography: science and systems of the human environment. John Wiley & Sons, Inc., New York, pp. 188-189.

3 Rowe, J.S. 1972. Forest regions of Canada. Publ. 1300, Can. For. Serv., Ottawa, Ont., 172 pp. [subalpine and boreal forest regions considered]

4 Ahti, T., Hämet-Ahti, L., and Jalas, J. 1968. Vegetation zones and their sections in northwestern Europe. Ann. Bot. Fenn. 5: 169-211. [southern, middle, and northern boreal forest regions considered]

5 Meidinger, D., and Pojar, J. (Compilers and Editors). 1991. Ecosystems of British Columbia. Spec. Rep. Ser. 6, B.C. Min. For., Res. Br., Victoria, B.C., 330 pp. [Engelmann Spruce-Subalpine Fir (ESSF), Boreal White and Black Spruce (BWBS), and Sub-Boreal Spruce (SBS) zones considered]

# 2 Response to soil temperature in the absence of site preparation

## 2.1 Controlled laboratory and nursery studies


1 Andersen, C.P.; Sucoff, E.I.; Dixon, R.K. 1986. Effects of root zone temperature on root initiation and elongation in red pine seedlings. Canadian Journal of Forest Research 16: 696-700.

2 Aubin, L. 1974. Overwintering container conifers in prairie Canada. *in* Proceedings of the International Plant Propagators' Society 24: 466-469.

3 Bigras, F.J. 1997. Root cold tolerance of black spruce seedlings: viability tests in relation to survival and regrowth. Tree Physiology 17: 311-318.

4 Bigras, F.J.; Calmé, S. 1994. Viability tests for estimating root cold tolerance of black spruce seedlings. Canadian Journal of Forest Research 24: 1039-1048.

5 Camm, E.L.; Harper, G.J. 1991. Temporal variations in cold sensitivity of root growth in cold-stored white spruce seedlings. Tree Physiology 9: 425-431.

6 Chalupa, V.; Fraser, D.A. 1968. Effect of soil and air temperature on soluble sugars and growth of white spruce (*Picea glauca*) seedlings. Canadian Journal of Botany 46: 65-69.

7 Chapin, F.S. III; van Cleve, K.; Tryon, P.R. 1986. Relationship of ion absorption to growth rate in taiga trees. Oecologia 69: 238-242.

8 Coleman, M.D.; Hinckley, T.M.; McNaughton, G.; Smit, B.A. 1992. Root cold hardiness and native distribution of subalpine conifers. Canadian Journal of Forest Research 22: 932-938.

9 [6]Colombo, S.J. 1994. Timing of cold temperature exposure affects root and shoot frost hardiness of *Picea mariana* container seedlings. Scandinavian Journal of Forest Research 9: 52-59.

10 Coursolle, C.; Bigras, F.J.; Margolis, H.A. 2000. Assessment of root freezing damage of two-year-old white spruce, black spruce and jack pine seedlings. Scandinavian Journal of Forest Research 15: 343-353.

11 DeLucia, E.H. 1986. Effect of low root temperature on net photosynthesis, stomatal conductance and carbohydrate concentration in Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) seedlings. Tree Physiology 2: 143-154.

12 DeLucia, E.H.; Day, T.A.; Öquist, G. 1991. The potential for photoinhibition of *Pinus sylvestris* L. seedlings exposed to high light and low soil temperature. Journal of Experimental Botany 42: 611-617.

13 Dobbs, R.C.; McMinn, R.G. 1977. Effects of scalping on soil temperature and growth of white spruce seedlings. Pages 66-73 *in* Proceedings of the 6th Annual British Columbia Soil Science Workshop: Energy, Water and the Physical Environment. *Edited by* T. A. Black. British Columbia Ministry of Agriculture, Victoria, British Columbia..


[6] Root temperature was not manipulated independently of shoot temperature in this study. However, shoots (but not roots) were covered during the freezing test, and the resulting root damage was assessed after 2 weeks.

14 Domisch, T.; Finér, L.; Lehto, T. 2001. Effects of soil temperature on biomass and carbohydrate allocation in Scots pine (*Pinus sylvestris*) seedlings at the beginning of the growing season. Tree Physiology 21: 465-472.

15 Gibbons, F.D. III. 1983. The effects of mulches and antitranspirants on winter injury of evergreens. American Nurseryman 157: 47-55.

16 Grossnickle, S.C. 1987. Influence of flooding and soil temperature on the water relations and morphological development of cold-stored black spruce and white spruce seedlings. Canadian Journal of Forest Research 17: 821-828.

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18 Grossnickle, S.C.; Blake, T.J. 1985. Acclimation of cold-stored jack pine and white spruce seedlings: effect of soil temperature on water relation patterns. Canadian Journal of Forest Research 15: 544-550.

19 Harper, G.J.; Camm, E.L. 1993. Effects of frozen storage duration and soil temperature on the stomatal conductance and net photosynthesis of *Picea glauca* seedlings. Canadian Journal of Forest Research 23: 2459-2466.

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22 Karlsson, P.S.; Nordell, K.O. 1996. Effects of soil temperature on the nitrogen economy and growth of mountain birch near its presumed low temperature distribution limit. Ecoscience 3: 183-189.

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27 Landhäusser, S.M.; Lieffers, V.J. 1998. Growth of *Populus tremuloides* in association with Calamagrostis canadensis. Canadian Journal of Forest Research 28: 396-401.

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31 Lawrence, W.T.; Oechel, W.C. 1983. Effects of soil temperature on the carbon exchange of taiga seedlings. II. Photosynthesis, respiration, and conductance. Canadian Journal of Forest Research 13: 850-859.

32 Lieffers, V.J.; Rothwell, R.L. 1986. Effects of depth of water table and substrate temperature on root and top growth of *Picea mariana* and Larix laricina seedlings. Canadian Journal of Forest Research 16: 1201-1206.

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## 2.2 Field studies in subalpine and boreal climates


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# 3 Response of planted stock to site preparation in subalpine and boreal climates


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# 4 Recommended reading

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Sutton, R.F. 1993. Mounding site preparation: a review of European and North American experience. New Forests 7: 151-192.

# 5 Species index

Individual papers from Sections 2 and 3 of the bibliography are categorized here according to the species or hybrid studied, as identified by the authors. Notable in this regard is that, in the genus *Picea*, citations listed for *P. glauca* (white spruce) or *P. engelmannii* (Engelmann spruce) may in some cases be relevant to the study of *P. glauca* x *P. engelmannii* ("interior" or "hybrid" spruce) and vice versa (for a description of the geographical distribution of *Picea* in northern climates, see Grossnickle 2000, Section 4). Numbers in parentheses denote repeat citations, i.e., those citations appearing in more than one section or subsection of the bibliography.

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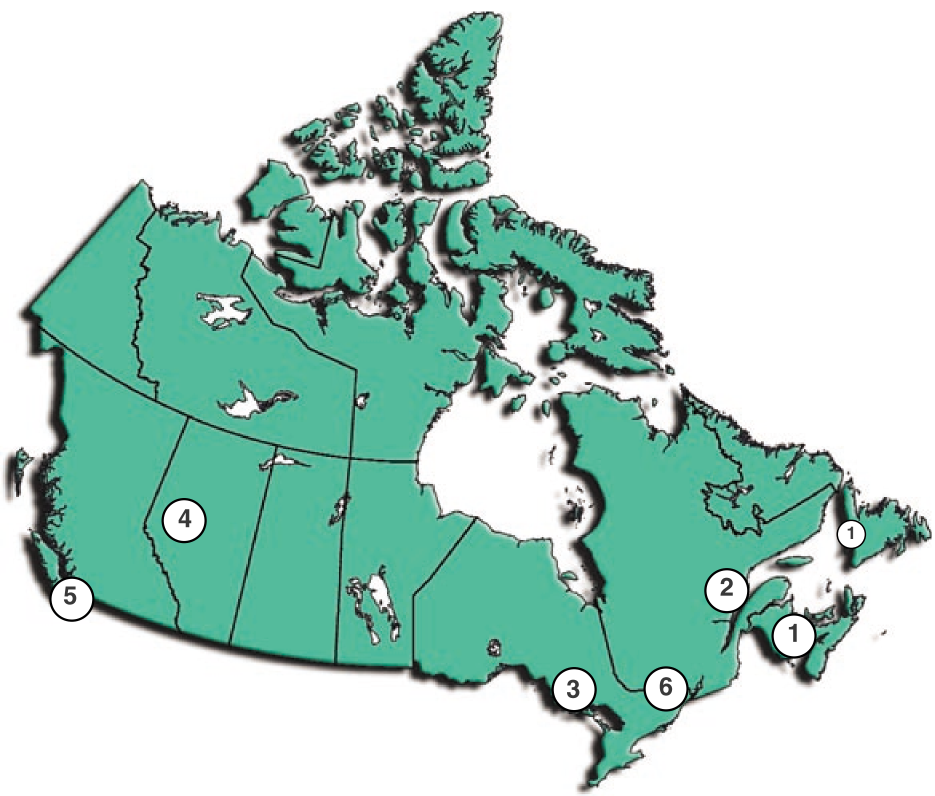


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