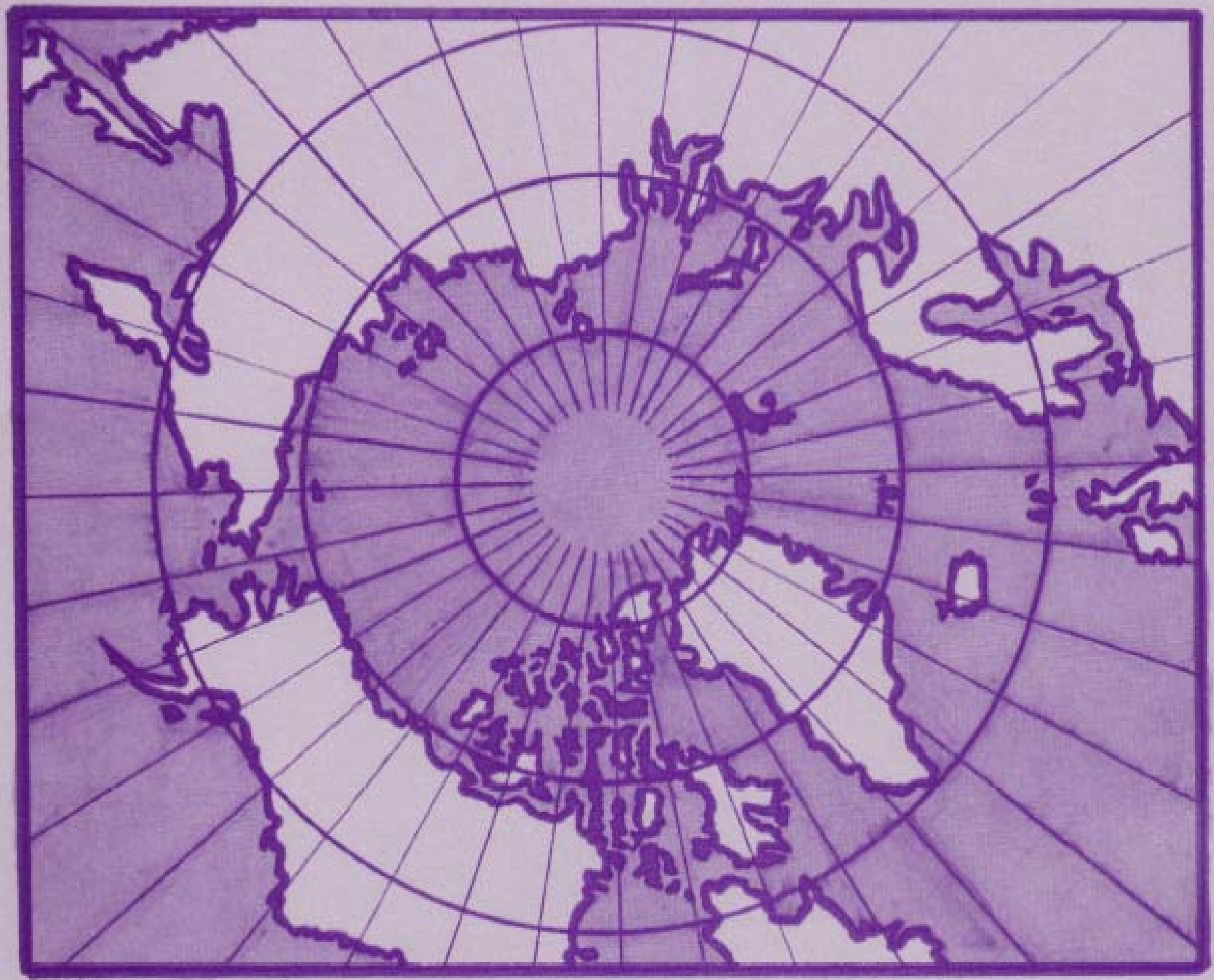
United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-247
April 1989

Forest Regeneration at Northern Latitudes Close to Timber Line



FOREST REGENERATION AT NORTHERN LATITUDES CLOSE TO TIMBER LINE

16-20 June 1985
Luleå-Galliväre-Östersund, Sweden

PROCEEDINGS OF THE
SEVENTH ANNUAL WORKSHOP ON SILVICULTURE AND MANAGEMENT
OF NORTHERN FORESTS

Owe Martinsson, Workshop Coordinator

Edmond C. Packee, IUFRO Working Party S1.05-12 Chairman

Anthony Gasbarro, Associate Editor

Teri Lawson, Technical Editor

INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS
WORKING PARTY S1.05-12
NORTHERN FOREST SILVICULTURE AND MANAGEMENT

Published cooperatively by
Pacific Northwest Research Station
U.S. Department of Agriculture, Forest Service
and
Agricultural and Forestry Experiment Station
School of Agriculture and land Resources Management
University of Alaska Fairbanks

General Technical Report PNW-GTR-247

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FOREWORD

Edmond C. Packee

This, the seventh international gathering of the group, is the first to be held as a Working Party of the International Union of Forest Research Organizations. As Working Party Sl.0S-12, Northern Forest Silviculture an Management, the group which met for the first time in 1979 formally established itself in the Worldwide Forestry Community. Emphasis of the Working Party is on the Northern Forest, referred to by others as the Boreal Forest, the Taiga, and the Pre-Tundra Forest. This forest is the northern forest of America, Europe, and Asia and is an important resource to the people's of the World.

The Northern Forest is an important supplier of wood fibre for lumber, veneer, reconstituted wood products, and pulp. It is an important source of recreation and is home to fish and wildlife. It provides forage and browse for domestic animals. It provides food for human consumption: lingonberries, blueberries, mushrooms, and delicate herbs as well as meat and fish. The Northern Forest is a source of freshwater which finds its way to three great oceans: the Arctic, the Atlantic, and the Pacific. The Northern Forest is home to citizens and guests of many countries. In establishing the Northern Forest Silviculture and Management Working Party within IUFRO, the importance to the world of this forest is acknowledged.

This was the seventh annual gathering of foresters and resource managers interested in the Northern Forest and the first as IUFRO Working Party Sl.05-12. Proceedings of the past workshops have been published by the USDA Forest Service Pacific Northwest Forest and Range Experiment Station in cooperation with the School of Agriculture and Land Resources Management of the University of Alaska Fairbanks. Proceedings of the IUFRO Working Party Symposia will be published in a similar manner.

Previous Workshop locations and Topics were:

Year	_Location	Topic
1979	Fairbanks, Alaska U.S.A.	General problems related to forest regeneration in the circumpolar north.
1980	Umea, Sweden	Forest regeneration problems in Sweden.
1981	Prince George, British Columbia, Canada	Forest regeneration problems in Northwest Canada.
1982	Hinton, Alberta, Canada	Management of lodgepole pine in the boreal forest.
1983	Fairbanks, Alaska U.S.A.	Forest classification at high latitudes as an aid to forest regeneration.
1984	Edmundston, New Brunswick, Canada	The yield advantages of artificial regeneration at High Latitudes

IUFRO Working Party Sl.054-12 Symposia

1985	Lulea, Sweden	Forest regeneration at northern latitudes close to timber line.
1986	Grand Prairie, Alberta & Dawson Creek, British Columbia	
1987	Rovaniemi and Lapland, Finland.	

EDMOND C. PACKEE is an Assistant Professor of Forest Management at the Agricultural and Forestry Experiment Station, University of Alaska Fairbanks.

At this time, as Working Party Chairman, I would like to thank the organizers and hosts of the Lulea, Sweden IUFRO Sl.05-12 Symposium, especially Dr. Owe Martinsson and his colleagues of the Department of Silviculture of the Swedish University of Agricultural Sciences, Umea, Sweden; Domanrerkets; and the Swedish Cellulose Company. Also appreciated are the time and efforts of the authors of the papers in this publication as well as the individuals who prepared and presented much information at the field stops. Without their superb efforts, the first IUFRO Northern Forest Silviculture and Management Symposium would not have been such a great success.

INTRODUCTION

Owe Martinssen

It is a great pleasure to see this group come together in northern Sweden.

This workshop is going to stress problems of forest regeneration at northern latitudes, close to the timber line, and you will see some of the most problematic parts of Sweden in terms of forest regeneration.

However, you should consider that you are new at 65°30'N latitude, and before tomorrow night we will cross the 67th parallel. That is the same northern location as Verkhojansk in north central Siberia or Coppermine in the Northwest Territories or Old Crew in the Yuken. Compared to these places, I would say it is not too bad here in northern Scandinavia, especially if we consider the highly productive spruce forests growing in northern Norway at latitude 70°, which we unfortunately will net be able to see en this excursion.

With these comparisons I will draw your attention to the unique situation that exists here in northern Scandinavia: the combination of a relatively mild climate and almost continuous day light during the growing season.

A few words of technical information: This workshop is going to be four rather tough days in terms of travelling. We will start tomorrow at 08.00 and head north to Gällivare which is about 200 km from here. There we will stay in the vacation village Börnfällan (The Bear Trap) for two nights and have indoor sessions on Tuesday and Wednesday morning. On Wednesday we sill leave Gällivare and arrive at Storuman late in the night. The distance that day will be about 500 km with several steps and excursion points along the read. On Thursday we w111 cont1nue from Storuman west and south crossing altitudinal tree line and end up in Jämtland. The total distance of driving will be about 1500 km.

The weather conditions should be geed; but you should be prepared for cold and rainy days.

With these words I wish you geed luck and I hope you will have some profitable and enjoyable days in Sweden.

OWE MARTINSSON from the Department of Silviculture at the Swedish University of Agricultural Sciences in Umea, Sweden.

A HISTORICAL OVERVIEW AND FUTURE PROGRAM DIRECTION 0F THE NORTHERN FOREST SILVICULTURE AND MANAGEMENT WORKING PARTY

Anthony F. Gasbarro

INTRODUCTION

Since 1979 a group of research scientists and land managers from northern countries has he1d annua1 workshops to discuss research and land management activities related to forest regeneration at high latitudes. Our group, formally known as the International Committee on Forest Lands of Northern Latitudes, has recently been incorporated into Division 1, Forest Environment and Silviculture, of the International Union of Forest Research Organizations (IUFRO). We are now known as the Northern Forest Silviculture and Management Working Party with IUFRO designation SI.05-12.

The purpose of this presentation is to provide background information and stimulate discussion concerning the future direction of the working party. I will discuss the following:

- the historical development of the working party;
- how we have operated;
- some considerations concerning our future direction;
- benefits derived from the workshops.

HISTORICAL DEVELOPMENT OF THE WORKING PARTY

The idea for what would eventually become the Northern Forest Silviculture and Management Working Party originated at a symposium held at the University of Alaska Fairbanks, USA in 1977. The symposium, entitled "North American Forest Lands at Latitudes North of 60 Degrees," was designed to lib ring together and discuss the broad array of information needed for the management of forest lands a4040t high northern 1atitudes.1I At this meeting research scientists and land managers from North America, Scandinavia and the Soviet Union exchanged ideas concerning the biological and socio-economic aspects of high latitude forestry. The concepts discussed at this symposium and the desire to continue international cooperation to so1ve northern forest management prob1ems 1ed to the establishment of an International Committee of Forest Lands of Northern Latitudes. This committee came into being through the efforts of the School of Agriculture and Land Resources Management of the University of Alaska Fairbanks and the United States Forest Service, which also provided generous financial support. The purpose of the committee was "to stimulate and facilitate international cooperation on applied forest management and to plan and coordinate applied research requiring widespread rep1ication in northern forests." The committee's first organizers were particularly interested in bringing technology and research results from Scandinavia to Alaska and the Yukon Territory, Canada.

We wrote to forest research scientists and 1and managers throughout the circumpo1ar north asking them to identify areas of concern to forest managers in each of their respective countries. The 1etter was accompanied by an appendix identifying the fo11owing four broad prob1em

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areas: long term trends insitequa1ity, fire management, timber harvesting and processing, and forest regeneration.

Replies enthusiastically supported the idea of forming such a committee. A majority of the respondents identified forest regeneration as the area of most concern. The School of Agriculture and Land Resources Management, including the Agricultural and Forestry Experiment Station, University of Alaska Fairbanks, took responsibility for coordinating the committee.

The first international workshop organized by the committee dea1t with forest regeneration at high 1atitudes and was he1d in Fairbanks, A1aska in November 1979. Since then six additional forest regeneration workshops, including this one, have been held. The proceeding so if five of the workshops have been published and another is in press. A list of the first six workshops and the papers presented is included (see Appendix).

Since its inception in 1979, the committee envisioned conducting workshops in co1-1aboration with the International Union of Forestry Research Organizations (IUFRO). This collaboration was slow to materialize; nevertheless, in 1983 at the sixth annual workshop in Edmundston, New Brunswick, Canada, the committee decided to actively pursue becoming a member of IUFRO. In- early 1985 the International Committee on Forest Lands of Northern Latitudes was recognized' by IUFRO as the Northern Forest Silviculture and Management Working Party. Dr. Edmond C. Packee, Assistant Professor of Forest Management, University of Alaska Fairbanks, was appointed working party 1eader. In the 1etter of recognition, the IUFRO section chairman recognized the past work of the committee and indicated it was one of the most active groups of its type in the world. It is not very often a working party in IUFRO begins as an institute sponsored organization and is then fully recognized without first going through another working party.

HOW WE HAVE OPERATED

From its inception and until it became a working party of IUFRO, the International Committee on Forest Lands of Northern Latitudes remained a relatively informal group. The committee met once a year for a workshop which included a short business meeting. Until last year's meeting there was no official chairperson. The leadership of each annua1 workshop was assumed by the host country person responsible for organizing the workshop.

The School of Agriculture and Land Resources Management of the University of A1aska Fairbanks has been the principa1 coordinator of the committee. This has involved assuming responsibi1ity for publishing the proceedings of each meeting in cooperation with the U.S. Forest Service, maintaining an updated mailing list and assisting the host country of each annual workshop with the preparation and distribution of announcements.

Another aspect of the committee's operation has been its changing geographic perspective. The original intention was to focus only on research and management north of 60 degrees north latitude. It soon became evident, particularly in the case of Canada, that much of the relevant research and management case histories are from areas south of that 1atitude. Thus, the tendency has been to include in the workshop discussions of research and management practices from more southerly latitudes, but only when these were related to both the tree species and management practices for potential app1ication north of 60 degrees north latitude.

The committee once attempted to expand its activities and take on an additional task. This task, initiated during the 1979 workshop, involved the preparation of a bulletin on the regeneration of white spruce in A1aska and the Yukon Territory. Emphasis was to be placed upon research from Alaska and the Yukon Territory as we 11 as information for Norway spruce and other circumpolar species similar to white spruce. The bulletin was to contain sections on: seed availability, site preparation, site productivity, nursery practices and planting techniques, and stand establishment. Individual scientists were assigned responsibility for each section and it was agreed that detailed chapter outlines and research documentation would be presented for review and discussion at the 1980 workshop; however, the assignments lost their priority when the individuals returned to their regular work and only one publication resulted from this effort. A manuscript prepared for the bulletin by Dr. John Alden, Institute of Northern Forestry, United States Forest Service, was pub1ished early this year by the Agricu1tura1 and Forestry Experiment Station, University of Alaska Fairbanks as a separate bulletin entitled Bio1ogoly and Management of White Spruce Seed Crops for Regeneration in Sub-Arctic Tiaga Forests.

SOME CONSIDERATIONS CONCERNING OUR FUTURE DIRECTION

As an official working party of IUFRO we should have formally stated goals and objectives to guide us in our future endeavors. We could begin to develop these goals and objectives at this workshop and finalize them before the 1986 meeting. With this in mind, I would like to discuss a few elements from our past and pose a few questions we might consider as we think about the direction we should take.

When the International Committee on Forest Lands of Northern Latitudes first began, its overall goal was “to stimulate and facilitate international cooperation on applied forest management and to plan and coordinate applied research requiring wide spread replication in northern forests.” Our current focus on forest regeneration fulfills only a part of this broad goal. Initially, it was envisioned that work wou1d continue on one topic re1event to high latitude forestry for as long as it was necessary and then shift to another, perhaps unrelated, topic. Are we now ready to proceed with another topic or should we continue discussing forest regeneration Changing to another topic could mean starting a new working party, perhaps in another IUFRO division.

Other topics were identified by forest managers and scientists from northern countries who replied to the 1979 questionnaire. These include:

- social problems in northern forest management;
- economics of northern forest management;
- conservation of northern forest genetic resources;
- nutrient cycling in the boreal forest;
- problems relating to forest seed supply;
- fire management;
- stand growth and yield;
- forest protection;
- biogeoc1imatic classification and evaluation of forest ecosystems;
- stand treatment methods;
- management of forestry operations at northern latitudes;
- wood transport operations.

A second consideration concerns the interrelationship of management and research within the working party. At its onset the committee expected to deal with both forest management and applied research prob1ems. Many of the papers presented in the past six workshops and the orientation of the workshop field trips reflected the former committee Is desire to have an interchange of ideas between managers and research scientists about the problems and direction of management and research in the northern forests. Can we continue this management/ research emphasis now that we a re an IUFRO working party, or should we primarily focus on research? Much of the success of the original committee can be attributed to the participation of both forest scientists and managers in the workshop sessions.

A final point for discussion concerns the area of the north that will be the target of our management and research deliberations. How should the northern forest area be defined and which species should merit our concern? We started by defining our target area using the term “high latitude.” By this we meant north of 60 degrees north latitude. In practice, certain ecological factors such as permafrost, length of growing season and species present cannot be adequate1y defined by latitude; thus, our workshops have dealt with areas and their attendant management and research problems considerably south of this latitude. Our last workshop was in Edmundston, New Brunswick at 47 degrees north latitude. In every case, however, our workshops have dealt with forest species that are present and management techniques that can be applied north of 60 degrees. Whether it was intentional or not, should this guideline be applied to future working party deliberations?

BENEFITS DERIVED FROM THE WORKSHOPS

In determining the future direction of our working party, we should consider some of the benefits which have been derived from the past activities of our group. As a result of contacts made during one of the meetings, forest managers from. Canada are sharing their experience in site preparation with their Alaska counterparts, including loaning the University of Alaska Fairbanks an experimental piece of site preparation equipment. Scandinavian site preparation and artificial regeneration equipment and techniques are being tried in Alaska. Recently the University of Alaska Fairbanks and the Alaska Division of Forestry jointly purchased a disc-trencher developed in Scandinavia for site preparation. This equipment is currently being eva1uated for use in Alaska. Research is also being conducted in Alaska on the use of two types of plastic seed shelters developed in Scandinavia.

After seeing forest management under permafrost conditions in Alaska during the 1983 workshop, Canadian forest managers have a better idea of what to expect as forest management moves north into the permafrost area of that country. The visit to extensive white spruce plantations during last year's workshop in New Brunswick, Canada made managers and research scientists aware that more research is needed to better evaluate the costs and benefits of plantation forestry so they can be compared with the costs and benefits of natural regeneration. Finally, the Scandinavians have been ab1e to observe and discuss at two of the workshops management problems associated with lodgepole pine, as management is now underway in extensive lodgepole pine plantations in both Finland and Sweden.

SUMMARY AND CONCLUDING REMARKS

The purpose of this presentation has been to provide background information and stimulate discussion concerning the future direction of what is now the Silviculture of Northern Forests Working Party. This working party evolved from the International Committee on Forest Lands of Northern latitudes which had a broad goal of international cooperation on applied forest management and research' in the northern boreal forest. That goal was subsequently narrowed to enab1e the committee to focus on the prob1em of forest regeneration which has been the topic of seven annual workshops.

Since we are now a formal group within IUFRO, it is important that we have a clear idea about our future direction. The task now before us is to begin setting goals and objectives for our working party. In doing this we will need to determine: 1. what subject matter we wi11 cover; 2. the interrelationship between management and research in future working party activities; and 3. the geographic focus of our problem solving effort.

How successful we wi11 be as a working party of IUFRO wi11 depend on our abi1ity to define and carry out a flexible plan of action. Let us get started toward this goal.

APPENDIX

PAPERS PRESENTED AT THE FIRST SIX WORKSHOPS SPONSORED BY INTERNATIONAL COMMITTEE ON FOREST LANDS OF NORTHERN LATITUDES

1979 - Forest Regeneration at High Latitudes - Fairbanks, Alaska

Braathe, Peter. Developing a Program for Research and Applied Management Related to Forest Regeneration. Norway.
Chrosciewicz, Z. Some Practical Methods for Securing Adequate Postcut Forest Reproduction in Canada. Canada.
Gardner, A.C. Regeneration Problems and Options for White Spruce on River Floodplains in the Yukon Territory. Canada.
Kerr_ Cal. Alaska Regeneration: State Policy and Problems. U.S.A.
Putkisto, Kaile. Site Preparation Techniques for Reforestation. Finland.
Remrod, Jan. Experiences and Practices Related to Forest Regeneration in Northern Sweden. Sweden.
Van Cleve, Keith, Ted Dyrness and Les Viereck. Nutrient Cycling in Interior Alaska Flood Plains and its Relationship to Regeneration and Subsequent Forest Development. U.S.A.
Weetman, G.R. The Importance of Raw Humus Accumulation in Boreal Forest Management. Canada.
Zasada, John. Some Considerations in the Natural Regeneration of White Spruce in Interior Alaska. U. S. A.

1980 - Forest Regeneration at High Latitudes: Experiences from Northern Sweden - Umea, Sweden.

Axelson, Bo. Forestry in Northern Sweden. Sweden.
Backstrom, Per-Ove. Forest Regeneration in Northern Sweden. Sweden.
Bergman, Fritz. Seed Availability, Cone Collection and Natural Regeneration. Sweden.
Hagner, Mats. Direct Seeding. Sweden.
Soderstrom, Vadim. Site Preparation. Sweden.

1981 - Forest Regeneration at High Latitudes: Experiences from Northern British Columbia - Prince George, British Columbia

Clark, M.B. Regeneration Problems and Their Significance with Lodgepole Pine in the Southern Interior of British Columbia. Canada.
Draper, Dale A. Spruce Regeneration in the Prince George Forest Region: A Research Perspective. Canada.
McMinn, R.G. Ecology of Site Preparation to Improve Performance of Planted White Spruce in Northern Latitudes. Canada.
Todd, A.M.D. Natural Regeneration: Policies, Procedures and Practices in the Prince George Forest Region. Canada.

1982 - Lodgepole Pine: Regeneration and Management - Hinton, Alberta

Alden, John N., John Zasada. Potential of Lodgepole Pine as a Commercial Forest Tree Species on an Upland Site in Interior Alaska. U.S.A.
Belle, Imre E., W.D. Johnstone, Richard Yang. Natural Lodgepole Pine in West-Central Alberta: Part I - Regeneration Stocking, Part II - Juvenile Spacing, Part III - Fertilization. Canada.
Dhir, Narinder K. Development of Genetically Improved Strains of Lodgepole Pine Seed for Reforestation in Alberta. Canada.
Ferdinand, 5.1. Site Preparation for Natural and Artificial Regeneration of Lodgepole Pine in Alberta. Canada.
Hellum, A.K. Seed Production in Serotinous Cones of Lodgepole Pine. Canada.
Ives, W.G.J. Insect and Disease Pests and Allied Problems Affecting Lodgpole Pine in Alberta. Canada.
Martinsson, Owe. Lodgepole Pine in the Swedish Reforestation - Problems and Prospects. Sweden.
Ranger, Raymond. Land-Use Conflict in West-Central Alberta, Particularly Within the St. Regis (Alberta) Ltd. Forest Management Area. Canada.
Simak, Milan. A New Method for Improvement of the Qua1ity of Pinus Contorta Seeds. Sweden.

1983 - Forest Classification at High Latitudes as an Aid to Regeneration - Fairbanks, Alaska

Corns, Ian G.W., Richard M. Annas. Ecological Classification of Alberta Forests and its Application for Forest Management. Sweden.
Draper, Dale A., Evelyn H. Hamilton. The Importance of Predictive Models of Forest Succession to Silviculture Management. Canada.
Packee, Edmond C. An Ecological Approach to Forest Management. U.S.A.

Pfister, Robert D. Development and Use of an Ecological Classification System. U.S.A.
Stahl, Per H. How to Choose Site Preparation Methods Based on Site Classification. Sweden.
Viereck, Leslie A., C.T. Dyrness, K. Van Cleve. Potential Use of the Alaska Vegetation System as an Indicator of Forest Site Productivity in Interior Alaska. U.S.A.
Zasada, John C. Site Classification and Regeneration Practices on Floodplain Sites in Interior Alaska. U.S.A.

1984 - The Yield Advantages of Artificial Regeneration at High Latitudes - Edmunston, New Brunswick

Bayandeh, B. A Simulation Model for the Economic Evaluation of Forest Regeneration Systems. Canada.

Hall, J.P., B.A.. Roberts, R.S. van Nostrand. Growth and Development of Larch in New Foundland. Canada.

McMinn, Robert G. Comparison of Various Types of Stock and Seeded Regeneration in Different Site Preparations for White Spruce Clearcuts. Canada.

Robertson, A. Boreal Energy Plantation Research and Development with Salix Species. Canada.

Sandvik, Martin. The Impact of Artificial Regeneration on Rotation Age in Norway Spruce and Scots Pine Areas. Sweden.

Smith, C.R., J. Johnson, L.F. Riley. Economics of Precommercial Thinning in Jack Pine. Canada. Stiell, Will. Development of White Spruce Plantations at the Petawawa National Forestry Institute, Chalk River, Ontario. Canada.

Timonen, Mauri. Yield Impacts of Artificial Regeneration at High Latitudes in Finland. Finland.

FOREST REGENERATION AT HIGH ALTITUDES IN NORTHERN SWEDEN

Gunnar Olofsson

ABSTRACT: This article describes the area of difficult regeneration forests in north Sweden. History, data and results from the project “Silviculture in Norrlands high altitude area" run by the National Board of Forestry are presented. The purpose of the project is t_ acquire a basis for more effective handling of cases concerning final felling and regeneration in the high altitude area of Norrland's forest region.

INTRODUKTION

In Sweden there has for the last years been an intensive debate about the high altitude areas of Norrland. Different questions about land use have been raised. the possibilities for forest regeneration in the high altitude areas of Norrland is one of the questions raised in this debate on the so-called "mountainclose forests". People generally think that what they debate is new, but this is in fact nothing new; more than a century ago researchers and farsighted foresters had begun to discuss possibilities for regulating forestry within the high altitude areas and preventing the timberline from moving to lower a1titudes.

GUNNAR OLOFSSON is a forester at the National Board of Forestry, Silviculture division, Jönköping temporarily stationing Östersund, north Sweden.

HISTORICAL REVIEW

In conjunction with the industrialization of forestry in the mid-1850s the inland region of Norrland came to playa significant role due to major timber potential and good quality saw timber.

Forestry _Acts

At the end of the 1800s harvesting in these forests was so great that, as it was expressed_ by the 1896- Forestry Committee:
"There can be no doubt that the state has the right and duty to prevent the reduction of significant areas to treeless wasteland, with no possibility of recovery for national production. Such

conditions do exist in our country, especially in the mountain regions. If the existing forest are further thinned to any extent the younger plants will be destroyed by mountain winds and the soil will thereby be eroded to the extent that it will be unusable for supporting forest growth. Consequently the coniferous timberline moves increasingly to the lower altitudes."

Therefore laws were passed to regulate exploitation of forest raw materials and to prescribe regeneration measures. (see inset: Forestry Acts)

FORESTRY ACTS

1873 Delimination Act for Norrbotten and Västerbotten's lappmark (limited right of disposition and marking requirement).
1903 Forest Protection Act for Jämtland county (marking requirement and obligation to regenerate).
1915 Act on marking in the province of Lappland
1923 Forestry Act (area for difficult regeneration forests is specified, marking requirement and regeneration req.
1932 Lappmark Act (forestry act concerning the province of Lappland).
1938 Act on Public Forest in Norrland and Dalarna.
1948 Forestry Act (Lappmark Act rescinded and protection forests grouped with difficult regeneration forests with the common name for the concerned forests being difficult regeneration forests. Marking requirement and relatively intensive legislation concerning regeneration).
1979 Forestry Act (increased regeneration state forests covered by the Act).

Research and Practical Applications

At the end of the last century researchers such as *C.G.Holmerz* and *Th. Örtenblad* investigated regeneration results in the forests of Norrland. Among their findings was that contemporary selective felling had in no case resulted in satisfactory regeneration. *Örtenblad, Schotte* and *Wibeck* stated in different investigations that it would not be possible to achieve satisfactory regeneration of Norrland's inland forests without radical soil treatment in the form of controlled burns and cultivation in the shape of sowing or planting. Among the practising foresters who began to apply intensive forestry methods at the turn of the century was district forest officer A. *Holmgren*
At the company Mo and Domsjö a flexible area cutting was employed with draining and cultivation.

Level of ambition

But the level of ambition of regeneration work in the inland of Norrland has fluctuated considerably. During the first decade of the 1900s relatively flexible and intensive reproduction work was carried out, but later, reflecting shifts in the economic situation, increasingly stereotyped and shallow regeneration techniques were employed.
At the end of the 1940s regeneration work intensified again to be followed at the end of the 1960s by a period of lower intensity extending to the middle of the 1970s, when greater demands for regeneration began to be made. (see inset: Commentary on regeneration of high altitude forests in Norrland.)

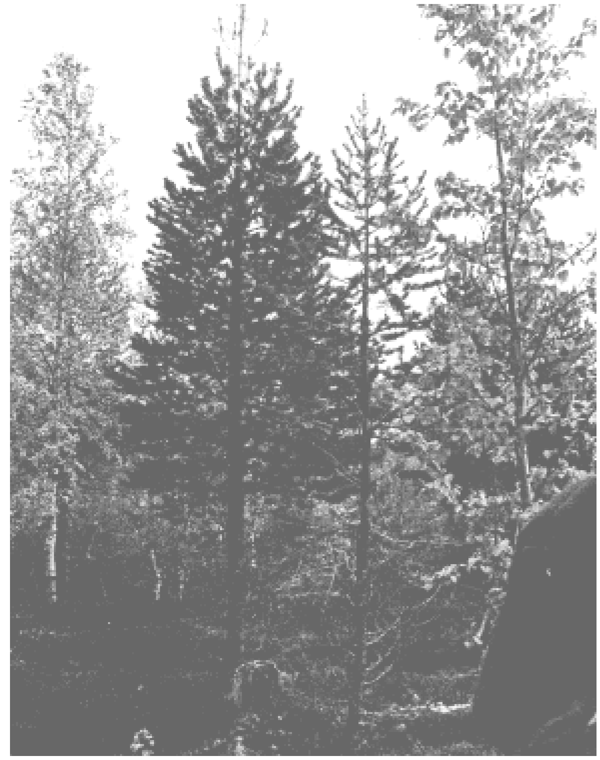


Figure 1. Pinus Sylvestris (L.) at lat. N 64°40' and altitude 500 metre above sea level. Planted 1954. (North Jämtland)

COMMENTARY ON REGENERATION OF HIGH ALTITUDE FORESTS IN NORRLAND

"Yet it still seems that in our own times and for a longer period in the future cultivation of forests will play the comparatively largest role on lands at the higher altitudes. Natural regeneration here must as we have seen fight against difficulties that are at these heights so disproportionately great that at present comprehensive and more or less costly regeneration measures in one form or other are often necessary to achieve good results within a reasonable time. "
(Lars Tirén, 1947)

" In the extreme high altitude areas nature is certainly a hard teacher, but a teacher who gives clear and distinct answers as to the efficacy of regeneration measures. Only a regeneration methodology that is built to the smallest detail on biologically correct principles has any chance of successful results.
Bitter disappointment and failure of reproduction work in high altitude areas has taught us that the methodology of regeneration work must be formed with particular consideration for the following three main factors:
- forest type
- altitude of growth area above sea level, its latitude and local climate conditions
- the history of the growth area stand.
(Fredrik Ebeling 1969)

CONDITIONS TODAY

Legal requirements are today more stringent than earlier and economic conditions favorable for intensive regeneration work.
Basic conditions are, in principle the same today as at the beginning of the century, when researchers such as *Wibeck, Hesselman, Malmström, Tamm, Enekoth* and others presented pioneering work on biotic and edaphic factors influencing, among other things, regeneration work.
Bedrock, soil type, geographic situation; altitude above sea level and latitude are factors that have not changed.
Climate has on the other hand changed when seen in the perspective of the last century, with both warmer and colder periods. (fig.2.)

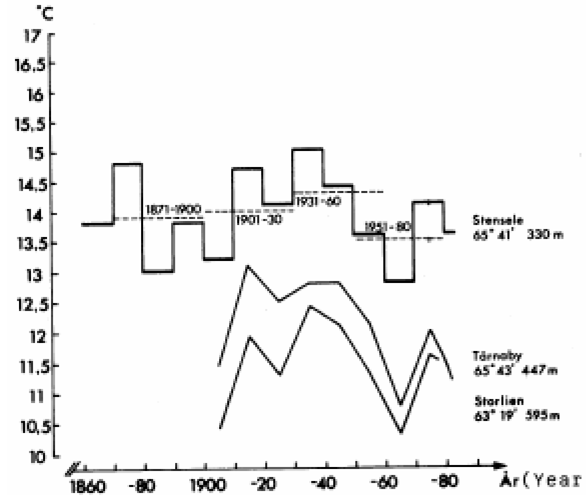


Figure.2. Average temperatures for July per 10 years. Withy the two lower curves the values have been placed in the middle point of the periods and linked to each other. (H.Odin 1984)

AREA FOR DIFFICULT REGENERATION FORESTS

Since 1923 Forestry Acts have included descriptions of an area in northern Sweden in which County Forestry Board permission is required to harvest timber; the area is referred to as the area of difficult regeneration forest. (fig.3.)

<u>Forestry Act (SFS 1979:429)</u>
<u>18§</u> *"The government has the power to prescribe that forest difficult to regenerate due to unfavorable location on which is needed as protection from sand or soil erosion or to prevent movement of the timberline to lower altitude shall be set aside as difficult regeneration forest."*
<u>19§</u> *"In difficult regeneration forest harvesting is not permitted without County Forestry Board permission. In conjunction with permission being granted the County Forestry Board can decide on measures to limit or combat unfavorable conditions and secure regeneration. Permission is not required for cleaning or thinning which supports forest development."*

Total area of difficult regeneration forests totals 4 million hectares, distributed:

Norrbotten County	(BD):	2.1 mil hec
Västerbotten County	(AC):	1.0 mil hec
Jämtland County	(Z):	0.7 mil hec
Kopparberg County	(W):	0.2 mil hec

Local Variations

The area of difficult regeneration forests however exhibit great local variations in local climate, soil types, field and ground layer vegetation and stand history. (fig.4.)

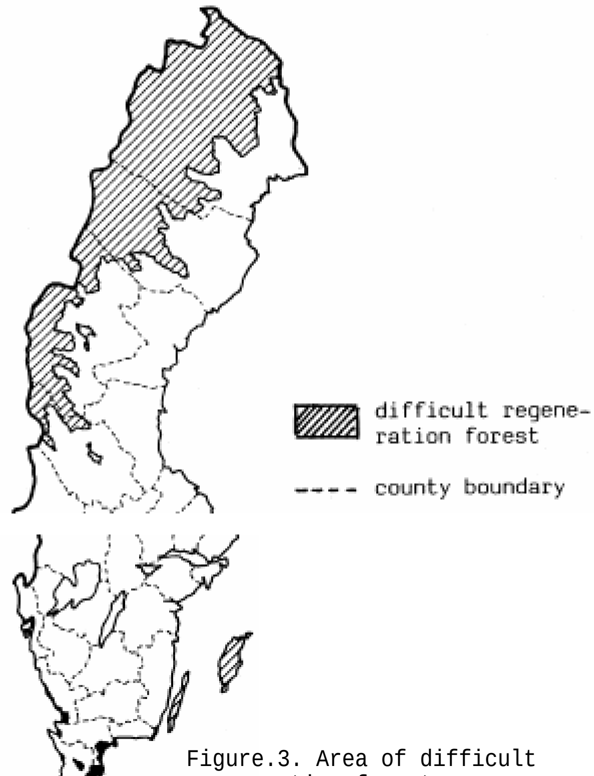


Figure.3. Area of difficult regeneration forest

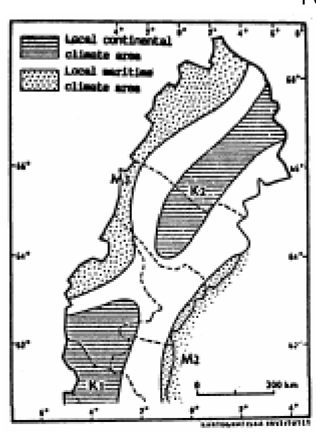


Figure.4. Local climate area (A. Angstrom 1973)

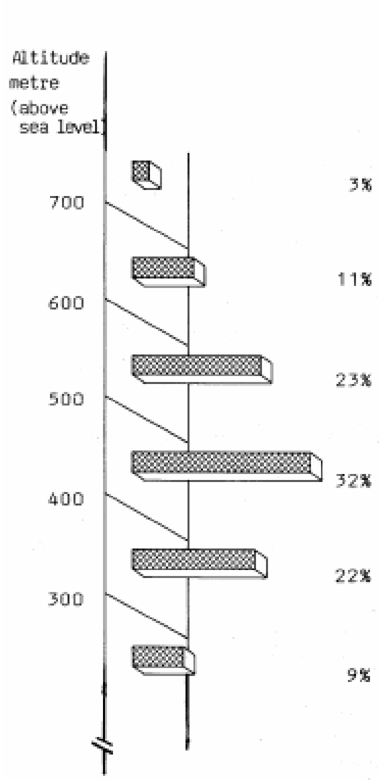


Figure.5. Area of productive forest (%)

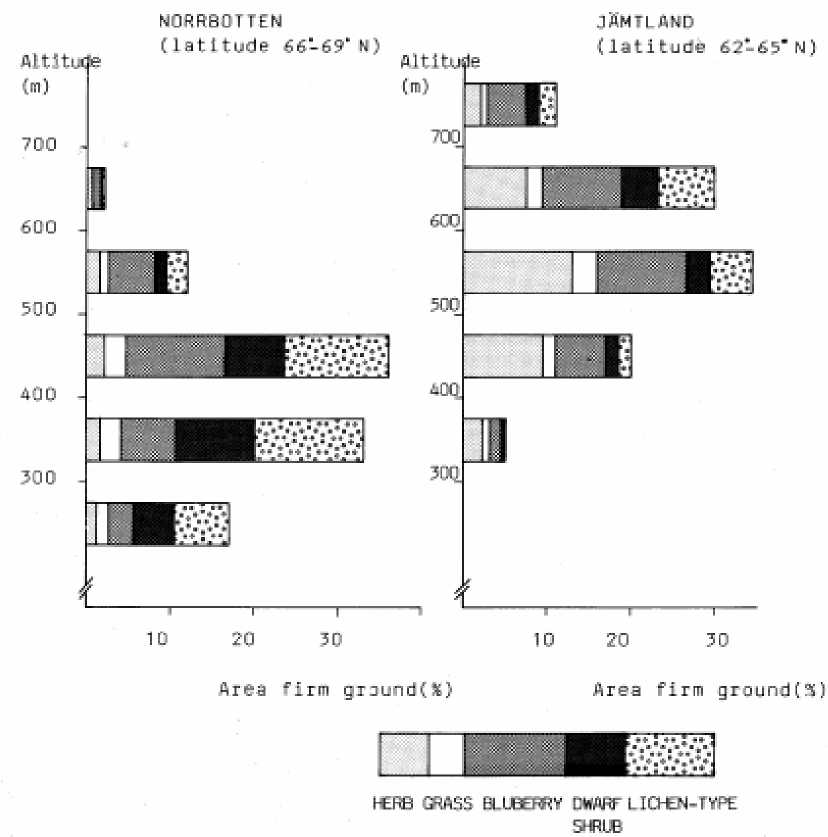
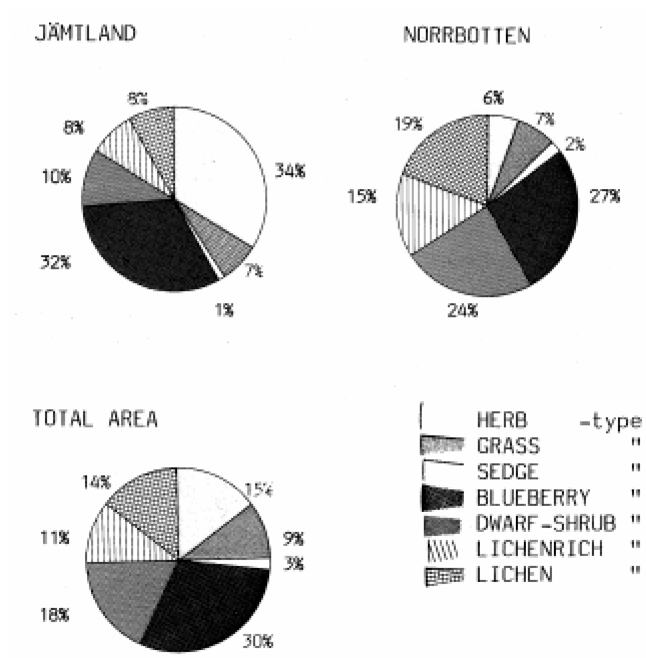


Figure.6. Field and ground area vegetation type (prod. forest)

Field and ground vegetation type

In Jämtland County the dominating field and ground vegetation is herb type, while in Norrbotten County lichen and lichen-rich type dominates. The difference in field and ground type largely reflects the differences in soil type and bedrock composition.
The high altitude area of Jämtland is affected by the Cambrosilurian-area and by easily eroded mountain slate, which gives rise to relatively good production possibilites.



Source: Area of Difficult Regeneration Forest, National Forestry Survey 1973-82

Age distribution

The proportion of older forest dominates the area, especially at increasing altitudes above sea level. If we look at Jämtland County, the forest, mature for final felling within the difficult regeneration area, comprises approximately 30% of the county's total forest mature for final felling. In volume this is equivalent to approx. 40% of the county's total final felling volume.(fig.7.)

The proportion of young forest (age class 2 - 20 years) comprising productive forest area in the difficult regeneration areas of the respective counties:

Norrbotten	: 15%
Västerbotten	: 11%
Jämtland	: 15%
Kopparberg	: 15%

What is the appearance of these young forests ? Have regeneration measures been acceptable or have they failed?

FOLLOW-UP OF OLDER REGENERATION

Within the "Silviculture in Norrlands high altitude area" project, the National Board of Forestry has investigated conditions in older regeneration areas within the area for difficult regeneration forests. The project started in the autumn 1982, and the final reports are expected during summer 1986.

Silviculture in Norrlands High Altitude Area Project

Project goal: to acquire a basis for better handling of cases concerning final felling and regeneration in the high altitude area of Norrland's forest region.

The following project tasks can be distinguished:
1) Description of regeneration results after final felling in recent decades.
2) Attempts to identify areas with major regeneration problems.
3) For practical use combine research results and practical experience.
4) Formulation of practical silviculture directives and education of concerned personnel.

The project is confined to the area of difficult regeneration forests in the four northernmost counties of Sweden.

Field investigation

Field ivestigations have been carried out as an inventory of young forests and the investigated sites are geographically distributed between latitude N 61°30' – 68°30' and altitude 250m - 800m above sea level (fig.8).

There were 172 investigated sites.

Collection of field data has been conducted through the inventory of older regeneration areas established between 1945-1974. The sites selected objectively are situated most commonly within the more severe climatic areas of BD, AC, Z and W counties.

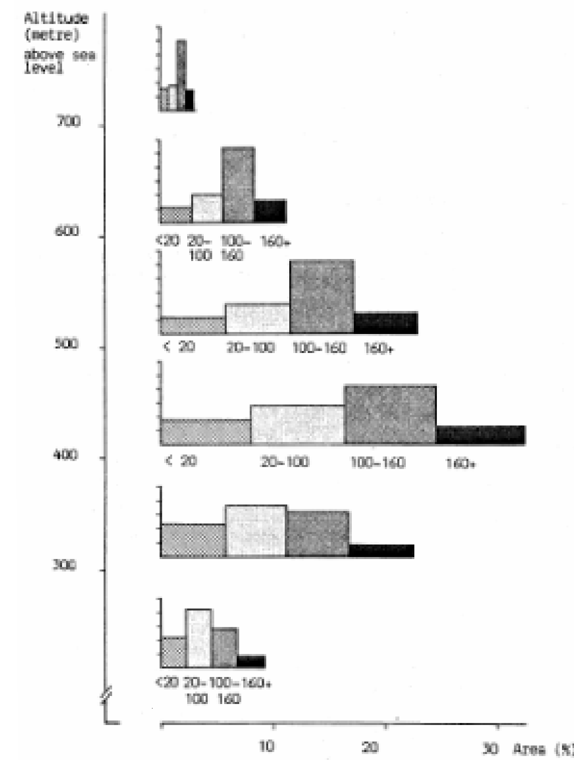


Figure.7. Age-class Distribution (prod. forests)

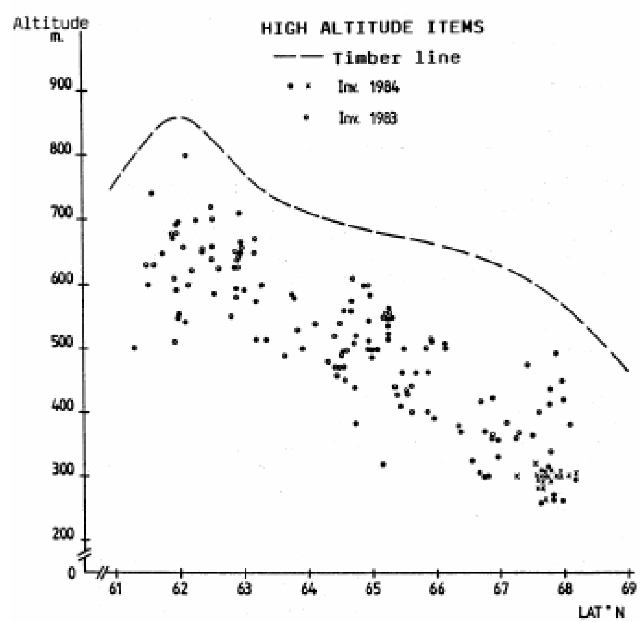


Figure.8. Investigated items.
Field period 1983 and 1984.

The investigated regeneration areas had earlier during the 1960s and 1970s been surveyed for regeneration under the direction of the National Board of Forestry.
Each item has undergone a systematic regeneration survey conprising a plant count on the basis of circular pots (area 10m2) minimum 50 plots/item and additionally 5 sample plots/item (area 100m^2) in which were regi9tered site factors, damage to trees, sample trees, growth, etc. (fig.9.)

Item representativity

Comparison with proportion of forest at different height intervals (altitude above sea level) and distribution of inventoried items.

Altitude above sea level (metre)	Area of productive forest (%)	Proportion of investigated items (%)
700+	3 %	4 %
600 - 700	11 %	19 %
500 - 600	23 %	29 %
400 - 500	32 %	19 %
300 - 400	22 %	22 %
- 300	9 %	7 %

Regeneration results

Number of investigated sites	: 172
Proportion of sites, (artificial regeneration)	: 60% (104)
Proportion of sites, (natural regeneration)	: 40% (68)
Site age average (1984)	: 28 years
Number conifer main stems	: 1.100 st/hec
Number main stems total (incl. foliiferous)	: 1.200 st/hec
Gap proportion	: 9%
Proportion accepted sites	: 85% (144)

(According to Forestry Act)

Reflections

Differences between species

Investigation of different regeneration groups reveals that pine plantings and natural regeneration groups (especially pine) show the largest spread in number of main stems per hectare. Spruce plantings on the other hand never exceed 700 main stems per hectare.(fig.10.)

Damages

Some form of damage has been registered on approximately half of the main stems.
Classifying the seriousness of damage (damage grade): 41% of the damaged stems have classified as insignificantly damaged and 6 % as very seriously damaged.
Most common causes of damage:

* moose 18%
* insects 15%
* snow pressure 6%
* pine canker 9%

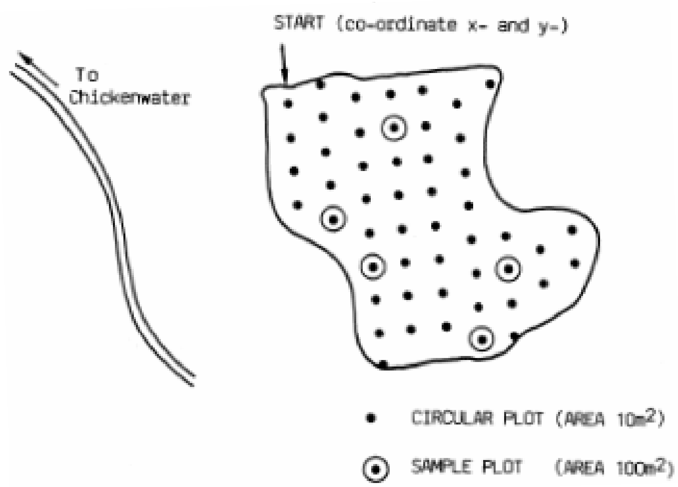


Figure.9. Regeneration survey, pattern.

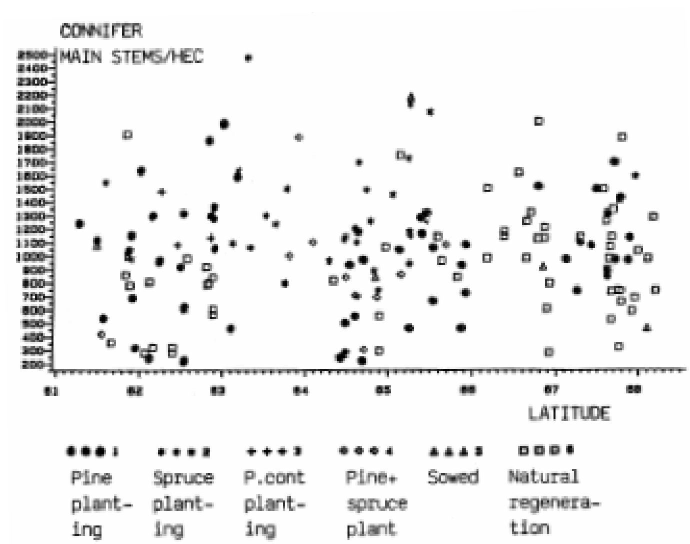


Figure. 10. Conifer main stem at different latitudes

Most serious damage caused by:

* snowblight, pine and spruce
* pine canker
* reindeer
* moose

Annotations about the results

The presented results are only preliminary and the investigation will continue this summer (1985) The results still gives a idea of the appearance of the, elderly regeneration areas of north Swedens high altitude area.

ARTIFICIAL REGENERATION ON THE POLAR TIMBERLINE IN FINNISH LAPLAND

Mauri Timonen

ABSTRACT: Experiments in artificial regeneration have been carried out from the 1910's on the polar timber line. The results have mainly been quite satisfactory. Particularly, the good results on the northern side of the polar timberline indicates that artificial regeneration can be used succesfully in reforestating barren areas.

THE STUDY AREA

The northernmost part of Finnish Lapland between latitudes 68^{o} and 70^{o}N (fig. 1)is discussed here in the light of artificial regeneration. The polar timberline of both Scots pine (Pinus silvestris L.) and Norway spruce (Picea abies Karst.) split this area (fig. 2). The alpine timberline is also clearly visible on the slopes of many hills.

There are many ways of interpreting the concept "timberline". According to Hustich (1966) "timberline" ,means an "economical or productive forest line". By this he means the limit where commercial cuttings endanger natural regeneration. The actual position of this limit should in fact be measured each year, because the conditions for natural regeneration vary from one year to another. During good seed years the timberline is the same as the visible forest line, and during poor years it can be quite far away from it.

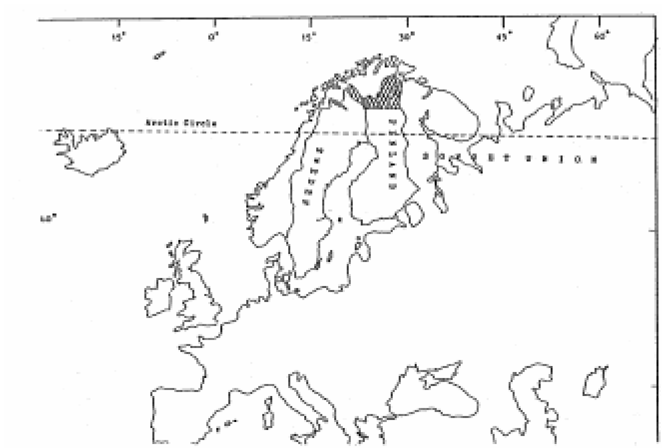


Figure 1.--The geographical location of the study area.

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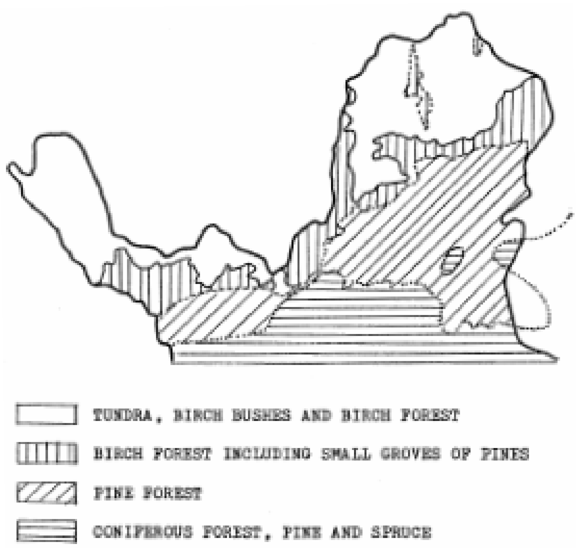

Figure 2.--Areas of the polar timberline in Finnish Lapland.

In practice foresters have defined their own economic timberline, the treatment limit, at 250-330 meters above sea level depending on location. No commercial cuttings are made at elevations higher that this.

THE PROTECTION FOREST AREA AND ITS HISTORY IN FORESTRY

The future of the forests in Northern Lapland was secured by the Protection Forest Law passed in 1922. According to the law, management of forests above latitude 68°N was to be the responsibility of professional foresters. All types of forestry treatment that could lead to the lowering of the timberline were forbidden.

The total area of the protection forest area is about 3 million ha. The amount of forest land is 780,000 ha, 260,000 ha of this being situated at high elevations (over 300 m above sea level). Forestry is practiced over on area of about 220,000 ha. The high areas, special conservation forests, nature management forests, nature and national parks and primeval forest areas lie outside the realm of commercial forestry.

Intensive-economical utilization of the protection forests was not begun until the 1950's. The decision was taken at the time to regenerate the overmature forests and make them productive. The role of artificial regeneration was emphasized. Making large clearcutting openings, even ones as large as 1,000 ha, was regarded as a quick and effective way of producing a. new generation of productive forests. A change of tree species from spruce to pine on sites unsuitable for spruce also was a common practice. The regenerating timetable was very fast.

The plantations developed rapidly until severe problems started to appear in the 1960's. The decade was exceptionally cold, and the plantations began to suffer and some of them to die. The situation was quite worrying. Luckily the favourable weather conditions in the 1970's prevented the plantations from being completely destroyed.

Today, new problems in forestry are the quality of the plantations and questions of land-use. It appears that the plantations will not at their present state produce enough good-quality timber. This problem has aroused plenty of discussion in Finland. The second problem is how to integrate use of the protection forest area for forestry, reindeer management, tourism, recreation, nature conservation e.g.

Public opinion has also put pressure on forestry circles. The protection forest area is regarded as the unique property of the Finnish nation. As a result of all this, foresters have had to consider using lighter methods which would also satisfy other interested parties outside forestry.

NATURE CONDITIONS IN THE PROTECTION FORESTS

The protection forest area provides many interesting forestry research topics. The timberline is one of the most important international research objects currently being carried out in Finland. Information covering a wide range of fields is available about forestry practiced under severe conditions over on area of 23,000 ha. One special and often forgotten factor is the effect of long-term climatic fluctuations on the forestation result.

Apart from the most continental parts of Siberia, the forests in Lapland have spread further to the north than in any other place in the world. The timberline is also easily accessible. The structure of the timberline is unique: the absolute forest line is covered with mountain birch (Betula tortuosa Led.), while elsewhere it is composed of a coniferous species. The conifer growing closest to the forest line is Scots pine, while elsewhere it is spruce. Pine covers 80 % and spruce 12 % of the area of mineral soil.

The climate in the protection forest area is cool. However, thanks to the proximity of the Gulf Stream and the warm winds coming from the southwest, it is more favourable than in parts of Siberia, Alaska or Canada, for instance, lying on the same latitudes. The mean temperature for June is +14...+16°c and for February -13 ... 10°C. The precipitation is 400-500 mm per year. The climate is humid, which means that forest soils retain plenty of moisture. Most of the protection forest area lies between altitudes of 300 and 600 m above sea level. The coniferous forest limit reaches a height of 400 m. One common characteristic of the timberline area is the large fluctuation in the climatic conditions, e.g. the annual stand growth may vary by 40-50 % from the long term mean index. The further north you go, the greater are the fluctuations.

THE POSSIBILITIES OF UTILIZING ARTIFICIAL REGENERATION ON THE POLAR TIMBER LINE

When regenerating naturally the protection forests, the first problems appear already in the seed formation phase. In order to get a good seed crop, two warm, favourable summers are needed: both the summer before and after flowering must be warmer than average (Sarvas 1971). Pohtila (1981) has calculated that the probability of a good seed year occurring at the latitude where Sodankylä (68°N) is situated is only 0.06. This means that a good seed year occurs only every 16th year. Further north the probability is even smaller.

The advantages of utilizing artificial regeneration increase owing to the lack of good seed years. Some advantages of artificial regeneration are:

- the regeneration work can be done quickly;
- the rotation time from one cutting to another is shortened by 5-15 years (Putkisto 1980);
- a change of tree species is possible;
- the quality of the seed material can be controlled;
- the development of the growing stock can be controlled from the very beginning.

Important factors in the protection forest area are the possibility of changing tree species and the reduction in the rotation time. Changing the tree species is necessary in order to convert the common old thick-moss spruce forests into productive pine forests. Shortening the rotation period would be important because natural regeneration may take over 20 years before reforestation succeeds.

Foresters have tried to make the best use of artificial regeneration and now there are over 23,000 ha of plantations in existence. However, how well they grow has been a question of great speculation. Some foresters suspect that the low stem number and other factors have brought about a deterioration in quality. Some pessimists have even predicted that all the plantations will soon die owing to the use of incorrect cultivation methods. Are they really dying? This question was answered in 1978.

INVENTORY OF THE PROTECTION FOREST PLANTATIONS

The inventory was carried in 100 plantations representing about 10 % of the whole cultivated area. The main results are discussed in the following:

There were 1,771 stems/ha on the inventoried plots (Pohtila & Timonen 1980). The proportion of natural seedlings was surprisingly high, 45 %. It exceeded 50 % in the plantations less than 30 years old, and was about 25 % in those less than 30 years old. The distribution of the seedlings was: pine 70 %, spruce 10 % and broad-leaved trees 20 %. Only pine had originally been cultivated. The great number of natural seedlings was due to seeding from emergent trees and the growing stock before cutting, the effect of the border stand and site preparation.

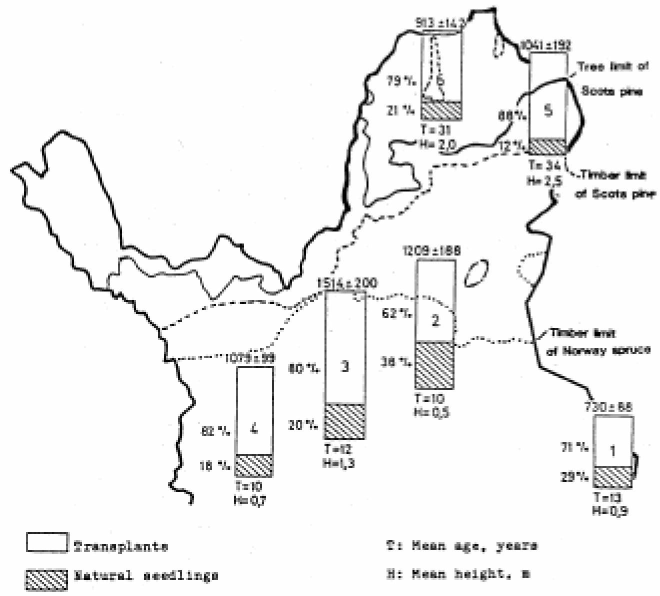

Figure 3.--Number of satisfactory young trees in sample areas: 1 = Tuntsa, 2 = Laanila-Vuotso, 3 = Sammalselkä, 4 = Kittilä, 5 = Pakanajoki and 6 = Utsjoki.

The oldest plantations were over 60 years old. The stem number varied by age from 1,600 to 3,600/ha. Fluctuations occurred in the macro-climate and the density of the plantations during the 60 year period. The warm 1930's and the cold 1960's differed clearly from the average.

The density of the plantations also varied regionally (fig. 3). The best results were achieved at Kittilä in the Sammalselkä area (1,514/ha). A very poor result was recorded on the high Tuntsa area in Salla (only 730/ha). The result for the timberline area was surprising: in the Utsjoki valley and at Pakanajoki the densities were close the average for the whole area (913 and 1,041/ha).

When the results were analysed in more detail (results indicative), plowing and the effect of slope were found to be positive, and stoniness, small mounds, depressions and high elevation (over 300 m a.s.l.) negative factors on the density of the plantations. No differences were found between the sown and planted stands.

1,001 seedlings were classified, on the average, as capable of further development. The proportion of naturally regenerated seedlings was only 24 %. It is clearly smaller compared to the corresponding proportion out of the total stem number (45 %). This is due to clusterwise spacing and the unsuitable size of the seedlings. However, the percentage was higher, about 35 %, in young plantations (less than 30 years old). In older stands there were practically no naturally regenerated seedlings at all. One possible explanation may be site preparation which was not begun on a large scale until 30 years ago.

The question of quality was also examined. 30 % of the seedlings were found to be healthy and of good quality. 36 % of the other seedlings had damage such as crookedness and 9 % of them needle damage. Naturally regenerated seedlings were as a rule more healthy than planted ones. The survival percentage of the cultivated plants is approximately 30-40 %. In the calculations it has been assumpted that artificial regeneration has been carried out only once. In fact it is even smaller since all subsequent supplements should be taken into account.

SOME THOUGHTS ARISING FROM THE INVENTORY

The cultivation result in the protection forest area is satisfactory according to Finnish yard-sticks. One must not expect too much from the forests on the timberline. The main task of such work is to prevent the timberline from moving south. Every effort which causes the timberline to move up the slopes of the fells or further to the north is a victory. Quality questions may be of only secondary importance in these latitudes.

Earlier experiences with artificial regeneration have also been mainly positive. Some researchers (Mikola 1952, Siren 1957) have even suggested that the mountain birch area could be converted into coniferous forests if the climatic conditions continue to be favourable. Furthermore, Mikola recommended that spruce ought to be cultivated on the northern side of the visible forest line. Nowadays we are no longer so interested in such extensive plans.

Three factors are associated with the successful cultivation: the fluctuation of the macroclimate, the timetable of plantation establishment and the cultivation techniques.

If the climate each year remained the same, we Would know quite precisely how to raise the forests. A great deal of the problems we are faced with could be forgotten. But as we know, this is not the case. In the protection forest area the rotation time may be close to 200 years. Just one cold and unfavourable year with storms, frost and other forms of damage may destroy the stand completely.

However, the problem is not so serious as it would appear at first sight. The critical time for survival are the first decades of the rotation period. After the plantation has become established (the mean height in the protection forest area is 2-5 m), total destruction seldom occurs. A plantation which is not yet properly established is in danger: it is not able to go through several poor years without suffering severe damage. The 1960's in Lapland showed this clearly.

If the cultivation work is done at the start of a 10-30 -year favourable period, its development will probably be quite satisfactory. Bad years which occur during the late phases of its life cycle may cause some growth losses, visible as narrower annual rings, but nothing more dramatic occurs. Unfortunately, we do not know when the bad years are coming, so we have to use a careful strategy. This means that the poorest years during the rotation period are taken into account.

A good policy is to use natural regeneration whenever it is possible. One idea brought up by the inventory results is how to combine the good points of natural and artificial regeneration. We know that natural seedlings often appear on the clearcutting openings after cultivation in the protection forest area. As this study has indicated, natural regeneration produces seedlings which can be raised as part of the future forest. Owing to the good properties of naturally regenerated trees, e.g. better timber quality, health and site adaptation, the utilization of naturally regenerated seedlings in artificial regeneration is worth considering.

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REFORESTATION AND AFFORESTATION AT HIGH ALTITUDES IN NORTH NORWAY

Jarle Bergan

ABSTRACT: A brief survey of forest conditions and afforestation plans in North Norway is given. Some results from climatic investigations and field experiments at two study areas at 69°N are presented. The results show the necessity of taking into account the climatic birch timberline when estimating the possibilities of afforestation at high altitudes in North Norway. The sum of growth units is found to be the best general expression of temperature conditions at the climatic timberline. Methods for stipulation of the timberline by means of data from lowland meteorological stations are presented. The paper points at some restrictive factors to be considered when establishment of conifer plantations is planned at high altitudes. When estimating the fitness of provenances for afforestation purposes in harsh areas, it could be more useful to know their habitat in relation to the vertical distance from timberline than the height above sea level.

FOREST CONDITIONS

North Norway is situated between 65°N and 71°N. As in Western Norway the deciduous trees play a more important role in North Norway than in the rest of the country. Between 65 N and the Polar circle the deciduous trees (mainly Betula pubescens) occupy about 14% of the forest areas below the conifer timberline, while the corresponding percentage north of the Polar circle is 73%. Except for some inconsiderable occurences in the eastern part of Finnmark, Norway spruce does not exist naturally north of the Polar circle.

The main conclusions of an investigation where the yield of birch and Norway spruce were compared on localities up to 150 m a.s.l. are referred in figure 1. The natural stands of birch reached only 25% to 45% of the maximum mean annual increment in spruce plantations (Braastad 1966, 1968). The lines marked P = 25%, P = 34%, and P = 45% denote the bounderies for plots where birch have/produced less than 25%, 34% or 45% of the maximum mean annual increment in Norway spruce plantations.

AFFORESTATION

The afforestation which is going on in North Norway makes possible an expansion of the present conifer forest areas of about 150.000 hectares with a calculated increase in the volume increment of 600.000 to 700.000 m^3 per year. Afforestation in North Norway usually means conversion of birch forest to spruce

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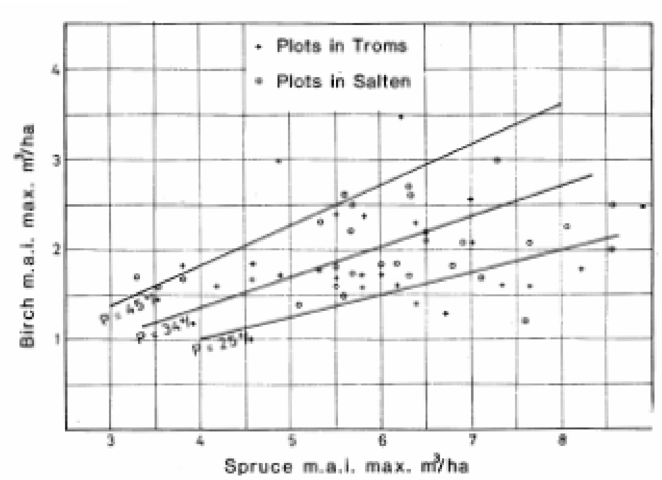

Figure 1.--The relation between the mean annual increment (max.) for Norway spruce and birch (Braastad 1968).

since 1967. One of the areas is representative of the climate in the inland districts of Troms (69°N, 190CO' E.G.) while the other is located at the coast (69°N, 17°53' E.G.)

Within each observation area climatic stations have been established at different altitudes up to the climatic birch timberline. Field experiments utilizing different tree species and provenances, using birch as shelter trees in spruce plantations a.s.o. have been laid out from the lowland and upwards to the timberline.

The timberline is made up of birch throughout the two observation areas. At the inland station it has an elevation of 500 metres and at the coast station 310 m a.s.l. The timberline is defined as the altitude at which the distance between individual trees, exceeds 30 metres

Table 1.--Yield data per hectare o.b. on some experimental plots laid out by the Norwegian Forest Research Institute, Division of Forest Managment and Yield Studies, in spruce plantations on afforestation land of North Norway.

District	Latitude	H.a.s.l. m	Site class H_{40} m	Age years	Main crop: Number of trees	Main crop: Mean height m	Main crop: Volume m^3	Total prod. m^3	Annual increment: Volume increment m^3	Annual increment: Mean increment m^3
Vefsn	65°50'	100	16,0	40	2821	10,8	182	221	15,90	5,52
Leirfjord	66°05'	50	17,4	61	933	18,1	301	486	9,44	7,97
Fauske	67°17'	100	15,6	50	2097	12,8	203	297	10,06	5,95
Bodø	67°17'	120	16,0	52	2086	14,0	251	338	14,12	6,49
Bardu	68°51'	135	14,4	60	1553	15,2	334	416	14,05	6,94
Bardu	68°56'	160	15,5	45	2016	14,1	304	441	17,30	9,81
Harstad	68°50'	40	13,8	43	1377	11,7	188	331	12,32	7,70

plantations. (P. sitchensis at the coast and P. abies in the inland.

Yield data from some experimental plots at different latitudes at the coast and in the inland districts are given in Table 1. The mean annual increment in 40 to 60 year old plantations varies from 5,0 to 10,0 m^3 per hectare, while the annual volume increment is 9,0 to 17,0 m^3 per hectare.

So far, afforestation in North Norway has been concentrated mainly on the lowland forests up to 200 m a.s.l. However, the birch timberline varies from 750 m a.s.1 in the inner parts of Troms (69°N) and the southern part of the country (65°N) to 0 m a.s.l. at the outmost coastal areas.

CLIMATIC INCESTIGATIONS AND FIELD EXPERIMENTS

A main question of afforestation in North Norway is bow far above sea level it should be recommended to establish conifer forests. To answer this question, the climatic influences on forest growth, regeneration and extension towards the alpine zone have been studied in two experimental areas at 69°N

(Mark 1968). The birch timberline in both areas is dependent on climate and the absence of poor soil conditions and disturbance by cuttings, and, grazing, or poor soil conditions.

THE TEMPERATURE EFFECT ON FOREST GROWTH AT DIFFERENT ALTITUDES

In the. following some results from the period t967-72 are presented (Bergan(1974). The figures 2-4 show the heat effect at Different elevations for three temperature expressions: Mean maximum temperature, mean temperature and the sum of growth units for the months June-Sept. A growth unit is the heat effect on height growth when the temperature average for the six warmest hours of the day is 8°C or greater (Mork 1941). Comparisons between temperature. data from the periods 1967- 7 2 and. 1931-60 observed by the Norwegian meteorological institute in the same district have revealed very good conformity.

MEAN TEMPERATURE

Figure 2 shows how the daily mean temperature (mean 24-readings) varies at different height levels. Calculated linear

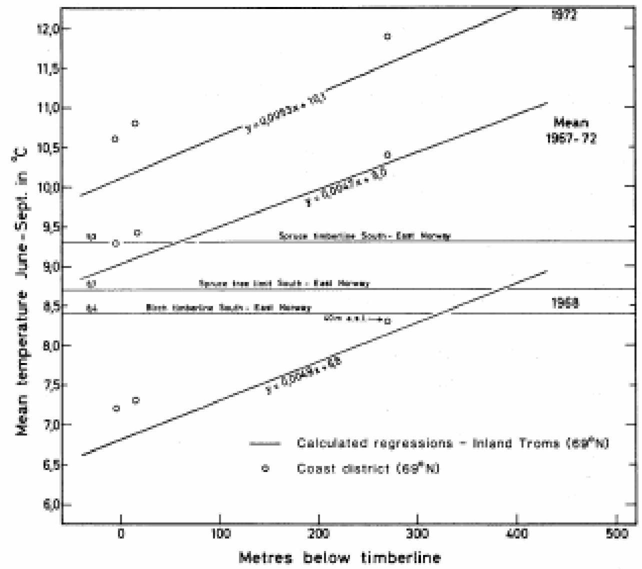

Figure 2--The relation between vertical distance below birch timberline and the mean temperature for June-Sept. in Troms (Bergan 1974).

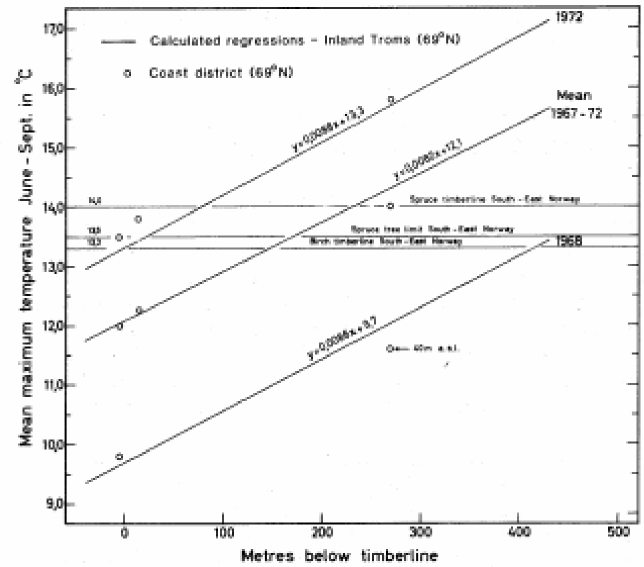

Figure 3_-_Tbe relation between vertical distance below birch timberline and the mean maximum temperature for June-Sept. in Troms (Bergan 1974).

regressions of observed data_ at the inland station are drawn in the figure. The corresponding results from the coast station are also marked off. Comparisons of the observed temperature data between the stations at the coast and in the inland have shown that when using the height above sea level, the temperature values do not correspond very well. However, if the evaluation is defined as the vertical distance below the climatic timberline) the temperature conditions at the same levels in the two areas match very good. The lowland station at the coast is situated 40 m a.s.l. The mean temperature at this station cor-_ re spends with t/he mean temperature at 250 m a.s.l. in the inland. Both stations are situated about 250 metres below the birch timberline.

The mean temperature (June-Sept.) for the period 1967-72 at the birch timberline is 9,0°C in the inland area, and about 9,4°C at the coast. The corresponding value found by Mork (1968) in South-East Norway, is 8,4°C. Studying Figure 2, the difference between years attracts attention. In these marginal areas of forest extension, cold summers like 1968 can result in heavy damage to the plantations. If the regression line for 1968 had represented the normal temperature for the region, most of the natural pine forests in the lowland would probably be above the current birch timberline.

MEAN MAXIMUM TEMPERATURE

Figure 3 shows the mean maximum temperature tube similar to the mean temperature in Figure 2. The maximum temperature at

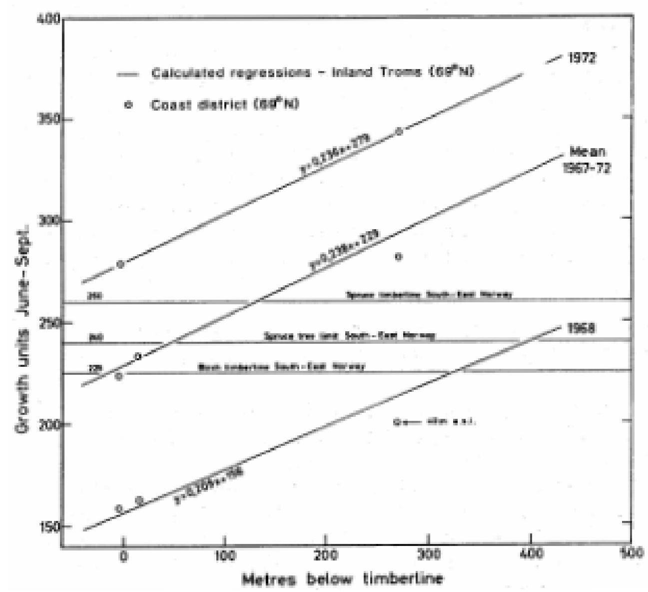

Figure 4.--The relation between vertical distance below- birch timberline and the sum of growth units for June-Sept. in Trams (Bergan 1974).

the birch timberline is found to be 12, 1°C both at the coast and inland station. In South-East Norway the corresponding value is 13,3°C.

Figure 4 shows the sum of growth units for the months June-Sept. The sum of growth units at the birch timberline is calculated to 229. The corresponding value given by Mork (1968) was 225, which Hork found by interpolation between observations made close below and above the_ timberline. Handling the observed data at 69°N in the same' way, the sum of growth units would be 226. The spruce timberline is found to be about 80-10 metres below the birch timberline.

STIPULATION OF THE CLIMATIC BIRCH TIMBER-LINES AT DIFFERENT LOCALITIES

This investigation has pointed out the growth units to be the best general expression for the temperature limits for forest growth at the timberline at various localities situated at different latitudes. The results have also underlined the neessity of taking into account the birch timberline when estimating the possibilities of afforestation at high altitudes.

At many localities the location of the climatic timberline is not so *easy* to see. At such localities the timberline can be estimated by means of the regression in Figure 4 and temperature data from meteorological stations in the lowland. However, the calculation of growth units was originally based on daily observations of the six warmest hours; eventually as a substitute, the daily temperature at 14.00 hours was used, which is also not accessible data for the majority of official meteorological stations in Norway. Bergan and SkrØppa (1975) therefore evaluated methods for estimating the sum of growth units based on the monthly mean temperature at 12.00, 13.00, or 14.00 hours. At the present, the monthly mean temperature at 13.00 hours is published for most of the meteorological stations allover the country.

FACTORS TO BE CONSIDERED BY AFFORESTATION AT HIGH ALTITUDES IN NORTH NORWAY

Figure 5 gives a simplified schematic survey of important factors to be taken into account, when establishment of conifer plantations at high altitudes in North Norway is planned. At elevations below 250 metres fro_ the bircb timberline, successfull results can be expected. Down to 150 metres from the timberline, the forest management must be based on natural regeneration of birch. In the zone between 150 to 250 metres below the birch timberline, snow conditions, soil fertility and exposure to eastern winds are also decisive factors for a plantation success. When the yearly snow depth is exceeding 1,0 to 1,5 m, it reduces the length of the growing season and increases the snow damages considerably. Cold, dry eastern winds in winter are also a restrictive factor as we 11. as poor soil quality_ Use of northern provenances is more important in the upper areas than in the middle part of the hillsides. The provenances are usually defined by latitude and height above sea level. When estimating the fitness of different provances for afforestation, purposes in harsh areas, it would have been more useful to know their habitat in relation to the vertical

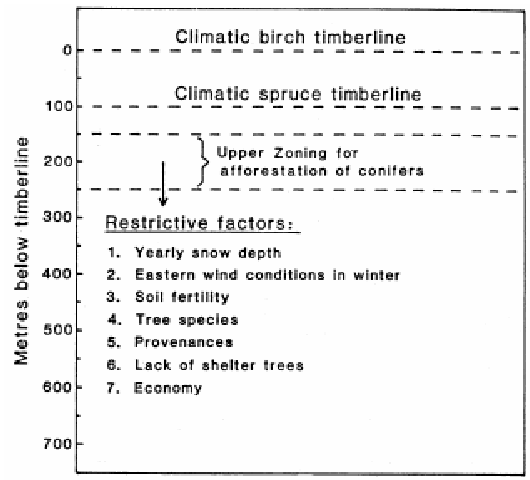

Figure 5.--Restrictive factors by afforestation at high altitudes in North Norway.

distance from timberline.

The use of birch shelter trees must be strongly considered. The zone between 150 and 250 metres below the birch timberline might be characterized as the zone where you have to choose between birch and conifers more carefully.

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FOREST RENEWAL RESEARCH IN CANADA

David A. Winston

ABSTRACT: The need for forest renewal and forest renewal research in Canada is briefly described. At present, only $18.4 million (Canadian) is spent annually for forest renewal research for all Canada. New fields of study are being actively pursued, including biotechnology, seedling physiology and site dynamics.

INTRODUCTION

Canada is a vast nation covering 9.9 million square kilometers. Only 20% can be considered to be stocked, productive, non-reserved forest land available for harvesting (Bonnor 1982), while 48% is non-forest (primarily tundra) and 8% is water.

Wood volumes are greatly affected by climate, soils, species and land ownership. In general, however, wood volumes average only 113 m^3/ha on provincially owned lands; with mean growth3rates of only. 1.5 m^3/ ha/yr. This increases to 5 m ^{3}ha/yr. in Coastal British Columbia (B.C.) on good sites (Bickerstaff et al.1981). These figures are, however, misleading in that they include all forested land, not just the productive and they represent virgin forest, not potential growth from intensively managed forests.

THE NEED FOR FOREST RENEWAL RESEARCH

Two major forest regions of Canada (Rowe 1959) have permitted the development of the forest industry in Canada; the Boreal Forest, and the B.C. Coastal Forest. Each year over 800,000 hectares of forested land are harvested throughout the country. An additional one million hectares (or more) are destroyed by fire and many more are damaged by insects and disease (although not all is productive forest land) (Anonymous 1985).

Traditionally, forestry in Canada has relied heavily on natural regeneration. This was acceptable in pre-mechanized harvesting days when not all stems were removed and advanced reproduction remained undamaged. The past 25 years, however, has seen a dramatic change in harvesting patterns, large residual slash volumes, and damage to advanced growth and to site by machinery. For example, soils and sites not previously accessible, such as shallow soils over bedrock and steep slopes are now harvested. Furthermore, as the readily accessible forests have been depleted, forest harvesting is being conducted in areas of slow growth and cold climate ever closer to the northern tree limits. In addition, the demand for timber has forced a shift in species site combinations harvested.

Canadian provincial agencies, which form the largest component of land ownership in the country, have attempted to cope and adjust to these new trends in various ways and with varying degrees of success. Despite these efforts, only 200,000 ha of the harvested areas are site prepared annually with approximately 600,000,000 trees planted annually on all lands. Another 300,000 ha are considered to be reforested naturally with the remainder relegated to an “unknown” category. Hopefully this situation will improve. During the last two years, the federal government of Canada, through the Canadian Forestry Service, has entered into cooperative agreements with the provincial governments to dramatically increase the amount of reforestation and also to reforest a large number of the backlog areas that were not previously reforested either naturally or artificially.

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The need for forest renewal research has become painfully obvious over the past 25 years as harvesting intensified throughout Canada. We have a need to reforest areas more efficiently and economically, to manage forest lands to minimize damage, to maximize productivity, and to treat soils, sites and species not previously dealt with.

Traditionally, most forest renewal research in Canada has been conducted by the Canadian Forestry Service (CFS). Some research, usually on specific regional topics, has been conducted by provincial forest agencies, the forest industry and universities. Close cooperation is generally achieved among all organizations through federal-provincial advisory committees and joint working groups.

In a recent (September 1984) survey of expenditures in forest renewal research, an estimated $18.4 million was spent annually by all forest agencies. The CFS contributed $8.2 million with all others contributing the remaining $10.2 million. Most notably the province of British Columbia alone spent $2.9 million for Coastal B.C. renewal research (primarily genetics related) (table 1).

The forest renewal research program of the CFS has been conducted throughout Canada at six regional research centres and two national institutes (table 2). Research can be grouped into three main activity areas: 1) reforestation, 2) genetics, biotechnology and seed, 3) forest ecology.

In the past, heavy emphasis in research was given to natural regeneration and harvesting systems to encourage this. During the 1970's and 1980's, nursery and greenhouse culture and artificial regeneration have been intensively examined. This has led to a need to expand research in seedling physiology, nutrition, soil development, autecology and site preparation, all within the context of an extremely harsh climate with very challenging ecological conditions. At present a major portion of our resources is dedicated to site preparation, seedling quality and vegetation control.

The improvement of genetic quality of trees, with resulting increases in stem form and productivity, has been the goal of CFS and provincial tree breeders for over 20 years. Success is on the horizon as seed orchards are now producing seed and forest management agencies are developing comprehensive seed crop management programs. The dawning of the age of biotechnology has now caught the imagination of tree breeders throughout the world. The CFS has rapidly developed programs in vegetative. and micropropagation, iso--enzyme analysis as a tool in genetics, and most recently molecular genetics. Despite our long history of leadership in forestry research, we still have a relatively poor knowledge of the dynamics of our forest ecosystems. Currently, considerable research is underway to develop site classification systems that can relate site to, forest productivity and management objectives. And as forestry activity moves into new ecotypes and fragile soils, we have expanded research into factors such as the effects of harvesting on nutrient balances, the need for effective control of competing vegetation and the potential for soil degradation following site preparation by heavy machinery.

Table 1--Funding of forest research in Canada, by all agencies, according to cover type complex

Cover Type[1/]	CFS	Other	Total
	dollars(000)		
Boreal	2,821	2,062	4,883
Coastal (British Columbia)	630	2,900	3,530
Interior (British Columbia & Alberta)[2/]	2,133 (CFS & Other)		2,133
Acadian	1,260	470	1,730
Tolerant hardwoods[3/]	472	2,398	2,870
Miscellaneous[4/]	884	2,368	3,252
	8,200	10,198	18,398

1/ Incorporates forest regions described by Rowe (1959).

2/ Includes subalpine and montane Regions.

3/ Includes deciduous, Great Lakes - St. Lawrence regions.

4/ Includes non-specific research including hybrid poplar (*Populus* spp.), exotic species, larch (*Larix* spp.).

Table 2--Distribution of funding by Canadian Forestry Service establishments on forest renewal research

Establishment	Person-years	Finance
		dollars (000)
Newfoundland Forestry Centre	15.8	735.0
Maritimes Forestry Centre	23.2	980.9
Laurentian Forestry Centre	30.0	1,346.1
Great Lakes Forestry Centre	30.0	1,509.3
Northern Forestry Centre	22.1	945.0
Pacific Forestry Centre	17.4	807.8
Forest Pest Management Institute	6.0	313.4
Petawawa National Forestry Institute	21.6	967.5
Headquarters	1.0	600.0[1/]
	167.1	8,205.0

1/ Grants, student support

SUMMARY

Canada is a vast forested nation. The rapid expansion of mechanized harvesting combined with the harvesting of more fragile climatic zones and sites has required a considerable shift in emphasis in forest renewal research during the past 25 years. At the same time, constraints on funding of forest research in Canada have limited the flexibility and options available to research managers. At present, the Canadian Forestry Service has only 76 scientists and 91 technicians assigned to forest renewal research, including genetics, seed, forest ecology, site, soils, nutrition, physiology, site preparation, greenhouse and nursery culture and herbicides.

When combined with funding from other agencies, only $18.4 million is spent annually including salaries for forest renewal research. Nevertheless, Canada has a commitment to forest management and to forest renewal, to ensure that our forests will be present for future industry and social use. We anticipate that exciting times are ahead in forest renewal research as scientists explore biotechnology, the use of remote sensing in forest and land evaluation, and modelling of stand dynamics. These fields, combined with current research, offer many challenges and hopes for the future.

Through this report to IUFRO I have attempted to demonstrate the scope of forest renewal research in Canada. Since the majority of our research is in northern forests, we are fully supportive of this new IUFRO Working Party and encourage cooperation among member nations. I hope that this report will help to bring this to scientists' attention.

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THE BEST REGENERATION METHOD FOR VARIOUS CATEGORIES OF OWNERS

Mats Hagner

ABSTRACT: Four planting methods and three methods for direct seeding are compared: a) manual planting in scarified patches b) fully mechanized planting c) and d) manual planting directly into the humus layer e) cone seeding f) funnel seeding directly into the humus layer g) row seeding after disc trenching.

In (c) a plastic shelter is manually attached to the seedling prior to planting. In (d) the shelter is attached with a machine at the nursery. In (e) and (f) the seed is sown at the bottom of plastic shelters.

Four types of land owners are considered: 1) private owner working in his own forest 2) private owner using hired labour 3) company working on its own property 4) company regeneration connected to a timber contract

The methods are looked upon from nine different aspects: economy, administration, need of knowledge, labour, general adaptability, reliability, total volume production, possibility to produce timber of high quality, rotation age.

Without consideration of the difficulties involved in a change over to a new method, it was found that row seeding (g) was best for owners no 1 and that this method together with fully mechanized planting (b) was best for 2,3 and 4. However, these conclusions are valid only where mechanized scarification can be carried out. This is not the case on about 30 % of the forested ground in Sweden. In these areas, where hoeing has been obligatory, the new methods d, c and f were the best.

INTRODUCTION

In Sweden about half of the forested land is owned by private persons. The rest is divided equally between the government and companies. Regeneration methods employed are mostly designed to fit in with large scale forestry practices. Centralized production of seedlings combined with mechanized scarification and planting totally dominates the artificial reforestation practice. In northern Sweden (_ latitude 600) direct seeding is used on not more than 5 % of the area, mostly carried out as row seeding after disc trenching.

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As private owners have very small clearcut areas (0.5 - 5 ha) and as they mostly deal with regeneration problems only three times during their active lives, they are seldom well informed about plant ordering, plant transport, plant storage, scarification, planting technique or labour organization. Accordingly, it would be desirable if less complicated methods could be adopted.

This is why regeneration research at the University of Umeå has been focused on direct seeding methods during the last decade. The result of direct seeding is fairly independent of the knowledge of the one who carries out the operation, as the storage of seed can be done in a normal refrigerator, the transport is no trouble at all and the dispersal is technically simple. Tirèn (1952) considers the method "foolproof". However, the old method, employed as open sowing into scarified patches, is very seed-consuming. 50-100 seeds must be sown into each patch: corresponding to 1 kg/ha.

It is well known that covering the seed prevents predation and that it stimulates the plant formation (Wiksten 1948, Hagner & Lundmark 1982). This is why a cone-shaped plastic shelter was tested from 1972 on (Hagner & Sahlen 1977). As this proved to be very successful the question occurred of whether the cone could be used also without the laborious removal of the humus layer. After an intensive research for ten years with numerous plastic shelters we believe we have managed to design the proper "funnel". Funnel seeding results in one seven-year-old seedling in every second funnel, which is an economically tolerable result. However, more tests have to be carried out before this method can be recommended for large-scale practice (Hagner & De Jong 1981).

Having come this far and having learned so much about plant survival in an unscarified environment, it seemed logical to design a shelter adapted to a plant directly placed into the humus layer (Hagner & De Jong 1982a). This method, PUM, (PUM; a swedish shortening of "planting without scarification"), has been investigated since 1980 and is being used this year on a practical scale. So far the plastic shelter has to be attached to the plant by the forest owner himself (at home), but we are heading for an automatic application at the nursery.

Parallel to the scientific work on sheltered seedling we have carried-out intensive studies on open seeding in disc trenches: row seeding (Hagner & De Jong 1982b). From the arrival of disc trenchers with separate arms, the area of uncovered mineral soil reached above 10 %. The former patch scarifiers did not reach more than one tenth of this. Therefore the probability for the seeds to hit good microsites was greatly enhanced with the new technique. Our biological and technical research has resulted in a very well functioning system, adopted in full scale by many companies. This spring around 2500 ha were seeded by manual row seeding, mostly on company land.

Today the private owner with a small clearcut_ area in northern Sweden can choose between the following systems:

* Order funnels and seed in the winter and perform funnel seeding directly after clear cutting in the spring.

* Buy plastic shelters (PUM) and plants in the first spring after clear cut. His wife attaches the shelters to the plants at home and he plants them directly into the humus.

* Wait some years while the governmental agencies arrange a mechanical scarification. Order cones and seed during the winter and perform cone seeding in the spring.

* If the authorities are able to organize harrowing with a disc trencher and deliver enough seed, he may perform the row seeding.

* After scarification he may order plants in the spring and plant them within one week.

* In the future the private owner may order plants with plastic shelters (PUM) and plant them the first spring following clear cutting, or

* order fully mechanized planting and let the machine take care of the whole operation.

In the following paper I have evaluated these methods according to my personal experiences. Of course, every forest owner who performed an analysis similar to this would set the priorities somewhat differently_ However, I belive the conclusions would be about the same. In any case, this work has motivated us at the University of Umeå to go further with research around row seeding and PUM.

A similar analysis was carried out at the start of the scientific work on row seeding (Hagner 1977). That result indicated, as here, that row seeding is of great interest, but contrary to this study it did not show fully mechanized planting to be of any significance.

METHOD

The regeneration methods considered are:

a. Manual planting in scarified patches (fig. 1) This is usually preceded by mechanized scarification. If the ground is covered with boulders or too steep for a tractor, the scarification has to be done by hoeing.

   After mechanized scarification, as many as 2000 plants can be planted per man day, but then an intense organization is prerequisite. Normally about 1000 rooted plants are planted per day. Manual scarification cannot be done much faster than 300-600 patches per day, which is 1-2 SEK/patch. With mechanized scarification the price/patch is 0.2-0.3 SEK.

   The cost of high quality labour is about 600 SEK/day or 1 SEK per effective minute. The price of a rooted seedling is about 0.8 SEK. However the company which produces its own plants pnobablyha9 an internal price which is half of this.

b. Fully mechanized planting (fig. 1). In Sweden there are two different machines available for performing simultaneous scarification and planting. The cost of planting using these is assumed to amount to the same as manual planting.

c. Manual planting without prior scarification (PUM) (fig. 1). This can be successful only if the seedling is protected from beetle attack and dehydration. This is why the plastic shelter (PUM) has to be attached to the seedling. The application is done as a separate operation at home. The price of PUM is 0.2 SEK, 400 SEK/ha.

d. Manual planting without prior scarification (PUM AUT). In this case it is assumed that the forest owner can order plants with PUM already attached to the plant. The price for PUM AUT will probably be 0.3 SEK.

With the methods (c) and (d) the planting should be done in the first summer following clear-cutting. This will decrease the rotation age and reduce the competition from hardwoods and grass.

e. Cone seeding after disc trenching (fig. 1). A plastic cone is placed over 5 seeds and the number of cones should exceed the number of plants desired by 10 %. The total cost of regeneration by this method is somewhat lower (~90 %) than that of planting. Cone seeding is restricted to fresh and dry sites with few stones in the soil surface.

f. Funnel seeding directly into the humus layer (fig. 1). A plastic shelter (funnel) is pushed down into the moss layer and five seeds are sown at the bottom of the funnel. To get the same number of trees in the stand as after planting, denser spacing is required; number of plants x 1.6. The total cost for this regeneration method is about the same as for planting.

Funnel seeding has to be done very soon after clearcutting in order to reduce the competition from herbs and hardwoods. Even though the funnel seeding is performed one or two years earlier than planting, the rotation age will be increased by 1-2 years. The reason is that the seedling is starting fairly slowly when placed in the humus layer.

More scientific studies have to be carried out before this method can be recommended for large-scale practice.

g. Row seeding after disc trenching (fig. 1). The seed is delivered in a continous row, as broad as the exposed strip of mineral soil. The tool used is a 150cm tube with a simple seed dispersal mechanism at one end. This manual operation is very simple and consequently the walking speed can be very high, 2-5 ha/day. The total cost is only 30-80 % of that connected to planting. However, the cost of seed is a critical factor because 20 pine and 10 spruce seeds should be delivered per meter of furrow. With 4000 meters of furrow/ha and a germinability of 85 %, 0.40 kg pine and 0.20 kg spruce are used per hectare, or a total of 0.6 kg.

The officical seed prices have drastically increased within the last years and vary from 1000 to 5000 SEK/kg. A discussion is going on as to whether these prices actually reflect the true costs of seed production.

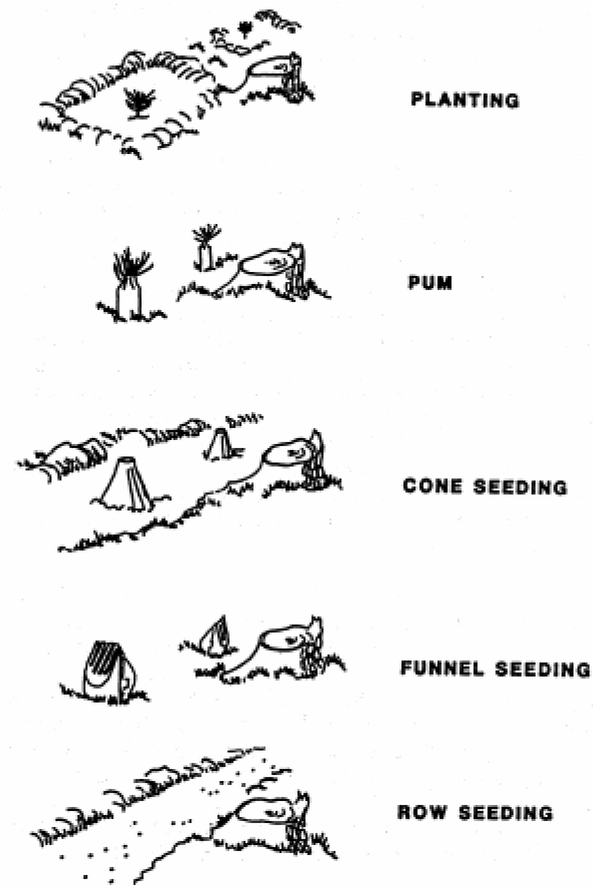

Figure 1.--Regeneration methods

The land owners considered here are:

1) Private owner employed in his own forest. The typical features are:

* low_ willingness to make capital investments
* low administrative costs
* low labour costs, or he is willing to choose methods connected with high labour input because labour costs constitute his own salary
* high priority on quality timber production
* very small clear cut areas

2) Private owner using hired labour. Typical features:

* very low administrative capacity
* low level of knowledge
* high labour costs
* long-term production has low priority
* small clear cut areas

3) Company on its own property. Main features:

* high willingness to make capital investments
* high level of knowledge
* high administrative costs
* manpower should be minimized
* long-term production should be kept high but

timber quality is less important
* large clear cut areas

4) Company reforestation connected to a timber contract. The typical features differ from above in the following aspects:

* low willingness to make capital investments
* low priority on long-term production and timber quality
* small clear cut areas

In the following calculation every method has been given a value, 1-9, when viewed from a certain aspect (table 1). A high figure indicates a positive feature. The aspects considered were: economy, administrative effort, need of knowledge, manpower requirement when mechanized scarification can or cannot be carried out respectively, general applicability, reliability, total volume production (high density = small spacing = high long-term production), possibility of producing high timber quality (=high density of young stand), rotation age. Each one of these aspects was first given the same power (average 5)(col. 6-12), and then a general level of priority was given to the different aspects (col. 1). Finally, these aspects were given a priority level 1-9 for each category of owner (col. 2-5).

Calculation

Example: Private owner, self-employed, mechanized scarification is possible. Planting. (Gen. Factor 9) x (Private self. 8) x (Planting 4) + 5x1x2 + 5x8x2 + 8x1x3 + 7x8x7 + 9x6x6 + 5x2x4 + 4x9x4 + 5x1x6 = 1332. This sum is set to 100 % when compared to the other methods.

Table 1--Figures of priority: Low = 1 High = 9

GENERAL FACTOR	PRIVATE, self-employed	PRIVATE, hired labour	COMPANY, OWN HOLDING	COMPANY, OTHERS HOLDING		PLANTING	MECHNIZED PLANTING	PUM MANUAL	PUM AUTOM	CONE SEEDING	FUNNEL SEEDING	ROW SEEDING
9	8	6	8	8	ECONOMY	4	4	5	4	5	4	7
5	1	8	3	5	ADMINISTRATIVE EFFORT	2	7	1	4	5	7	6
5	8	8	1	1	NEED OF KNOWLEDGE	2	8	3	4	5	5	8
8	1	8	9	9	LABOUR MECH. SCAR. POSSIBLE	3	9	2	3	4	3	7
8	1	8	9	9	LABOUR MECH. SCAR. IMPOSSIBLE	1	-	8	9	1	8	-
7	8	8	8	8	GENERAL ADAPTABILITY	7	6	8	8	3	3	3
9	6	8	6	8	RELIABILITY	6	4	5	5	5	5	4
5	2	1	8	1	LONG-TERM PRODUCTION	4	4	4	4	4	4	9
4	9	5	1	1	QUALITY PRODUCTION	4	4	4	4	4	4	9
5	1	1	7	1	ROTATION AGE	6	6	8	8	2	2	2

RESULTS AND DISCUSSION

The relative figures presented in figures 2 and 3 show that the self-emplyed private owner seems to have great interest in row seeding where mechanized scarification is possible. Where hoeing is the only way to scarify he would prefer the PUM method. In the latter case it is equally advantageous to attach the plant shelter manually as it is to buy plants with PUM.

Considering the effort to change from planting to these new methods, it may be concluded that neither of the two is so difficult to learn that this factor would be an obstacle. The limitation lies rather with the advisory foresters at the governmental board. These must discover the potential of the new methods and include them in their consulting service.

The private owner who has to carry out regeneration with hired workers should gain most by simply ordering fully mechanized planting. The lower price of row seeding does not compensate for the simplification of the whole operation. However, if the clearcut is unfit for a fully mechanized operation he should benefit most by ordering plants with PUM-shelters. Also funnel seeding would be a much better choice than planting with manual scarification.

The company operating on its own property should find it most advantageous to adopt fully mechanized planting wherever this is possible. On suitable sites, row seeding would be almost as good.

Where mechanized scarification cannot be carried out, manual planting directly into the humus layer (PUM) would be best. An additional operation such as manual application of the shelter would not decrease the economic feasibility of this method.

When the company carries out regeneration as part of a timber contract the interest of fully mechanized planting is even greater than when operating on its own property. Row seeding is also of great interest.

If the clearcut is too small or unsuited for mechanical scarification, planting directly into the humus layer is of great advantage. However, funnel seeding would also be beneficial.

The only method which proved advantageous for all types of owners in both environments was planting directly into the humus with sheltered plants. The shelter should then be attached to the plant at the nursery.

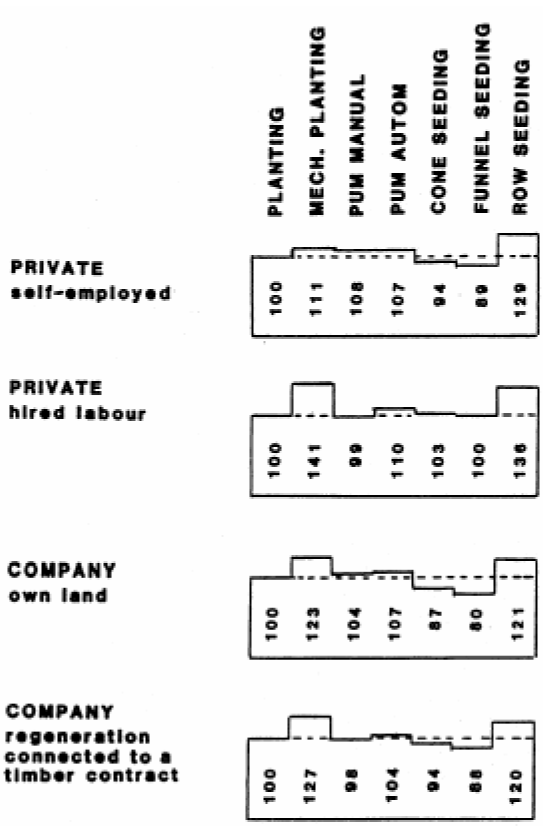

Figure 2.--Relative values on site where mechanical scarification is possible.

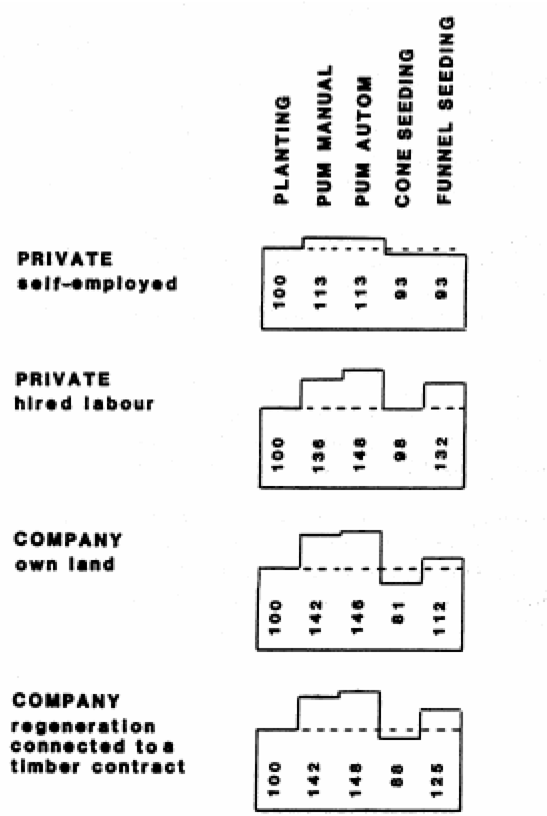

Figure 3.--Relative values on site where mechanical scarification is impossible.

Concluding Remarks

As a conclusion it may be stated that all of the mentioned methods should be considered usable. The few examples shown here do not cover all occasions. For instance, cone seeding received a fairly low overall figure. The private owner with hired labour will still consider cone seeding the suitable method, if he cannot arrange mechanized planting in a region where seed shortage is acute. Though unable to furnish the 0.6 kg/ha needed for row seeding, he may be able to obtain the 0.05 kg/ha needed for cone seeding.

The assumptions underlying the presented calculations are of course resting on my personal experience. Accordingly, others repeating this work may arrive at different relative figures. However, I do not think the conclusions would be very different from mine.

Finally, I want to stress that a change over to a new regeneration method is accompanied by a large extra investment in the form of education and organizational reconstructions. In the calculation presented above, this is not included at all. Accordingly, a new method should not be introduced unless it is so much better than that used formerly _hat the gain will overrule all the drawbacks connected to the change over to the new system.

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THE INFLUENCE OF MICROENVIRONMENT UPON SURVIVAL AND GROWTH IN PINUS SYLVESTRIS.

Mats Hagner

ABSTRACT: The covariance between environmental features and behavior of fifteen-year-old Pinus sylvestris was studied at two areas in the harsh climate of northern Sweden. The topography, insolation and moisture were measured around each plant at radii of 0.1, 0.5, 2.25, 20 and 100 meters. 15-28 % of the variation in survival and growth could be explained. Most important factors were (in descending order): moisture, topography at r 0.5 m, exposure at r 0.5 m, topography at r 20 m. It is concluded that such studies are indispensable for research around site-adapted regeneration techniques.

INTRODUCTION

The survival and growth of forest plants varies greatly with the environment. An enormous research has been put into studies where the environment has been manipulated by some kind of soil scarification, mounding or ploughing. It is always assumed that heavy scarification equipment has to be used on certain "problem sites". Surprisingly little has been done to define what the features of these "problem sites" are. One reason for this is naturally that it is difficult to measure an environment, as well as to analyse all the data. Modern computer facilities have drastically increased the possibilities in this respect.

Lyford and MacLean (1966) found that the long term growth and survival as well as survival in a natural stand in New Brunswick, Canada, was better on elevated places compared to depressions (diam 0.5-3 m; depth 10.50 cm).

At the University of Umeå we started environmental studies in 1972 (Ydgren). The dependent variable was the size of the leader in pine plants (Pinus sylvestris) four years after planting. The environmental conditions around 300 plants in each of three different clear cut areas (lat 640; 400 mas, 275 mas, 10 mas) were measured intensively. The reforestation was carried out with bare-rooted plants after mechanical spot scarification. The topography and exposure were registered in a way similar to that described in figure 1. The coverage of mosses, vascular plants and shrubs within an area of 2 m^2 was also tallied. The 36 variables were evaluated by regression and discriminant analyses. Highly significant covariation was found between plant growth and topography as well as with vegetation.

Topography at 400 mas. Best growth was found where the plant was elevated within the radius 0.1 m. Good growth was also found if the plant was elevated within radii 25 m, 0.5 m and 5 m, but the last correlations were not significant.

Topography at 275 mas. The covariation was not significant

Topography at 10 mas. Here the best growth occurred where the plant was southerly exposed (radius 0.1 m) and situated somewhat elevated (radius 0.1 m) in a depression (radius 0.5 m).

Vegetation at 400 mas. The growth was rapid if the 2 m^2 surrounding had a lot of Chamaenerion angustifolium and Linnaea borealis should be low. In places with a lot of slash from logging the plants grow less well.

Vegetation at 275 mas. The growth was rapid in the vicinity of Chamaenerion angustifolium and slow where a lot of Trientalis europaea was growing.

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Vegetation at 10 mas. Empetrum nigrum, slash and Vaccinium vitis-idaea indicated places where plants grow slowly. Linnaea borealis indicated good growth.

Andersson (1976) found that for five-year-old spruce in southern Sweden, early summer frost probably were the main cause of lower survival rate in depressions (28 %) than on slopes (56 %). Growth was also better on the slopes (45 cm - 75 cm). Sirén, et al. (1974) and Sinko and Nilsson (1976 A) found that in one area with harsh climate in northern Sweden, shelter tree density, topography, moisture and slope were the most important factors affecting regeneration. Later Sinko and Nilsson (1976 B) tested the influence of topography on two other areas, but found the correlation with plant height to be weak.

Bergsten and Winsa (1979) as well as Olsson (1982) found in harsh areas of northern Sweden that planted pine did not survive well in depressed (20 m^2) spots with high moisture and fine-textured soils. This corresponds with Andersson (1982), who studied 34 ten-year-old regenerations with pine in central Sweden. He found higher survival on elevated sites (10 m2) than in depressions. Hagner and De Jong (1981) found three-year-old sown pine to grow faster (50 %) when placed "high, bright and warm".

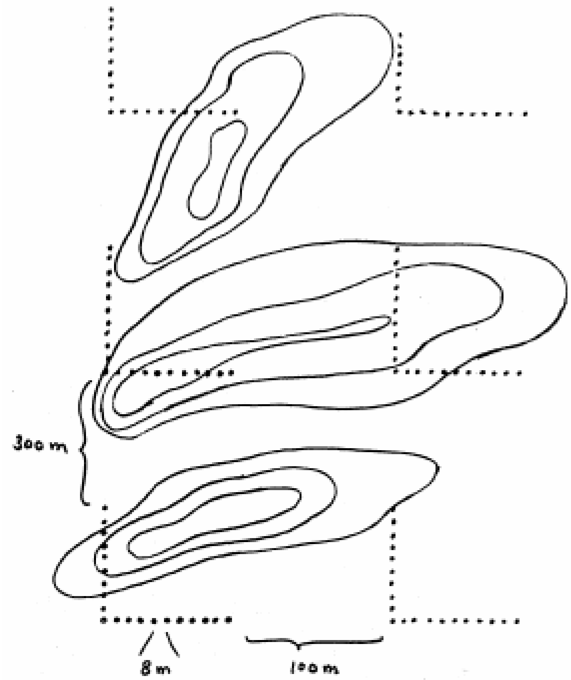

Figure 1.--Distribution of circular plots. The centre of the plot was a scarified patch (originally distributed with a spacing of 2 m). When the distance 8 m from the preceding spot was found, the closest scarified patch was chosen as the next centre.

MATERIAL AND METHODS

The present study was carried out in 1976 on two clear cut areas far north in Sweden:

ARTU, Latitude: 66°51' Altitude: 430 m
Area; 101 ha. Soil: moraine sandy loam. Clear cut 1946. Prescribed burning 1948. Planting 1954 with two-year-old bar-rooted pine after mechanical patch scarification carried out 1953.

PURNU, Latitude: 66°51' Altitude: 380 m
Area: 30 ha. Soil: moraine sandy loam. Clear cut 1943. Planted in 1963 with two-year-old rooted pine after manual patch scarification.

These two areas were chosen because they seemed to be fairly different. Although they are situated about 2 km apart, Artu is steadily sloping towards the north, while Purnu is horizontal, consisting of low hills as an island in a large complex of bogs.

Experimental Design

Although- 22 and 13 years had passed since planting, the scarified patches were easily found. In this harsh climate the growth of vegetation is fairly slow. The patches were considered to be the centres of each plot. In each one of the two areas, 200 plots were investigated. The plots were distributed with distances 8, 100 and 300 m apart (fig. 1).

It was assumed that each scarified patch had been planted. If the plant could not be found it was assumed to have been planted in the centre of the patch. Where seedlings were dead the remnants were mostly found standing or leaning.

The circular plots had a variating radius: 0.1 m, 0.5 m, 2.25 m, 6 m, 20 m and 100 m. All these sizes were used at each centre. Within each one the topography and exposure were registered according to the lowest and the highest points within the plots; see figure 2.

The moisture content (1-9) of the soil surface, within a radius of 1 m, was registered according to the coverage of mosses and lichens: Cladonia species. (1-2), Polytrichum commune (5-7), Sphangnum species (8-9).

Plant height was measured in dm (1/10 m). Plant condition was subjectively determined on a scale of 0-9, with 0 = dead, 9 = vital. Within the plot with radius 2.2_ m the number of pines, spruces and birches were tallied and their average height was determined subjectively.

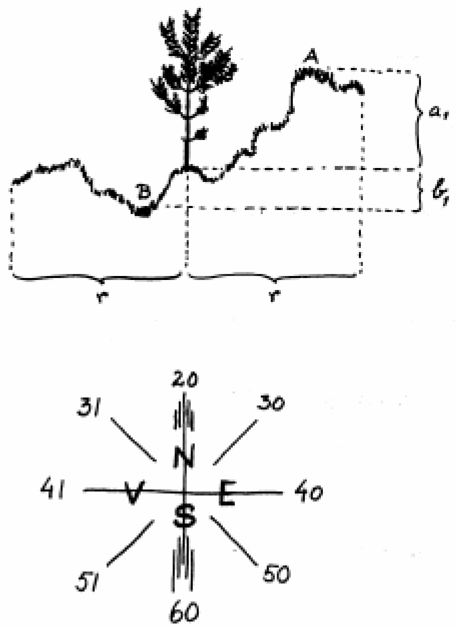

Figure 2.--Topography was registered as a_1 and b_1, which were the vertical distances between the base of the plant and the highest (A) and lowest points (B) within the circle (r=radius). Exposure was registered as an insolation figure (20-60) according to the direction from A towards B. Thus for each plant three measurements were taken for each radius. Radii considered: r=0.1 m, 0.5 m, 2.25 m, 6 m, 20 m, 100 m.

Analyses

To enable a proper characterization of topography the variables a_1 and b_1 were transformed as follows. To avoid division by zero, a_1 and b_1 were set to $a = a_1 + 1$ and $b = b_1 + 1$. The relative elevation of the planting spot was described as topography TOP = b/(a+b). If this figure is >0.5 the plants stands high, and low if it is <0.5. When TOP~1 the plant stands on the highest point of the plot (A) and if it is~0 the plant stands on the lowest spot (B) (fig. 2). In the following the elevation is described as i.e. TOP 0.5, which means the b/(a+b) for the plot with radius 0.5

In the regression analyses the TOP variable as well as its square has been used.

In the discriminant analyses, the two groups "living" and "dead" were compared.

Table 1-- Descriptive values of the two areas.

	ARTU Mean	NO/ha	PURNU Mean	NO/ha
Plant survival %	54		52	
Plant height m	2.35		1.62	
Plant condition 0-9	3.34		3.05	
Measurements within radius 2.25 m = 15.9 m^2				
Number of pines	1.80	1132	1.36	855
Height of pines m	2.37		1.57	
Number of spruces	0.08	50	0.43	270
Height of spruces m	0.90		1.41	
Number of birches	1.33	836	0.26	163
Height of birches m	1.15		1.48	
Moisture 1-9	2.48		4.53	
a 0.1 cm	6.41		5.15	
b 0.1 cm	2.05		1.55	
Exp 0.1	42.6		41.3	
a 0.5 cm	18.6		23.3	
b 0.5 cm	5.37		5.25	
Exp 0.5	42.1		41.6	
a 2.25 cm	59.8		51.5	
b 2.25 cm	53.0		33.0	
Exp 2.25	41.1		41.3	
a 6 cm	79.5		66.9	
b 6 cm	70.7		46.0	
Exp 6	41.5		41.2	
a 20 m	1.87		1.37	
b 20 m	1.44		0.92	
Exp 20	40.9		35.5	
a 100 m	12.6		5.20	
b 100 m	5.60		2.34	
Exp 100	41.1		32.8	
TOP 0.1	0.30		0.32	
TOP 0.5	0.24		0.20	
TOP 2.25	0.47		0.41	
TOP 6	0.48		0.42	
TOP 20	0.44		0.40	
TOP 100	0.33		0.35	

RESULTS

A descriptive analysis (table 1) shows that the average figures for TOP were below 0.5, which means the plants were placed below average elevation within the plot. This was especially the case in the small plots (r = 0.1 and 0.5 m). The patch scarification has thus forced the workers to place the plants in hollows. The average survival was around 50 % and the pines were mostly 1-3 m tall. Per hectare there were around 1100 conifers.

Comparing the two areas it is found that ARTU is less moist (2.5 - 4.5), has more and taller pines (1132/ha - 855/ha), a lesser number of spruces (50/ha - 270/ha), a higher number of birches (836/ha - 163/ha) and is sloping more ((a 100 + b 100); 18.2 m - 7.5 m).

Table 2--Regression and discriminant functions connected to plant condition and survival. In these calculations dead plants are assumed to have the condition = 0. * = significant at the 5 % level, ** = 1 %, *** = 0.1 %.

PURNU

Survival and condition. Regression (TOP and EXP).

Plant condition (0-9) = $11.1(\text{TOP }20)^{2***}+31.2\text{ TOP }0.1^{*}-52.5(\text{TOP }0.1)^{2*}-12.4\text{ TOP }0.5+36.0(\text{TOP }0.5)^{2*}+0.03\text{ EXP }0.5-3.47$

$R^2 = 0.18$ $F = 6.96^{***}$

Number of pines (r=2.25) = $4.67(\text{TOP }20)^{2***}+2.27\text{ TOP }0.5^{**}+\text{EXP }0.5^{*}+0.017\text{ EXP }100^{(*)}-1.10$

$R^2 = 0.14$ $F = 7.73^{***}$

Living/Dead. Discriminant analyses with TOP, EXP and MOISTURE. Standardized discriminant function coefficients.
Living = high value.

Moisture;-1.06, TOP 0.5;+ 0.46, EXP 100;+ 0.43, EXP 20;- 0.22

$P < 0.006$ 78 % of known cases correctly classified

ARTU

Survival and condition. Regression (TOP and EXP)

Plant condition (0-9) = $9.52\text{ TOP }0.5^{***}+110\text{ TOP }20^{*}-106(\text{TOP }20)^{2*}+0.07\text{ EXP }6^{**}+0.07\text{ EXP }20^{*}-12.1(\text{EXP }100)^{2(*)}-25.4$

$R^2 = 0.22$ $F = 9.23^{***}$

Number of pines (r=2.25) = $17.7(\text{TOP }20)^{2***}+3.06\text{ TOP }0.5^{*}-2.38$

$R^2 = 0.28$ $F = 37.2^{***}$

Living/dead. Discriminant analyses with TOP, EXP and MOISTURE. Standardized discriminant function coefficients.
Living = low values.

Moisture;+ 0.68, TOP 0.5;- 0.57, EXP 0.5;+ 0.33, TOP 2.25;- 0.44

$P < 0.007$ 73 % of known cases correctly classified

Table 3--Regression functions related to plant size.

PURNU

Height of pine. Regression (TOP and EXP).

Plant height = $+0.11\text{ EXP }0.5^{*} - 0.11\text{ EXP }20^{*} + 0.09\text{ EXP }6^{*} + 11.4$ $R^2 = 0.13$ $F = 5.01^{**}$

ARTU

Height of pine. Regression (TOP)

Plant height = $1140\text{ TOP }20^{***} - 1258(\text{TOP }20)^{2***} + 30.1\text{ TOP }100 - 98.6(\text{TOP }100)^2 - 230$ $R^2 = 0.28$ $F = 9.96^{***}$

Survival And Condition

At PURNU the regressions on condition and number of pines within r=2.25 show (table 2) that a dense stand is obtained on hills (TOP 20) and it is beneficial to avoid depressions (TOP 0.1 and TOP 0.5). The plant should be placed facing south in the scarified hollow (EXP 0.5).

Although significant, the regression cannot explain more than 18 % of the variation in plant condition.

The discriminant analyses included moisture, which was not the case in the regressions. This is probably why TOP 20 is not at all included in the discriminant function. There is probably a strong correlation between moisture and TOP 20. The function shows that good survival is obtained if moist spots are avoided. This is a very strong variable. In addition, a better result is reached by placing the plant in an elevated position in the scarified hollow (TOP 0.5) and facing north on smaller slopes (EXP 20).

At ARTU the regressions on condition and number of pines (table 2) are somewhat stronger; 28 % of the variation can be explained. The information is fairly similar to that at PURNU. Many and healthy pines occur where they have been planted in elevated positions on the scarified patch (TOP 0.5). The survival is best close to the top of hills (TOP 20) and on south-facing slopes (EXP 6 and EXP 20).

The discriminant analyses strongly emphasize that the survival rate is low on moist places and that survival is enhanced if the plant is placed elevated within the scarified hollow (TOP 0.5).

Plant Growth

At PURNU the regression could not explain more than 13 % of the variation. The most important factor for fast growth was a southerly exposure within the scarified patch (EXP 0.5), (table 3).

However, at ARTU the plant size seems to be strongly dependent of the position along slopes (TOP 20). The ideal position corresponds to TOP 20 = 0.453, which is between the top and the bottom. The regression function has an explanation capacity of 28 %, which is a fairly' high value.

Birch

Occurrence of birch has always been of interest. At ARTU a weak (R^2=0.03) but significant (p=0.01) regression showed that birch has the highest frequency in depressions (TOP 20). At PURNU the tendency was stronger (R^2=0.08) and birches here were also most frequent (p=0.001) in depressions (TOP 6).

DISCUSSION

In this study, as well as in the former carried out by Ydgren (1972), it stands clear that plants react strongly to the environment in their immediate vicinity (radius 0.1 and 0.5 m). Accordingly, it should be possible for the forester to use this knowledge in choice of microsite for the plant or to modify the environment by mechanical manipulation. In order to find out what a consistent choice of planting spot within the scarified patch would mean to the survival on the studied areas, plots with TOP 0.5 >0.3 and EXP 0.5 >40 were compared with the total. At ARTU, 18 % of the plots had this feature and in these the survival was 78 % compared to the total 54 %. At PURNU, 11 % were selected and their survival was 77 % compared to the total 52 %. This indicates a remarkable effect of a small adjustment in the planting procedure.

It is worthwhile to stress that the above-mentioned effect was reached just by choice of site within the scarified patch, in these cases equal to the avoidance of depressions. In the investigation carried out by Ydgren, a stronger effect on the fourth-year growth was found for the smallest circle (TOP 0.1 m) than for a somewhat larger (TOP 0.5 m). If the very closest environment plays such a marked role, there is a risk that foresters with great resources in the form of bulldozers and giant ploughs disrupt the ground to a much greater degree than is needed. The optimal might be to not manipulate the topography at all, and instead exploit the natural undulations already present.

The present study should be deepened in respect to questions such as, "where is a choice of environment most important?". It could be assumed that an elevated planting spot is of much greater importance in depressions with a high water table, than at the top of a hill. Maybe there is no need to consider the microenvironment at all in some types of terrain. Such things could be elucidated by further analyses of this material. The answers are certainly of great importance to scientific work in the field of scarification.

Although the present work has been successful because significant relationships of practical interest has been obtained, one must remember that 70-90 % of the variation was not explained by the functions. This is to say that the methods used should be completed with other sorts of mensuration. For example the very great influence from moisture, measured as coverage of mosses and lichens, points towards the need for a device for a more precise measurement of water content and soil density.

The present results clearly show that survival and growth are affected by a vast number of environmental factors, often on such a tiny scale that they are not at all noticed by a forester. Accordingly, we cannot expect to discover the true covariation and the most important environmental factors through mere subjective observations. To obtain -a deeper knowledge, necessary to define better types of scarification equipment or to prevent large-scale destructive manipulation of the forest ground, it is imperative that work similar to this continue. Of course, such investigations should be carried out not only in young stands, but in stands of all ages, in very dissimilar microenvironments and also be directed towards stands with species mixtures. When this research reaches its culmination, maybe we will see a regeneration technique which is modified to suit clear cut areas according to environmental indices.

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RESULTS FROM SOME EXPERIMENTS WITH DIRECT SEEDING OF SCOTS PINE AT HIGH ALTITUDES

Kenneth Sahlen

ABSTRACT: Six experiments located at high altitudes where direct seeding and planting of Scots pine were made in 1974 were investigated in 1984. When being sown, the seeds were sheltered 'by plastic cones. The results show that 90% of the germinative seeds had germinated on all localities after the first summer. There was at least one living seedling in almost 100% of the cones. After 11 years there were still living plants in 64-89% of the cones, whereas 42-90% of the planted plants had survived. The height varied between 36 and 118 cm for seeding and between 65 and 181 cm for planting. There was a positive correlation between height of the dominant plant and number of plants per seed spot. The probability for a seed spot to show at least one living plant after 11 years was a bit higher for seed spots with more than one plant after 4 years than for seed spots with only one plant

INTRODUCTION

During 1974 and 1975 a great number of experiments with direct seeding of mainly Scots pine under shelter of plastic cones were laid out over the whole of Sweden. The results obtained after one respectively two growing seasons have been reported earlier (Hagner & Sahlen 1977). In autumn 1984 six of these experiments, located at high altitudes, were again inventoried. In this paper the results from these six localities are presented.

MATERIAL AND METHODS

The experiments are located between latitude 61 and 68 but concentrated on around 67 (Figure 1). Site conditions varied, and all localities were scarified (Table 1).

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<u>Experimental design</u> (Table 2)
Along a 200-m line over the clearcut and scarified area ten sample plots were laid out. At each sample plot direct seeding was made on ten patches around the line; 50 m beside the line 3 sample plots were planted with 10 seedlings on each.

Seeding was done with exactly the same number of seeds on each of the 100 patches. A plastic cone sheltering the seeds was then placed on the ground. The cone used in 1974 was made of polypropylene, and the size and shape is shown in Figure 2.

Inventories were made after one, two, four (not all experiments) and eleven growing seasons.

Registrations after one growing season.
- -number of living and dead seedlings in each one
- -position and degree of damage to the cones
- -height of planted seedlings

Table 1--Description of the six localities

Exp. No.	Locality	Latitude	Altitude m	Site quality class h 100 m	Forest vegetation type	Type of soil	Scarification method
614	Silvertjärn	61°44'	500	18	mesic dwarf-shrub	sandy till	patch-scarifying
671	Kuusipää	67°10'	420	12	mesic dwarf-shrub	sandy till	burning+patch-scarifying
672	Melavaara	67°20'	410	12	very dry dwarf-shrub	sandy till	harrowing
674	Putjas	67°00'	410	14	mesic dryopteris	sandy silty till	ploughing
676	Naulavaara	67°00'	350	14	mesic dwarf-shrub	sandy till	harrowing
681	Saivo	68°10'	330	12	dry dwarf-shrub	sandy till	patch-scarifying

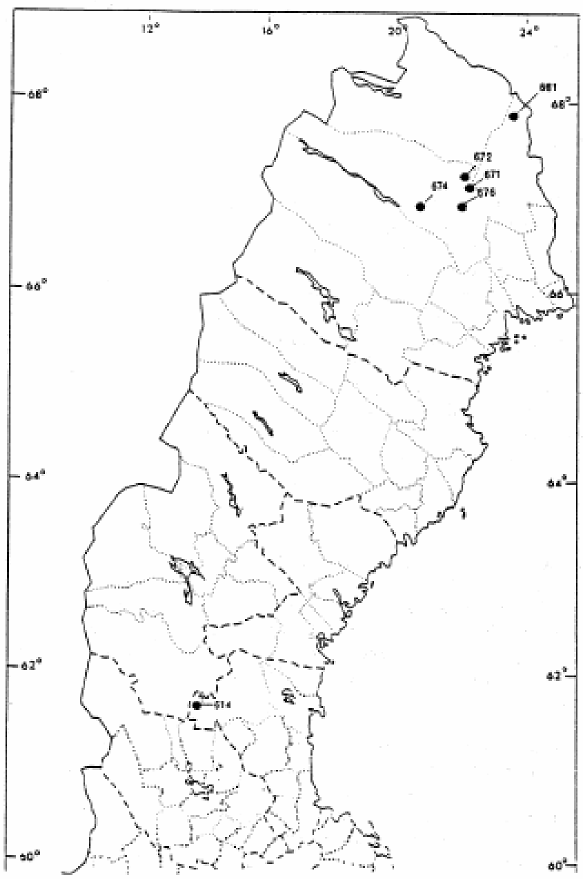


Figure 1.--Location of the six experiments.

Registration after two seasons.
- Only five of the cones on each sample plot were invented. These cones were removed to make it easier to count the number of seedlings and were not put back again. On this occasion the same registrations were made as after one growing season.

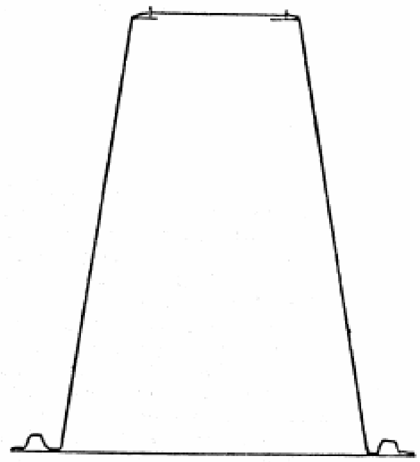


Figure 2.--Shape and size of the plastic cones used. Height = 80 mm, upper diameter = 25 mm, base diameter = 57 mm.

Registrations after four growing seasons.
- number of living seedlings at each seeding spot. If it was impossible to count the exact number because of the remaining cone, it was only registered whether seedlings were present or not
- height of the three biggest seedlings at each seed spot, if possible to measure
- height of the planted seedlings

Registrations after eleven growing seasons.
- number of living plants at each seed spot
- height of the three biggest plants
- length of the annual shoot of the biggest plant
- height and length of the last three annual shoots of planted plants'

Unfortunately, in 1982 a release cutting had been done in experiments 614 and 676. In 676 it was possible to count the number of released plants. Thus for Exp. 676 the number of plants shown in the results are living plants + released plants.

Table 2--Experimental data of the six localities

Exp. No.	Seeding and planting year	Seeding time week No.	Provenance of seeds Lat.	Alt.	Germination percentage	Number of seeds per cone	Planting time week No.	Provenance of plants Lat.	Alt.	Plant type
614	1974	23	61°44'	500	65	10	25	61°00	500	paperpot 1/0
671	1974	24	68°00'	330	82	6	24	68°00'	330	paperpot 1/0
672	1974[1]	24	68°00'	330	82	6	25	68°00'	350	bareroot 2/0
674	1974	24	68°00'	330	82	6		Not planted		
676	1974	24	68°00'	330	82	6	24	67°30'	400	bareroot 2/0
681	1974	26	68°00'	330	82	6	24	68°00'	350	bareroot 2/0

[1] planted 1975

RESULTS

Germination

After the first summer, on an average about 90% of the germinated seeds had formed a living seedling (Figure 3). In consequence, there was at least one living seedling in nearly 100% of the cones on all localities (Figure 4).

Survival

After eleven growing seasons the percentage of seed spots with living seedlings varied between 64 and 89, whereas the plantation had survived to 42-90%. On five of the six localities the percentage of seed spots with living plants was higher than the survival of the plantation (Figures 5-10).

Height increment

After 11 years, the mean height for the highest plants in each seed spot varied from 13 cm to 118 cm among the localities. The mean height in the plantation was always bigger than it was among the seeded plants (Figures 11-15).

Number of plants and percentage of spots with living plants

A higher percentage of the seed spots that after 4 years showed more than one plant still had at least one living plant after 11 years in comparison with seed spots showing only one plant after 4 years (Figure 16).

Number of plants and plant height

The plant height increased with increasing number of plants, up to 4-5 plants, at the seed spot (Figure 17).

Difference in plant height between seeding and planting

When the experiment started, the planted plants were already one or two years old. Thus the seeded plants were 1-2 years younger than the planted ones. If the plant height is compared at the same age for planting and seeding, the planted plants reached the same height as the seeded plants at a lower age. The difference has increased from 1 or 2 years at the beginning up to between 3.3 and 4 years after 11 years (Table3).

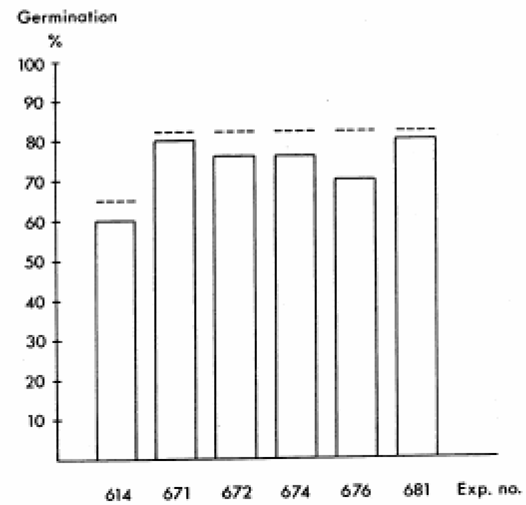


Figure 3.--Living seedlings in percentage of sown seeds after one summer. The broken lines show the germination percentage when testing was made in laboratory.

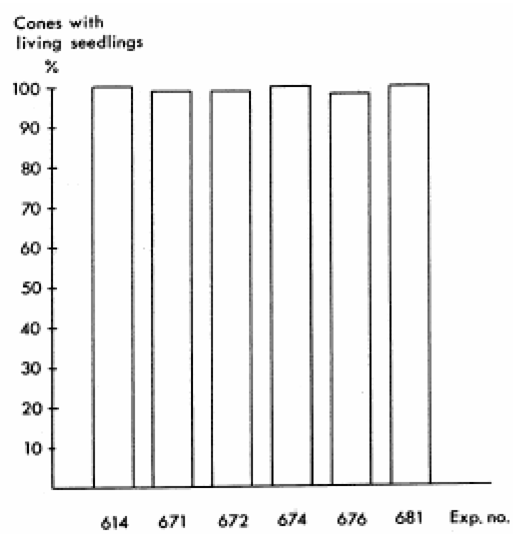


Figure 4.--Percentage of seed spots with at least one living seedling after one summer.

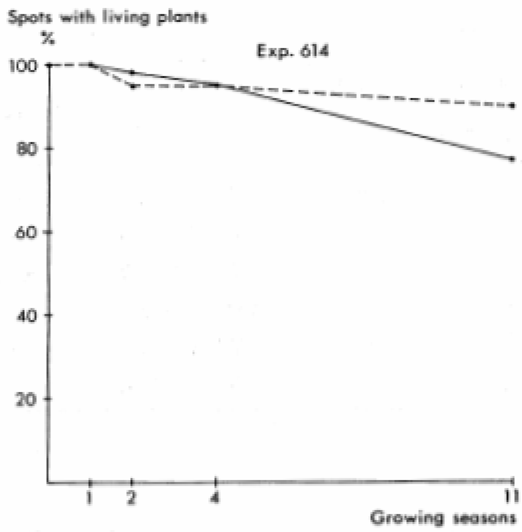
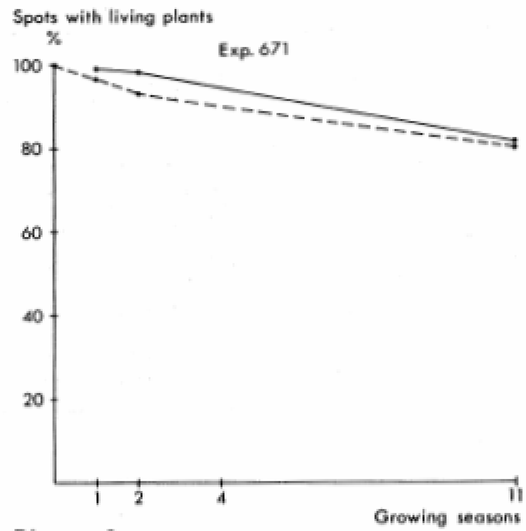


Figure 5.



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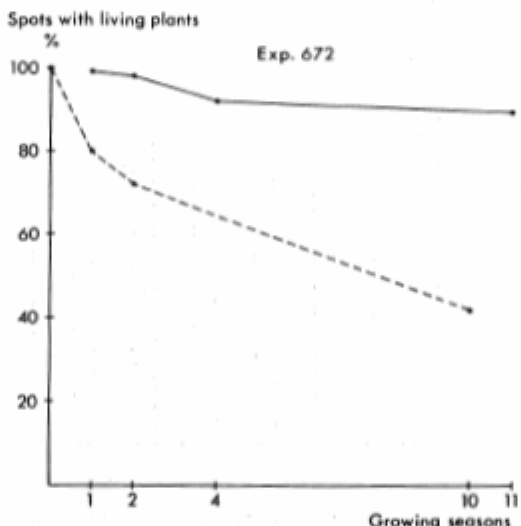

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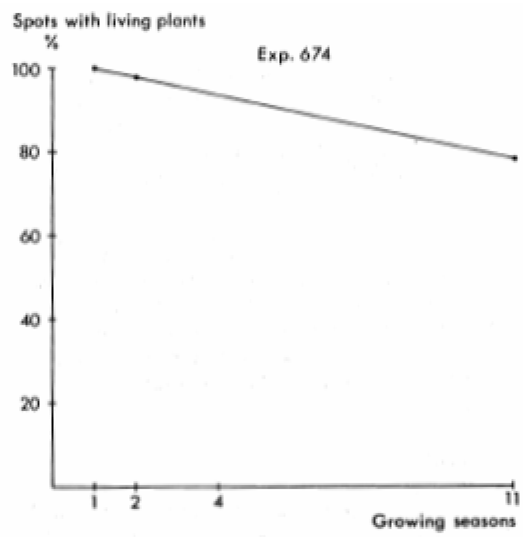

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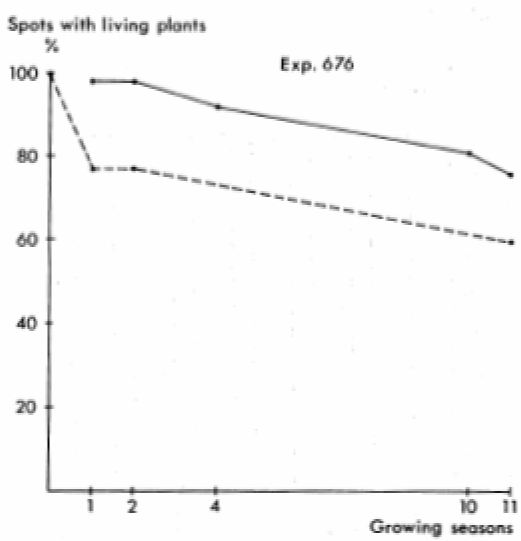

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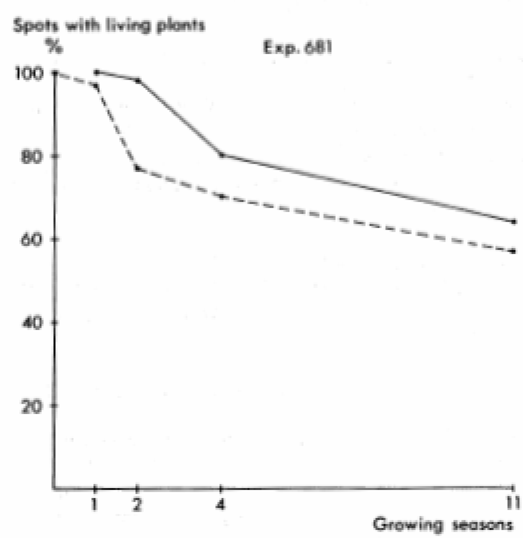


Figure 10.

Figures 5-10. –Percentage of seeding and planting spots with at least one living plant. The continuous line shows seeding and the broken line shows planting.

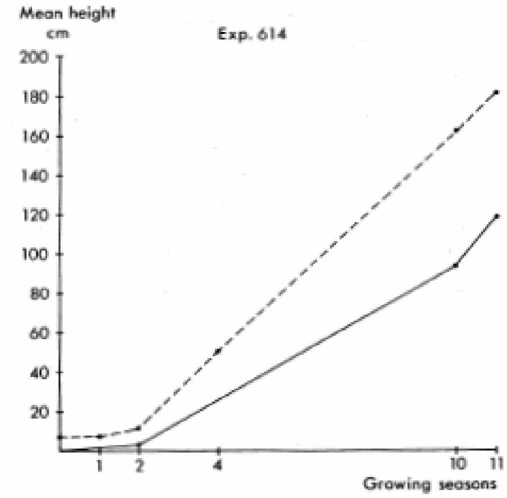


Figure 11.

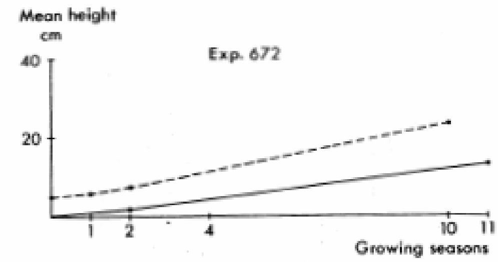
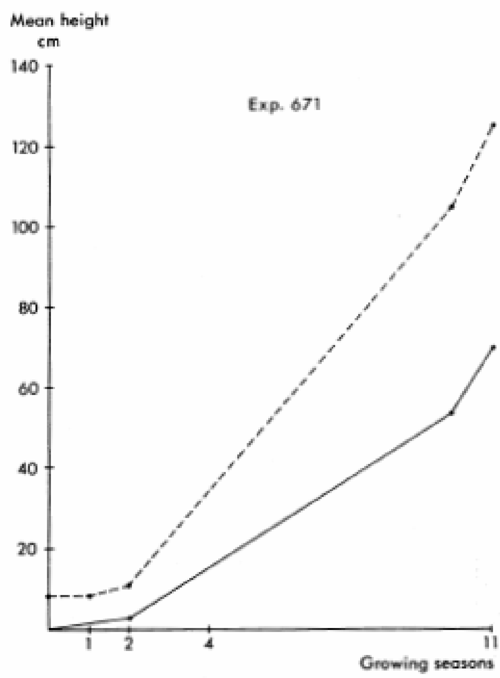


Figure 12.



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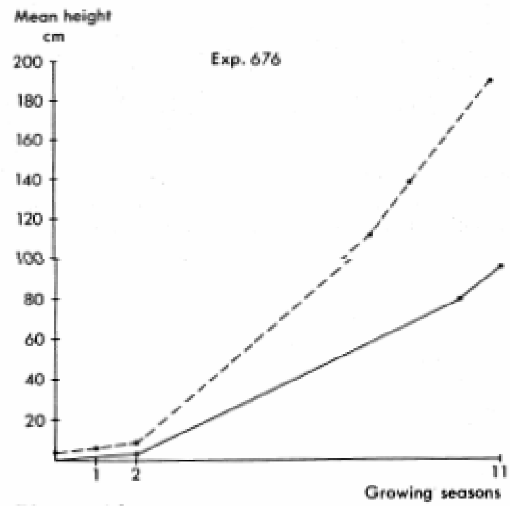

Figure 14.

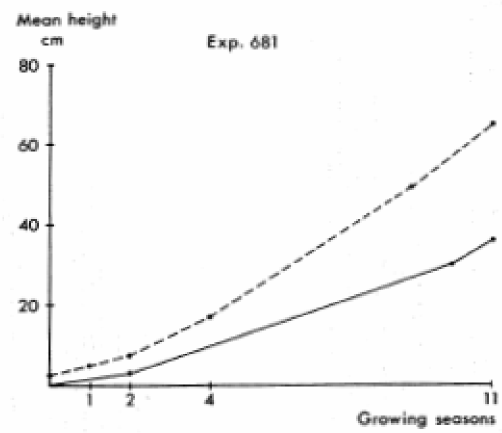

Figure 15.

Figures 11-15. –Mean height for seeded and planted plants. For seeding it is the mean height of the biggest plant in each seed spot. The continuous line shows seeding and the broken line shows planting.

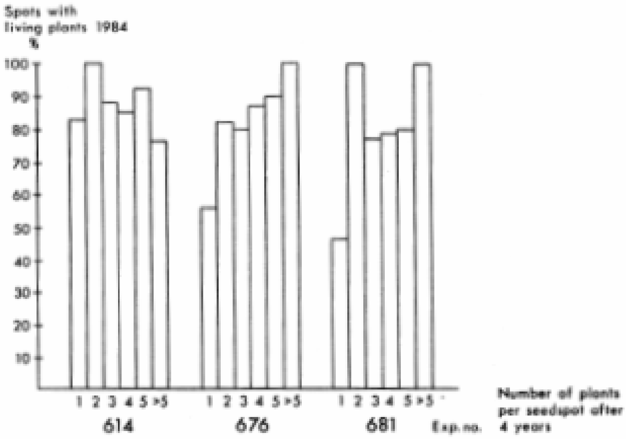

Figure 16.--Percentage of seed spots with living plants after 11 years divided among seed spots with different number of plants after 4 years.

Table 3--Comparison of height and age between planted and seeded plants.

Exp. No.	Plant age at the time of planting	Height of seeded plants after 11 years cm	Age in years of planted plants when height is equal to that of seeded plants after 11 years	Time in years for seeded plants to reach the same height as planted ones
614	1	118	7.7	3.3
671	1	70	7.3	3.7
676	2	95	7.0	4.0
681	2	36	7.0	4.0

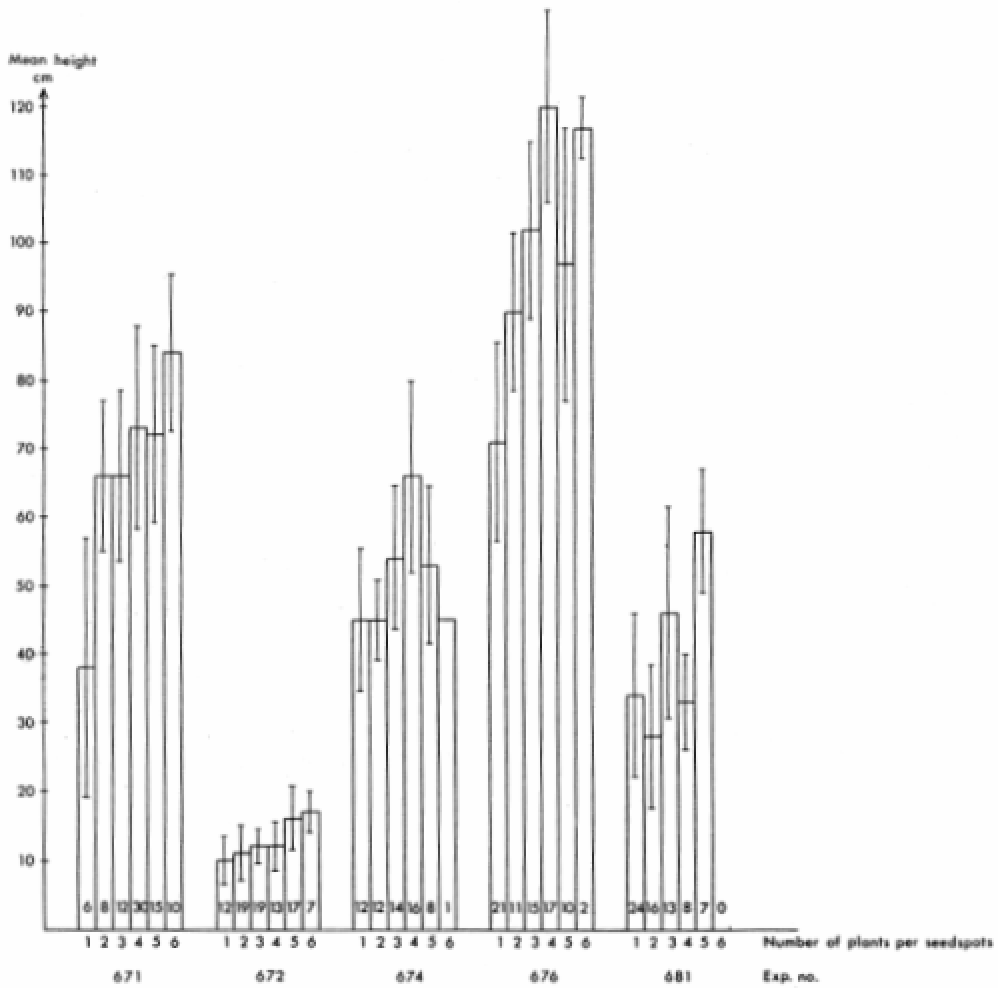

Figure 17.--Plant height after 11 growing seasons on seed spots with different numbers of plants. The vertical lines indicate the standard deviation. The numbers at the bottom of the staples indicate the number of seed spots in each class.

DISCUSSION

These experiments show that despite the harsh climatic conditions there are no problems for the seeds to germinate well, if a shelter is placed over the seeds. By a number of seeds amounting to 5-7 (germinative seeds) it was found that the number of cones without living seedlings was nearly zero after the first summer.

On the other hand, many of the cones had a high (5-6) number of seedlings. This high plant density has not been unfavourable to the future survival or height increment. On the contrary, the tendency is that the probability that a cone shows at least one living plant after 11 years increases if the number of plants after 4 years is high. It is also positive considering the height increment that there is more than one plant per seed spot. A special release cutting would therefore not. be necessary, at least not before the plants have reached the height of 1 metre. Similar results have also been found by Hagner (1984).

Because of the shortage of seeds for high altitudes, cone seeding with its low seed consumption (60 grams per hectare) can be most Suitable as a complement to planting.

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A HYPOTHESIS ON THE CAUSE OF ABNORMAL DEVELOPMENT IN SCOTS PINE SAPLINGS ON PLOUGHED SITES IN NORTHERN FINLAND

Eero Tikkanen

ABSTRACT: pine saplings in Northern Finland have been found to show retarded height growth and a weakening in condition 8-15 years after planting, having developed well initially, and this has led to rapid death. Weakness of the stems and branches and poor lignification are typical features, as also are short needles and a small number of annual needle crops. The saplings also suffer from frequent mechanical snow damage and various diseases, including dieback, canker fungus, twisting rust and various needle cast diseases.

The symptoms observed and the results of preliminary needle nutrient analyses point to a deficiency in phosphorus, and to some extent nitrogen, as the cause of this abnormal development, this being further exacerbated by the severe climatic conditions. Environmental stress is most pronounced at the point where the saplings grow beyond the level of the snow surface, a situation which places considerable demands upon their energy balance.

The major factors giving rise to a phosphorus deficiency may well be a decrease in the humus layer and certain chemical changes taking place in it, an increase in poorly soluble phosphorus compounds in the soil, a decline in soil microbiological activity, the poor condition of the sapling roots, leaching of nutrients and the binding of nutrients by the soil-acidifying ground-layer vegetation.

INTRODUCTION

It has been the custom in Northern Finland since the 1950's to promote forest regeneration after clear cutting by means of burning-over, or later tilling of the soil, with the ploughing of forest land becoming. an increasingly widespread practice from the 1960's onwards. The early development of pine saplings in ploughed areas is generally good (Lahde & Pohjola 1975, Mutka & Lahde 1977, Pohtila 1977), but there are cases in which a pronounced decline in vertical growth and the rapid death of some saplings have been observed some 8-15 years later. The aim of the present paper is to describe these problems and offer a possible explanation for them. It should be

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remembered, however, that debilitated pine saplings of similar appearance are also to be found in former clear-cut areas which have been tilled in other ways, left untilled or burned over, just as analogous cases are to be seen on poor growing sites in natural forests.

The Finnish version of this article was published in autumn 1984 (Tikkanen & Raitio 1984). The nutrient analyses published here were performed at the Rovaniemi Research station of the Finnish Forest Research Institute. The author thanks Mr. Malcolm Hicks, M.A., for the English translation.

DESCRIPTION OF THE PROBLEM

The growth disturbance in Scots pine saplings to be discussed here consists of a marked decline in condition and retardation of height growth followed by rapid death, only 2 or 3 years after the first appearance of the symptoms in the worst cases. The critical point is reached soon after the saplings have grown to a height at which they extend above the surface of the snow in winter. The saplings are more or less normal in form, but leading shoot failure or reduced growing tip dominance has been observed in places. Weakness of the stems and branches and poor lignification are also typical features, as also are short needles and a rapid shedding of needles, so that those present at anyone time represent only 2 or 3 years' growth (fig. 1). The change in growth rate in the needles takes place abruptly, and often simultaneously with the retardation in height growth. The needles are normal in form, but display some alterations in colour depending on the season. The saplings also suffer from frequent mechanical snow damage and various diseases, including dieback, canker fungus, twisting rust and various needle cast diseases. It should be borne in mind, of course, that pine saplings in artificial regeneration areas in Northern Finland can suffer from other types of disturbance as well, largely ones resembling the growth disturbances described by Raitio and Rantala (1977) and Raitio (1983a).

SAPLING DEATHS IN THE 1960'S

Burning-over was the predominant method of site preparation employed for artificial forest regeneration purposes in the 1950's, but methods involving breaking *up* the surface of the ground gained currency rapidly from around 1960 onwards. At first this was done by means of scarring, in order to create a suitable substrate for germination. This procedure was believed to lead to more successful forest regeneration, especially in more permeable soils.

From around 1965 onwards, pine sapling deaths began to be noted in forest regeneration areas in Northern Finland which had been clear-cut and then burned over or scarred during the 1950's. Particularly on compressed, moist till soils which had previously supported spruce forest, 1-2 m pine saplings began to show signs of retarded vertical growth and colour changes and growth

Figure 1.--pine saplings planted on tilts at Tuiskukivalo in the rural commune of Rovaniemi in 1975, photographed by E. Tikkanen in spring 1985, when some of the saplings were in poor condition.

disturbances in the needles, beginning with these turning yellow around the growth tips and leading to the occurrence of brown needles throughout and eventually to the rapid death of the sapling. The principal cause of this damage was thought at the time to be Scleroderris canker (Valtanen 1970), and Norokorpi (1971) concluded on the basis of research by Eiche (1966) and others that mechanical damage caused by frost and snow may well have rendered these debilitated pines susceptible to Scleroderris infection. The most serious debilitating factors were regarded as being the poor condition of the root systems and the associated compactness and unfavourable water and oxygen balance of the soil (Lahde 1971, 1973). It should be noted, however, that at that time it was quite common for saplings to be used which were of a provenance unsuited to northern conditions.

The ploughing of forest regeneration plots was widely adopted from this time onwards in the hope of achieving better results. At first the saplings were _planted only on the shoulder of the ploughed furrow, but when this failed to yield satisfactory results it became normal to plant them on the tilt wherever this was sufficiently well-formed. As a further retinement, the shape of the plough was even altered in order to create better tilts, i.e. the tilt plough was developed.

Now that some 8-15 years have elapsed since the planting which took place around 1970 and the pine saplings growing in these ploughed areas have reached heights of 1-3 m, a pronounced decline in vertical growth and general condition

Table 1--Nutrient content of the youngest generation of needles at Kuusikkolamuri (20 samples), Tuiskukivalo (7 samples) and Palolamuri (6 samples) in the rural commune of Rovaniemi in autumn 1983

Site \ Analysed nutrient		N %	P ‰	K ‰	Ca ‰	Mg ‰	Fe ppm	B ppm	Cu ppm	Zn ppm	Mn ppm	Al ppm
Kuusikkolamuri	$\bar{x}$	1.29	1.32	4.74	2.32	0.89	41.0	16.0	4.39	40.6	644	349
	min	1.10	1.16	3.80	1.69	0.71	30.6	9.8	3.07	29.6	340	242
	max	1.47	1.58	5.98	3.26	1.17	51.0	28.2	6.46	55.0	848	527
Tuiskukivalo	$\bar{x}$	1.08	1.23	5.53	1.93	0.73	25.9	12.1	3.55	43.5	396	242
	min	0.98	1.08	4.62	1.18	0.55	20.5	6.5	2.39	36.9	308	171
	max	1.20	1.39	7.17	2.76	0.99	30.8	18.7	5.45	48.0	512	474
Palolamuri	$\bar{x}$	1.21	1.64	5.30	1.90	0.83	48.8	12.7	4.71	47.3	613	264
	min	1.05	1.38	4.41	1.43	0.75	40.8	10.6	3.75	32.8	441	123
	max	1.38	1.93	6.11	2.39	0.89	61.1	15.5	5.77	56.6	883	442

followed by rapid death, as described above, has been observed in some places. The situation indeed bears close resemblance to that described by Valtanen (1970).

A POSSIBLE EXPLANATION

The symptoms described in the above are suggestive of a deficiency in nitrogen, or even more obviously in phosphorus. Since phosphorus is an important element for the energy metabolism of plants, a deficiency will usually lead to a decline in general condition and growth, and in the worst cases to rapid death, especially under severe climatic conditions. The typical symptoms of phosphorus deficiency in conifers are dwarfism, fragility of the stem and branches and an associated tortuous appearance. Other symptoms mentioned are exceptionally short needles and the occurrence of the first signs of withering at the tips of the one-year-old needles in the form of the adoption of a reddish colour in spring. In the worst cases the necrosis affects the whole of the previous year's leading shoot and the new buds, causing failure of the leading shoot. Such instances of phosphorus deficiency and its symptoms have been attributed to frost damage in spring (Baule & Fricker 1967, Reinikainen 1967, 1968, 1983, Binns et ale 198_ Raitio 1981). In the tree species found in Finland, a phosphorus deficiency will manifest itself in the form of symptoms only at the point at which it very obviously interferes with growth (Reinikainen 1983).

The preliminary results of nutrient analyses carried out on needle samples support the suggestivn of a nutrient deficiency made on the basis of the symptoms. Results for weakened saplings at two sites in the rural commune of Rovaniemi, Kuusikkolamuri and Tuiskukivalo, are presented in table 1. In both cases samples representing the youngest generation of needles were collected from pine saplings in ploughed forest regeneration areas in autumn 1983. The majority of the saplings at Kuusikkolamuri, which had been raised in containers or peat pots, have died, and all those still alive carry symptoms of the disturbance under discussion here. A lower proportion of the bare-root saplings planted at Tuiskukivalo have died, but many show abnormalities in growth.

For comparison, table 1 also includes the results of nutrient analyses on needles from a narrow strip of previously clear-cut forest lying between the spruce forest of Palolamuri and the forest access road, also in the rural commune of Rovaniemi. This site, which is located about 8 km west of Kuusikkolamuri, had not been subject to any preparation which broke up the surface of the ground and contained naturally seeded pine saplings which were normal in appearance and carried from 4 to 5 years' growth of needles.

As the aim was to analyse the samples for individual trees separately, it became necessary, especially at Kuusikkolamuri, to collect the needles only from the best trees in order to be sure of obtaining a large enough sample. It may also be mentioned that further samples gathered from Kuusikkolamuri in early spring 1984 gave similar nutrient content figures to those quoted here.

Data on the location, site type, soil type, year of felling, size of clear-felled area, soil preparation method, regeneration method, year of regeneration, seedling type and provenance for the Kuusikkolamuri, Tuiskukivalo and Palolamuri sites are presented in table 2.

The results of the analyses show the concentrations of the principal nutrients in the needles of the pines at the ploughed sites to be below the limits quoted in the literature for a state of deficiency, this being particularly true of phosphorus. The deficiency levels proposed by Paarlahti et al. (1971) for forests on peat soils, for instance, are 1.3 % for nitrogen, 1.4 %0 for phosphorus and 3.5 *%b* for potassium, and broadly similar figures are also given by Raitio (1978). In his analysis of principal nutrient concentrations in the needles or 'leaves of various tree species ,in forests of the Vaccinium myrtillus and Vaccinium vitis-idaea types, Aaltonen (1950) arrives at mean values of 1.33-1.39 % for nitrogen in pine needles, 1.57-1.61 %, for phosphorus, 5.8-6.1 % for potassium, 2.36-2.43 % for calcium and 1.33-1.50 %_ for magnesium. Similarly Norokorpi (1977) presents nutrient analysis results for a number of nitrogen-fertilized pine forests on mineral soils in Northern Finland and mentions

Table 2--Principal characteristics of the three sites studied

Characteristic \ Site	Kuusikkolamuri	Tuiskukivalo	Palolamuri
Location	Rural commune of Rovaniemi	Rural commune of Rovaniemi	Rural commune of Rovaniemi
Coordinates	66°20'N, 25°40'E	66°12'N, 26°00'E	66°20'N, 25°30'E
Height a.s.l.	210 m	195 m	165 m
Site type	moderately dry heath forest	moderately dry heath forest	moderately dry heath forest
Soil type	fine sandy till	sandy till	fine sandy till
Year of felling	1971	1972-73	-
Area clear-felled	50 ha	50 ha	-
Soil preparation	shoulder ploughing	tilt ploughing	unprepared
Regeneration method	planting	planting	natural
Year of regeneration	1972	1975-77	-
Seedling type	container and peat pot seedlings	bare-root seedlings	-
Provenance	Meltaus	Kemijoki	-

the concentrations in the needles of healthy trees as varying in the range 1.48-1.83 % for nitrogen, 1.5-1.8 ‰ for phosphorus and 5.0-6.4 ‰ for potassium. Correspondingly, the material compiled by Viro (1955) provides the following figures: nitrogen 1.64 %, phosphorus 1.8 ‰, potassium 4.5 ‰, calcium 3.2 ‰_ and magnesium 1.77 ‰. The values quoted above for phosphorus, and to some extent also nitrogen, in the needles of pines growing on mineral soils are very much higher than those recorded at Kuusikkolamuri or Tuiskukivalo as far as nitrogen and particularly phosphorus are concerned, whereas they show the results for the needles of the naturally regenerated pine saplings at Palolamuri to be around the normal level for mineral soils. This latter observation also serves to lend further support to the explanation proposed here. It should be noted that although the magnesium concentrations in the needles of the disturbed pines are low compared with the figures quoted in the literature, they are of the same order as those at Palolamuri.

PHOSPHORUS AS A PLANT NUTRIENT

Phosphorus is present in all plant cells as a structural component of nucleic acids, lipids and certain carbohydrates. In addition to its role in nucleic acids, its main function would seem to exist in the events associated with the storing and transfer of energy. Photosynthetic phosphorylation produces a number of high-energy compounds, the most important of which is adenosine triphosphate (ATP), which functions as an agent for the direct transfer of energy in plants. Consequently a phosphorus deficiency will be reflected in the whole metabolism of the plant (Halstead & McKercher 1975).

Phosphorus exists in the soil in both organic and inorganic form., the proportion of organic phosphorus varying in the range 15-80 %. The major part of the organic phosphorus is contained in inositol phosphates, and smaller amounts in phytine, nucleic acids and phosphatides. It is made available to the plant through the medium of micro-organisms. The principal inorganic forms are primary apatite phosphorus and secondary phosphorus bound chiefly to iron and aluminium compounds. These _gain require the action of micro-organisms to effect their mobilization (Alexander 1977, Amberger 1979, Mengel 1979, Mengel & Kirkby 1979). Plants extract phosphorus from the soil in the form of phosphate anions, an active process that in itself requires energy (Raitio 1983b).

Since phosphate and molybdate anions resemble each other in their chemical properties, it may be that pine saplings in ploughed areas also suffer from a deficiency in molybdenum, an essential element for the nitrogen and phosphorus balance in plants.

REASONS FOR THE PHOSPHORUS DEFICIENCY

The following factors may have contributed to the phosphorus deficiency encountered in Scots pine saplings from. ploughed forest plots:

- a reduction in the thickness of the humus layer and chemical changes in the humus,
- an increase in poorly soluble inorganic phosphorus compounds in the soil,
- a decline in microbiological activity in the soil,
- weakened condition of the root systems of the trees,

- binding of nutrients in the soil-acidifying surface vegetation, and
- leaching of nutrients.

Reduced Thickness Of The Humus Layer And Chemical Changes

The formation and decomposition of humus under natural conditions is a slow process in the dry or moderately dry heath forests of Northern Finland, and it is possible that even clear felling alone may accelerate humus decomposition, at least at first, not to mention disruptive soil preparation measures. This would of course lead to a reduction in the reserves of organic phosphorus and nitrogen in the soil, and also other nutrients. This effect would then be accentuated further by the elimination from clear-felled areas of the plants that tend to bind the major nutrients, produce beneficial litter and form humus, notably birches. Any chemical changes in the humus layer or reduction in its thickness in ploughed areas can be expected to have repercussions for the survival of saplings growing there, as may be seen from the fact that the humus layer was thinner around the dead saplings examined in areas of artificial forest regeneration in the early 1970's than around those which were still in good condition (Lähde & Siltanen 1973), and also the fact that saplings planted on the shoulders of ploughed _furrows, where there is practically no humus, fared worse than those planted on the tilts (Valtanen 1970). It would also appear that the humus buried beneath the tilts, where there is a "double humus layer", probably decomposes, becomes compressed or undergoes chemical changes within a relatively short space of time. The reduction in humus in ploughed areas and its chemical transformation may well give rise to a variety of disturbances in the nutrient balance of the saplings, among which the shortage of phosphorus would seem to be crucial at the early stages on account of the chemical properties of the phosphate anions and the major role which this nutrient plays in the energy balance of plants, since the adequacy of the supply of phosphorus seems to determine whether the plants can make full use of the other essential nutrients.

Increased Poorly Soluble Inorganic Phosphorus Compounds In The Soil

According to the observations of Kaila (1963) the largest amounts of inorganic phosphorus in podzol soils were to be found in the illuvial horizon and the subsoil, with very much smaller amounts in the raw humus and least of all in the eluvial horizon. The majority of that in the illuvial horizon was bound in the form of iron and aluminium phosphates, while that in the subsoil largely consisted of calcium phosphate. The same author also found by far the highest iron and aluminium concentrations in the illuvial horizon.

The result of ploughing in clear-felled areas is that the tilts have their illuvial horizon on the top and the eluvial horizon beneath it, with some mixing between them. Below these lie the "double humus layer" and then the original podzol profile. Thus the saplings planted on the tilts have their roots in the illuvial horizon at first, where according to Kaila (1963) the major proportion of the inorganic phosphorus should be located, bound as phosphate in iron and aluminium compounds. On the other hand, measurements made by Kubin (1983) in HMT spruce forests indicate that the highest proportion of phosphorus in soluble form is found in the raw humus, which would suggest that a sufficient supply of this nutrient should be available at the early stages after clear-felling and ploughing, but that later, as the humus in the intermediate surfaces of the furrows and in the buried layer undergoes chemical change and decomposes, the amounts of phosphorus available to the plants may decrease. It should be noted too that the metal ions in the soils of ploughed forest areas, and particularly those in the illuvial horizon which occupies the surface position in the tilts, are capable of binding phosphorus mobilized from organic material and other sources in the form of poorly soluble compounds as the soil becomes more acid (Troedsson & Nykvist 1973). Thus, although total phosphorus reserves in the soil may not be depleted as a result of clear-felling and ploughing, the increase in poorly soluble inorganic compounds and decrease in soluble inorganic and organic compounds may restrict the availability of phosphorus to the saplings.

Decreased Microbiological Activity In The Soil

One major mycorrhizal function is the taking up of inorganic phosphorus compounds and organic phosphorus from the soil and the mineralization of these for utilization by the host plants (Alexander 1977, Kelly et ale 1983), and other micro-organisms_ mainly ones existing on the surfaces of plant "roots, also utilize inorganic phosphorus:, transforming it into organic form and releasing some of the excess poorly soluble inorganic phosphorus in the form of phosphate. At least tricalcium phosphate, i.e. apatite phosphorus, and the phosphates of iron, aluminium, magnesium and manganese are subject to this action of micro-organisms (Alexander 1977, Amberger 1979). Many micro-organisms require organic substances to enable this solubilization to take place, and are then capable of decomposing carbohydrates in the soil and releasing sugars and organic acids (Dalton et ale 1952, Bradley & Sieling 1953). Many of the sugars_ e.g. glucose, fructose, galactose and maltose, and organic acids, e.g. citric acid, tartaric acid, oxalic acid and ascorbic acid, react with metals such as iron and aluminium to form organometallic molecules or ions, releasing the phosphate bound by these metals. Dalton et ale (1952) look on this as the plants way of ensuring a supply of available phosphorus.

Extreme climate or soil conditions, any decrease in the humus layer or alteration in its chemistry, compaction of the soil in the tracks left by ploughing, or any other changes of this kind may reduce the microbiological activity in the soil of ploughed areas with time, and this can easily lead to a slowing down in the mobilization of phosphorus and a depletion of the phosphorus balance of pine saplings.

Condition Of Root Systems

If pine saplings in ploughed areas do not have enough energy-rich compounds available they will not manage to produce sufficient carbohydrates to maintain growth in their own root systems, and particularly in the mycorrhizal parts. If this is the case the condition of the root system will suffer and the uptake of phosphorus and other nutrients will become more difficult. The phosphorus requirement of the roots alone is known to be considerable in all plants (Mengel & Kirkby 1979).

Clear-felling, ploughing and soil pH changes are all likely to lead to an increase in the solubility of metals in the soil, which in turn may restrict the uptake of nutrients by pine saplings, since high concentrations of metal ions can damage the meristematic cells at the root tips (Clarkson 1969, Abrahamsen & Tveite 1983). The toxic effects of aluminium, for example, are observable first of all in the roots of plants, where they resemble phosphorus deficiency symptoms in the aerial parts (Foy 1974, Bergmann & Neubert 1976, Woolhouse 1983).

Soil compaction, e.g. upon decomposition of the organic material, large fluctuations in moisture content or temperature, or any other marked changes in physical growth factors are also likely to affect the root systems of saplings growing in ploughed areas. In addition, saplings raised in paper pots in containers may suffer from the slow rate of decomposition of the paper pots themselves and the competition which arises between the saplings growing in the same container, both of which factors may have a detrimental effect on their root systems and nutrient uptake.

Binding Of Nutrients In The Ground-level Vegetation

One typical element in the flora of the dry and moderately dry heath forest types of the Peräpohjola region and Forest Lapland is ling, Calluna vulgaris, while other field-layer species normally include the bilberry, Vaccinium myrtillus, crowberry, Epetrum nigrum, bog whortleberry, Vaccinium uliginosum, and red whortleberry, V. vitis-idaea. Like the trees, these plants are able to ensure an adequate supply of nutrients within these forest types by virtue of their mycorrhiza. Forest regeneration by artificial means, employing clear-felling and ploughing, gives rise to extreme soil and climatic conditions, an effect which becomes more serious the poorer the site is in nutrients and the harsher are the climatic conditions. At the same time, any reduction or chemical change in the humus layer, acidification of the soil, binding of nutrients in a poorly soluble form or leaching will lead to further impoverishment of the site. One consequence of this would seem to be a decline in the cover of the Vaccinium species and often a spread of the structurally more xeromorphic species with a more efficient endomycorrhiza of the "ericoidal" type, chiefly Calluna and etrum. According to Read (1983), Calluna is able to survive in acid soils on account of its mycorrhiza, which enables it to make efficient use of the available reserves of organic nitrogen and phosphorus. Thus it is able to bind large quantities of nutrients, particularly in its underground parts.

Calluna and etrum in turn form an acid forest litter with a low nutrient content, while the acidification of the soil leads to increased solubility of metals and a tighter binding of phosphorus, effects similar in direction to those brought about by "acid rain" (Ulrich 1983). The binding of phosphorus to metals and to the acidifying ground-layer vegetation, principally Calluna, may cause a disturbance in the phosphorus balance of the pine saplings in ploughed areas. The increased solubility of metals does not restrict the growth of the ling itself, however, since this species is efficient in its uptake of phosphorus and presumably continues to obtain it in adequate amounts, in addition to which it has been shown to bind at least aluminium, copper and zinc from the soil by virtue of its mycorrhizal action, thereby protecting the growing shoot from the toxic effect of such metals (Bradley et al. 1981,1982, Read 1983). Acidification of the soil may also be one reason for the invasion of ploughed forest areas by Deschampsia flexuosa, which according to Hackett (1964) will tolerate a low pH and high aluminium content in the soil. Similar the experiments of Rorison (1969) show that Deschampsia will thrive well in a growth solution containing only low concentrations of phosphates. It also appears that the ploughing tilts and shoulders of the furrows are invaded within a short time by polytrichum commune (Ferm & Sepponen 1981), which like Calluna and etrum seems to do little to break up the soil or form humus.

It would thus appear that regeneration of the poorer forest types of Northern Finland by clear-felling and ploughing under extreme climatic conditions may lead to a long-term depreciation of the sites as far as forest growth is concerned as a consequence of "heathification", i.e. invasion by Calluna.

Leaching Of Nutrients

Clear felling and site preparation stimulates not only the mobilization of nutrients but also their leaching out of the surface horizons. Phosphorus is admittedly less prone to leaching than some other nutrients, e.g. nitrogen, since phosphate anions become efficiently bound to metals (Anti kainen 1977), but the losses are still considerable in view of the cold, humid climate. The material published by Kubin (1984) demonstrates that the phosphorus content of the run-off water from a ploughed pine forest regeneration site at Kivesvaara in the commune of Paltamo in spring was very much higher for eight years after clear felling and site preparation than it was in the next three years after that. Thus leaching may play its own part in disturbing the phosphorus balance of the trees in ploughed pine forest regeneration areas.

SUMMARY

After good initial development, pine saplings growing on ploughed areas in Northern Finland have been observed to, suffer from retarded vertical growth and a weakening in condition in some places about 8-15 years after planting, leading to their death within a short time. Typical symptoms are fragility of the stems and branches, short needles and small number of annual needle crops.

The symptoms observed and the results of preliminary nutrient analyses on needle samples suggest that the reason for the sapling deaths may lie in a deficiency in phosphorus, and to some extent also nitrogen (cf. Pohtila & Pohjola 1983), the effects of which are accentuated in many ways by the severity of the climate. This climatic influence becomes most marked at the point at which the saplings begin to extend above the surface of the snow in winter, as this evidently imposes the severest strain on their energy balance, i.e. phosphorus metabolism. An adequate supply of phosphorus is also needed to enable them to make full use of the other nutrients available. The demise of saplings which have been weakened by nutrient deficiency is further hastened by mechanical snow damage in winter and by various diseases.

The poor phosphorus balance in the saplings may be attributed to a number of interrelated factors, the most important of which would seem to be the reduction in the thickness of the humus layer and changes in its chemistry, the increased proportion of the phosphorus present in the soil in the form of poorly soluble inorganic compounds, a decline in microbiological activity in the soil, the poor condition of the root systems and the leaching of nutrients and their binding to a soil-acidifying ground-layer vegetation.

The Kuusikkolamuri site examined here had originally been of the moderately dry heath/forest type with spruce dominant. The area is located above the highest shoreline of the Baltic and possesses a highly podzolized till soil containing large amounts of fine material. The climatic conditions are humid and typical of hill locations. The Tuisku-kivalo site is similar in its soil and climatic conditions, and clear felling has taken place over extensive areas of both hills. The majority of the saplings planted at Kuusikkolamuri, which had been raised in containers or peat pots, have now died, and those still alive carry evidence of the growth disturbance described here. The bare-root saplings planted at Tuiskukivalo have survived somewhat better, but some show signs of abnormal growth. It should be remembered, however, that planting took place 3-5 years later here than at Kuusikkolamuri. The Palolamuri site represents the same moderately dry heath forest type as at Kuusikkolamuri but lies about 45 m lower down. Here the forest has regenerated naturally on unprepared land in a narrow strip between a spruce forest and the access road. Presumably for pre-cisely these reasons, needle samples from the pine saplings at Palolamuri show higher phosphorus concentrations than those from either of the ploughed artificial rageneration sites. The sapling deaths reported in the 1960's similarly occurred at sites with a compacted till soil which had previously supported spruce forest (Lahde 1971, Norokorpi 1971).

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THE EFFECT OF DENSITY ON THE DEVELOPMENT OF SAPLING STANDS IN NORTHERN FINLAND

Martti Varmola

ABSTRACT: Results of 11 thinning experiments in naturally regenerated Scots pine sapling stands in northern Finland are presented. Thinning had no effect on the growth of dominant trees. Branches grew thick and crown ratio remained large as the result of wide spacing. Density before thinning had a strong effect on branch growth.

BACKGROUND

Natural regeneration was the main method of regenerating forests in northern Finland up to the 1950's. Only in the 1950's did more intensive forestry make artificial regeneration popular. However, natural regeneration has been and will always be very important when regenerating forests in the whole of Finland and especially in Lapland.

Before intensive forestry, selection felling was the main method and forests regenerated mainly on their, own without any active measures. As the result of the studies of Prof. Sarvas (1950) seeding and shelterwood fellings became the main felling methods when using natural regeneration in Scots pine forests. Nowadays seeding felling with 50-100 seed trees/ha is the main practice, often' being combined with light site preparation.

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In northern Finland there are many sites where natural regeneration is a very secure way to regenerate forest, for example on dry sorted mineral soils.

The main problem with natural regeneration in Lapland is the rarity of good seed years. In this century there have been only a couple of years when a good seed crop has been obtained as far north as, the timber line. At the Arctic Circle, for example, a good seed crop can be expected every 15th year.

In spite of the difficulties in natural regeneration we have a lot of naturally regenerated young forests, which are an important resource for future saw timber, but only if treated well. This report demonstrates some results of thinning experiments in such young stands. Special attention is paid to the effect of density on the stand and quality characteristics.

MATERIAL

The material consists of 11 naturally regenerated Scots pine stands in different parts of northern Finland (fig. 1). These stands have grown untreated

Table 1--General information of the material

Number of stand	1	2	3	4	5	6	7	8	9	10	11
Latitude	66°11'	66°58'	67°12'	68°53'	66°53'	66°16'	66°27'	66°58'	66°58'	66°58'	66°26'
Longitude	26°48'	29°02'	24°13'	28°09'	25°03'	27°20'	25°22'	24°47'	24°47'	24°47'	25°49'
Height above sea level, m	210	220	200	160	140	210	115	160	160	160	160'
Site index (H_{100})	18	19	19	20	17	22	19	19	18	19	20
Unthinned plots, stems/ha	6,300	10,400	10,000	7,500	10,000	6,300	2,800	5,200	4,600	2,100	4,000
Number of plots	18	18	12	18	18	6	11	12	13	14	13
Year of thinning	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1976
Breast height age at thinning	39	18	22	19	34	23	30 1/	47 1/	47 1/	47 1/	41 1/
Dominant height at thinning, m	8.6	4.2	6.1	4.2	8.0	-	6.8	4.5	4.6	4.3	-
Year of measurement	1980	1982	1982	1982	1982	1982	1979	1979	1979	1979	1981

1/Total age

until the thinning at the sapling of pole stage. In six stands the thinning schedule has been the same: 625, 1111, 1600, 2500, 4444 stems/ha and unthinned. In these stands the density before the thinning varied from 6500 to 10500 stems/ha. In other stands the thinning schedule has varied so that often the thickest alternative is lacking because of the wider spacing (3000-5000 stems/ha) before the thinning. Replications in a stand vary from one to three, three being the most common. The area of a plot has usually been 0.25 hectare. A general description of the experimental stands is in table 1.

Six stands_ those with the equal thinning schedules, were thinned in 1972. Height and last year's height growth of trees before and after the thinning as well as some characteristics concerning health were measured. These stands were remeasured in 1982. In other stands the starting point, i.e. the situation after the thinning was examined more closely. Dbh of all trees and the height of sample trees were measured in order to make possible de--termination of the usual stand characteristics. These stands were remeasured 5 to 7 years later.

In addition to the normal sample tree measurings in remeasurement, some quality-describing measurings were made, such as the diameter of the thickest living and dry branch, the crown limit, and the length of the fully pruned part of the stem. Technical quality and health were classified. In stands with. a growing period of 10 years, diameter and height increment for the last 5 years were measured for a part of the sample trees. Site indexes were measured according to Hägglund (1976).

The stand characteristics were determined for all trees and also for the 500 thickest trees/ha, which will form the most valuable part of a stand in the final felling.

RESULTS

The effects of thinning are discussed as the results of different stand and quality characteristics at the time of the remeasurement. Because the stands

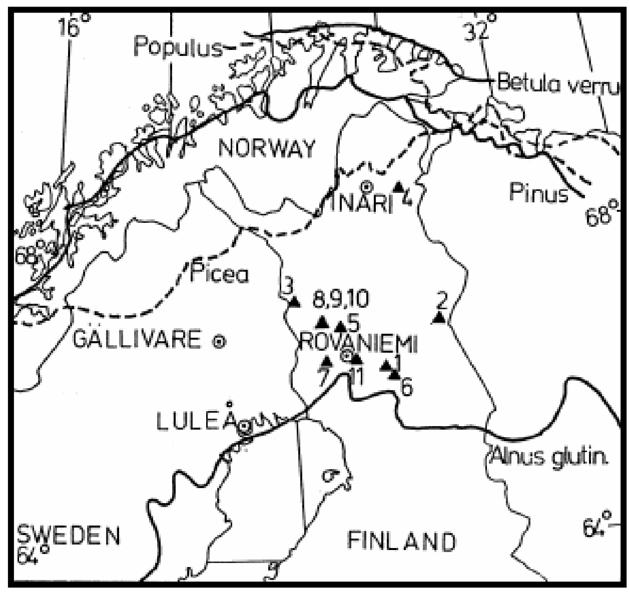

Figure 1.--Location of the stands and tree lines for some species (according to Kalliola).

were quite homogenous, it is assumed no signify-cant differences existed at the time thinnings were made. Thus possible differences in growth, for example, are expected to be affected by dif-ferent spacings after the thinning.

Stand Characteristics

The dominant height (the mean height of the 100 thickest trees/ha) is not affected by the thinning intensity (fig. 2). No clear tendency can be seen in the dominant height when the density changes from 625 stems/ha to unthinned (> 6000 stems/ha). The slight differences may be due to microchanges in the site. This result is consistent with other investigations, in which no differences can be seen in height growth with different spacings (Parviainen 1978, Varmola 1980).

Even the dominant diameter (the mean diameter of the 100 thickest trees/ha is the same in different spacings 5 to 10 years after the thinning (fig. 3).

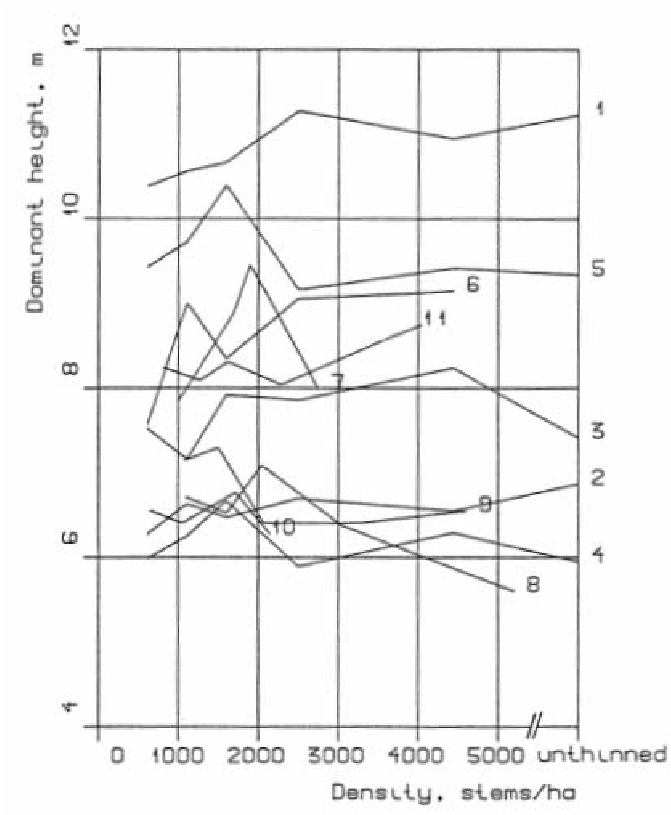

Figure 2.--Dominant height at the time of remeasurement as a function of stem number (numbers in figure mean different stands).

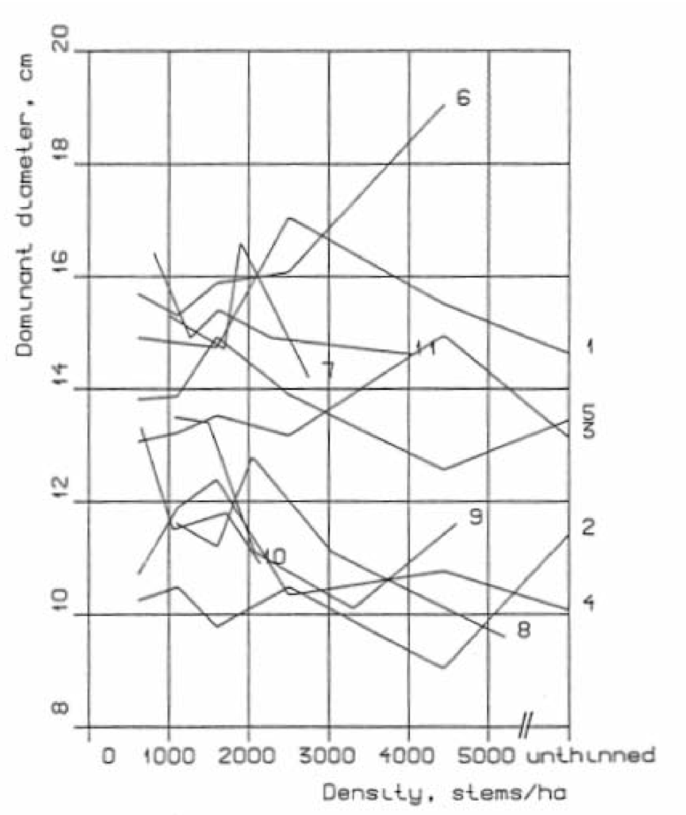

Figure 3.--Dominant diameter at the time of remeasurement as a function of stem number.

It seems the dominant trees have gained no advantage from wide spacing. In other words, the dominant trees can, keep their growth rate constant even with very dense spacing.

The volume growth of the basic trees is illustrated by the 500 thickest trees/ha. These basic trees will probably be left in the final cutting and thus form the most valuable part of the stand. Volume of these basic trees at the time of remeasurement is presented in figure 4. Even here no clear difference can be seen between different spacings. This indicates that the largest trees can maintain constant growth in different conditions.

The volume of all trees is presented in figure 5. There is a clear increase in volumes up to 2500 stems/ha, but after that the increase in volume is insignificant with increasing stem number. More important than the total volume is the amount of commercial wood. At the time of the remeasurement only some stand, nos. 1,5 and 6 were near to the first commercial thinning_ When looking at stands 1 arid 5 (fig. 6), it can be seen that the most suitable growing density depends on the requirement for the dimensions of the commercial wood. The peak at 'a spacing of 2500 stems/ha in the stand no. 1 and the dip at a spacing of 4444 stems/ha in the stand no. 5 are not real but due to the more favourable or unfavourable conditions in the site. Thus; generally, the smaller the requirements as to the dimensions of the commercial wood, the thicker a stand can be grown. Normally, if very large dimensions are required, wide spacing is necessary, too. It seems, however, that in these stands the amount of large-dimensioned wood (> 14..5 cm) is quite constant in different spacings.

Quality Characteristics

In Finland the quality of Scots pine saw timber is nowadays much discussed. It is said Lappish timber is of high quality and that this is due to the slow growing rate which usually means structural strength and thin branches.

The quality of a stem is determined by the root stock i.e. the first 4-5 m of the stem, which forms 2/3 of the value of a stem. When all the branches have died on this part of the stem, only a slight improvement in quality is possible. Thus the youth of a stand is the most important stage when determining the future quality.

The diameter of the thickest branch has been Found to be a good measure of the timber quality (Heiskanen 1965). For example, high-quality timber cannot be expected from stems with branches of more than mm. On the other hand, when the

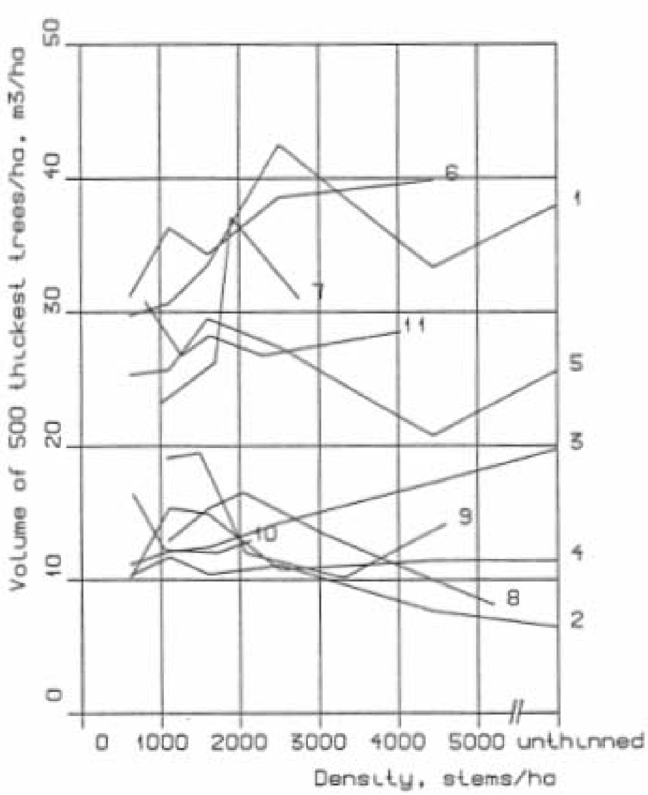

Figure 4.--Volume of the basic trees (500 thickest/ ha) at the time of remeasurement as a function of stem number.

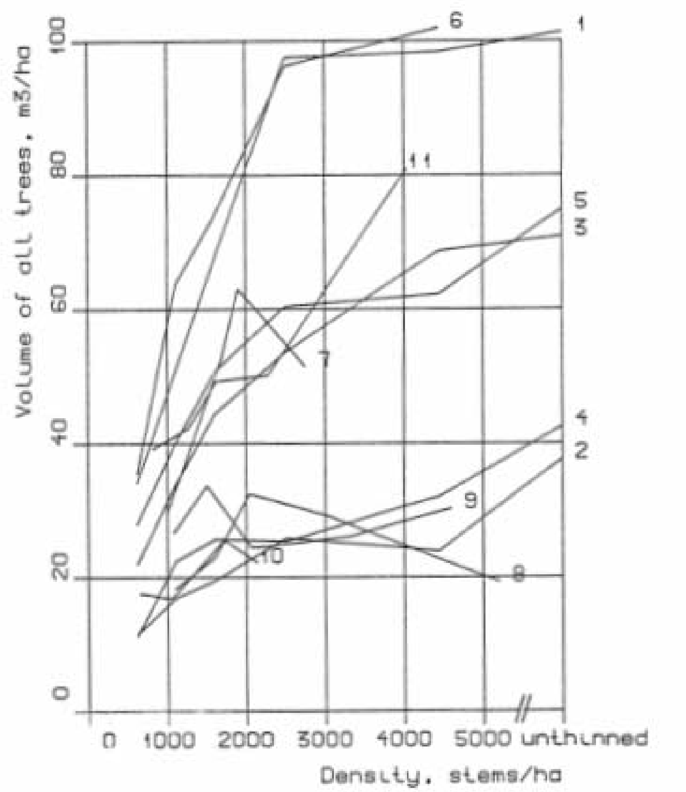

Figure 5.--Volume of all trees at the time of remeasurement as a function of stem number.

diameter of the thickest branches is over 30 mm, a tree is not even suitable for a green pruning in order to artifically improve the quality.

The mean of the diameters of the thickest green branches on the root stock with the 500 thickest trees/ha at the time of the remeasurement is presented in figure 7. A clear grouping of stands an be done according to the branch diameters. The one group with a dense spacing before the thinning (stands nos. 1-6) has very thin branches. The branch diameters are quite equal at the densities of 2500 and more, but when the density is smaller the diameters tend to increase. The increase is, however_ quite slow except in the. stand no. 6, where a remarkable increase in the diameters of branches can be seen in wide spacings. This can be du_ to prescribed burning_ which has caused a kind of long-term fertilization and thus a richness in nutrients in this stand. The other group (stands nos. 7-11) had before the thinning noticeably thicker branches, which is due to wider spacings. In these stands there is great variation between different spacings. On an average, even here thinner density. has caused thicker branches.

Altogether, a very dense spacing at the sapling stage is required in order to produce high quality stems.

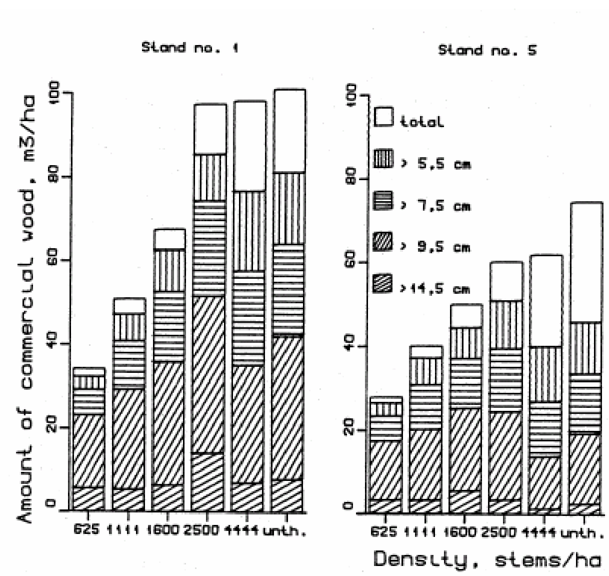

Figure 6.--Amounts of commercial wood with different dimensions as a function of stem number in stands no. 1 and 5.

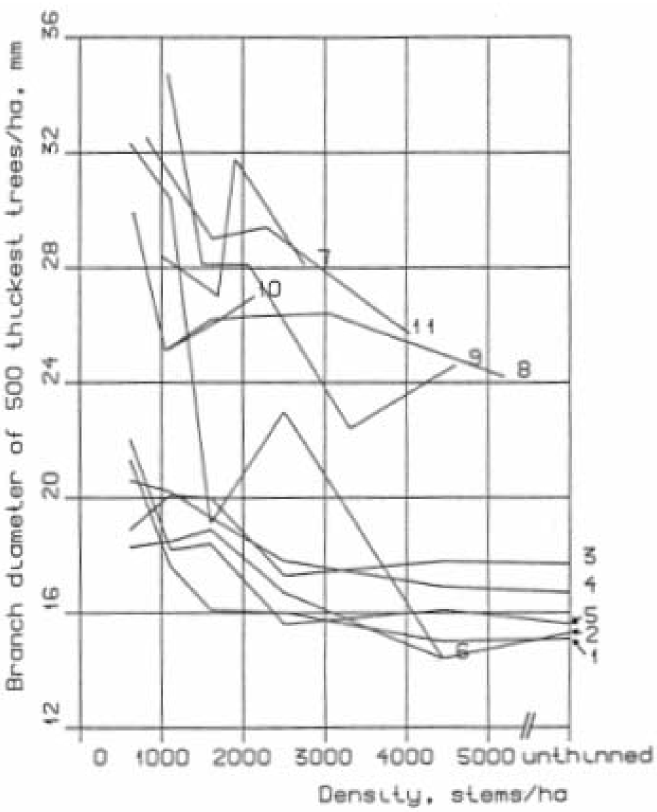

Figure 7.--Mean of the diameters of the thickest green branches on the root stock with the 500 thickest trees/ha at the time of remeasurement as a function of stem number.

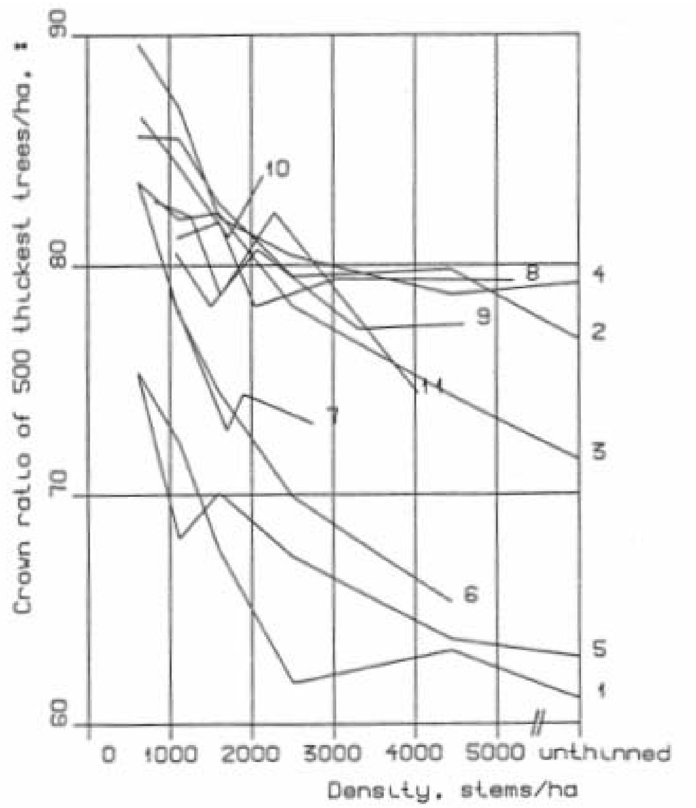

Figure 8.--Mean of the crown ratios for the 500 thickest trees at the time of remeasurement as a function of stem number.

The crown ratio at the time of the remeasurement for the 500 thickest trees/ha is presented in figure 8. The crown ratio of these basic trees is quite equal to that at densities of 2500 and more, and is larger the wider spacing. is. In trees with the widest spacing (625 stems/ha) probably no branches have died in the 10 years after thinning.

Only in stand no. 1 are the crown limits at the height of about 4 m, i.e. the branches have died on the root stock. In the other stands branches are still growing on the root stock and the differences between the different spacings will become larger.

DISCUSSION

The growth of the basic trees has not been affected by the thinning intensity. The dominant height and the dominant diameter are equal in all spacings from 625 to unthinned (= 10000 stems/ha) at the time of remeasurement. Even the volume of the basic trees is the same in various spacings. It seems no advantage in the form of accelerated growth in the remaining trees can be gained with the thinning. The reasons for this phenomenon are many.

First, in a naturally regenerated stand there are always openings, especially under the seed trees. The dominant trees often have space to grow towards these openings. Secondly, the trees are of varying age, because they have been born in dif ferent seed years. Thus the stand is uneven, too, and there is quite a large variation in heights, though these stands are not multi-layered. However, the dominant trees are the highest ones and can grow well because they have very little competition. Thirdly, the soils suitable for natural regeneration are so barren that a great reaction to thinning simply cannot exist.

The effect of thinning can be seen in the quality characteristics. In wider spacings the branches are growing thick and the crown remains long.

The results give many alternatives to a forest manager. Stands can be thinned at the normal time (when the dominant height is about 4 m). On the other hand, stands can stay unthinned up to 7-8 m and nothing is lost in the growth of the most valuable trees, and the technical quality will be high, too.

The density after thinning seems to be less important for branch growth. It is more important to grow a stand dense, i.e. nearly 10000 stems/ha up to the dominant height of 6 m if high quality is required.

There is no clear advantage in overdensity after thinning. It seems that when the density is over 2500 stems/ha, no real benefit can be reached in he technical quality and the increase in volume is insignificant. If large dimensions are required, a thinner density will be more suitable.

All the results concern a growing period of no more than 10 years after the thinning. The more precise results can be obtained when the first commercial thinnings are made, which means in northern Finland at a dominant height of 11-13 m.

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RESEARCH ON NATURAL SECONDARY FOREST IN HEILONGJIANG PROVINCE--KOREAN PINE-DECIDUOUS FOREST RECOVERY

by

Chen Da-Ko, Zhu Ning et. al

INTRODUCTION

Since 1903 large areas of the primary forest in Heilongjiang Province have been repeatedly destroyed by indiscriminate cutting, fires, grazing, and land conversion. Since that time, natural regeneration has taken place on these areas. The original plant community which included Korean pine has been replaced by various secondary plant communities.

THE SIGNIFICANCE AND PURPOSE OF PLANTING CONIFERS AND CONSERVING DECIDUOUS TREES

During the past twenty years, experience and research with the naturally regenerated secondary forests of Heilongjiang Province have demonstrated that the most desirable management of these areas is to plant conifers while conserving deciduous trees. Planting conifers, mainly Korean pine and preserving the naturally regenerated deciduous trees best establishes the mixed conifer-deciduous forest typical of the region.

This method of reforestation is important in the following:

a. Introduce conifers while conserving deciduous trees, conserving deciduous trees is a reliable way to guarantee the rapid establishment of the zonal climax forest.
b. Conifers "attract" the deciduous trees.
c. The planting of conifers permits the selection and retention of the most desirable deciduous tree.
d. The planting of conifers shortens the time required for forest regeneration.

THE RATIONALE FOR PLANTING CONIFERS AND CONSERVING DECIDUOUS TREES.

1. phylogenesis and floristic elements.

The mixture of Korean pine-deciduous trees retains the characteristics of the zonal climax community which occurs naturally in this region. The various members of the forest community typically include Tilla spp., Betula spp., and a number of herbaceous plants. The synecological relationships of members of the forest community are shown in Figure 1.

Komarov (1897, 1917, 1922) reported that the forest in Manchuria,' in its natural state, was mainly composed of conifers, with deciduous trees accounting for less than 30 percent. Any increase or decrease in the proportion of deciduous trees in the predominantly Korean pine forest was due to successional age of the forest. So the harmonious relationship between the Korean pine and its accompanying deciduous trees provides the basis for this management approach.

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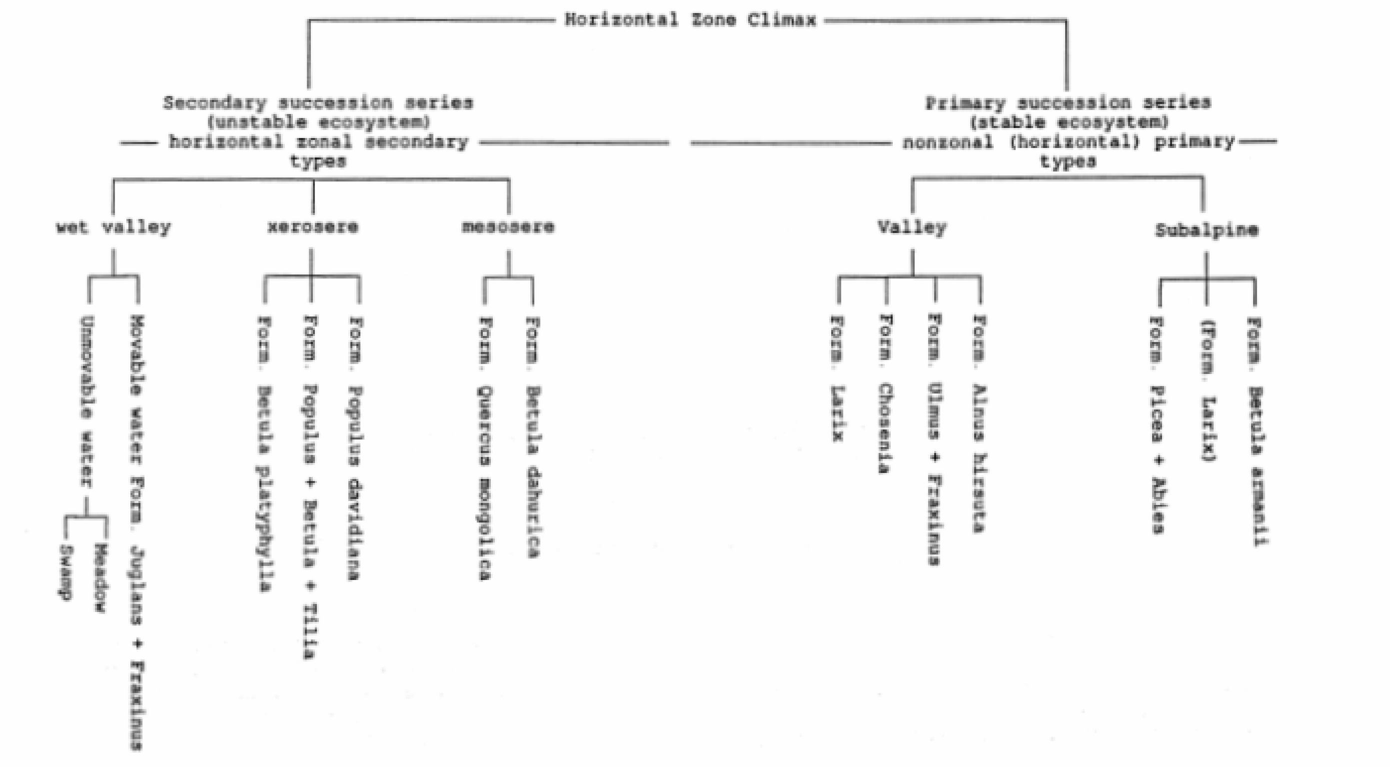
Figure 1.--Temperate Mixed Conifer-Deciduous Forest (The region of Korean pine forests).



2. Convergence and divergence of vegetation.

Since the end of the last century, the disappearance of large areas of Korean pine, due to the extensive effect of human destruction, has caused diverse plant communities to develop on bare land (see figure 2).

3. Succession and climax.

We predicted 20 years ago that the secondary forest in Heilongjiang Province would develop from the pioneer to the mesic stage of hardwoods and ultimately result in the zonal climax community. Studies have shown that closing a damaged hillside to use greatly enhances reestablishment of the mixed Korean pine/deciduous tree forest. The climax adaptive number and continuum index of various forests are shown in order in Tables 1 and 2 and on Figure 3.

4. Disturbance and stability.

The stability of the mixed Korean pine and deciduous tree forest was determined by measuring the increase and decrease of the deciduous trees and the succession of the Korean pine itself. The climax steady state of the primary Korean pine forest provided the basis by which the degree of disturbance of four types of forest ecosystems could be measured. This in turn permitted us to determine:

a. the ability of the forest to withstand disturbance;
b. the amount of protection against disturbance required in the naturally regenerated secondary forest;
c. the necessity and the degree to which conifers should be planted in the secondary deciduous forests (fig. 4).

Figure 5 provides a comparison of the diversity index of a number of representative types of communities as calculated by Shannon’s formula. It can be seen that the recovery ability of secondary forests in Heilongjiang Province has increased. This recovery confirms the fundamental ecological principle of "diversity leads to stability." This principle is an important aspect in the recovery of the productivity of woodland by planting conifers while conserving deciduous trees (fig. 5 and table 3).

5. R-strategy and K-strategy.

There are two patterns of evolution and adaptation among trees or plants in the secondary forest: r-strategy and k-strategy. In this paper, trees in secondary forest succession are divided into three

Table 1.--The Climax Adaptive Number of Each Tree*

Species	Sr	Pd	Ph	Bp	Jm	Ti	Bc	U	Am	Fr	Qm	Fm	P
Climax Adaptive Index	1.2	2.0	3.4	3.8	5.2	7.6	6.5	6.2	7.5	6.4	8.0	5.0	1

*Abbreviations used in the table are defined as follows:

Sr - Salix raddeana
Pd - Populus davidiana
Ph - Phellodendron amurense
Bp - Betula platyphylla var. mandshurica
Jm - Juglans mandshurica
Ti - Tilia spp.
Bc - Betula costata
U - Ulmus spp.
Am - Acer mono
Fr - Fraxinus rhynchophylla
Qm - Quercus mongolica
Fm - Fraxinus mandshurica
Pk - Pinus koraiensis

Figure 2.--The Convergence and Divergence of Secondary Forests

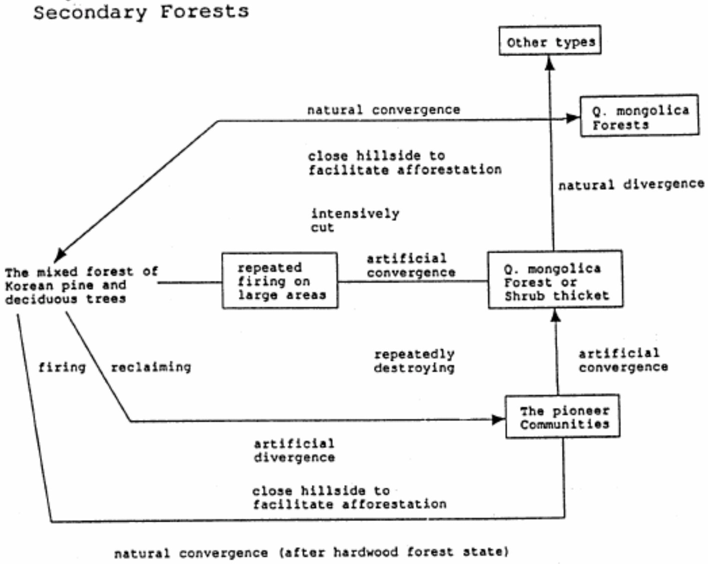


Table 2.--The Continuum Index of Each Secondary Community.

Community types	Continuum index	The distance from Korean pine forest
1.	1980.1455	23.7545
2.	1974.448	29.452
3.	1855.27625	148.6237
4.	1790.344	213.556
5.	1728.366	275.534
6.	1723.263	280.637
7.	1599.912	403.988
8.	1524.09	479.81
10.	1502.387	501.513
11.	1418.026	585.874
12.	1157.934	845.966
13.	1024.1175	979.783
14.	899.263	1104.637

Table 3.--Diversity Index of Trees in Every Community Type.

Community Number	Main Story H'	Succession Story H'	Regeneration Story H'	Subcompartment H
1	0.386	0.319	0.510	0.613
7	0.339	0.402	0.583	0.653
3	0.403	0.436	0.592	0.702
14	0.333	0.246	0.616	0.716
4	0.380	0.359	0.460	0.534
15	0.151	0.270	0.385	0.513

groups according to their bionomic strategy: r-strategy, k-strategy, and intermediate types.

R-strategy species include such species as Populus, Salix, and Betula. Their climax adaptation index as shown in Table 1 is less than 4.

K-strategy species include such climax adaptive species as Pinus koraiensis, Quercus monolica and Acer spp. Their Climax index is greater than or equal to 7.5. These species are florogenetically closely related; all are of the continental type in the phylogenesis of the Korean pine forest.

Intermediate types include the following species: Fraxinus mandshurica, Juglans mandshurica, Ulmus spp., and Betula costata. These are considered to be in the regenerative dominancy, which we term the hardwood forest stage of secondary forest development. Their climax indices are greater than 3.8 but less than 6.5.

Although we feel that closing the access to a hill side facilitates afforestation, the secondary forest may advance more rapidly to the zonal climax through the forests bionomic strategy and by planting conifers while conserving deciduous trees.

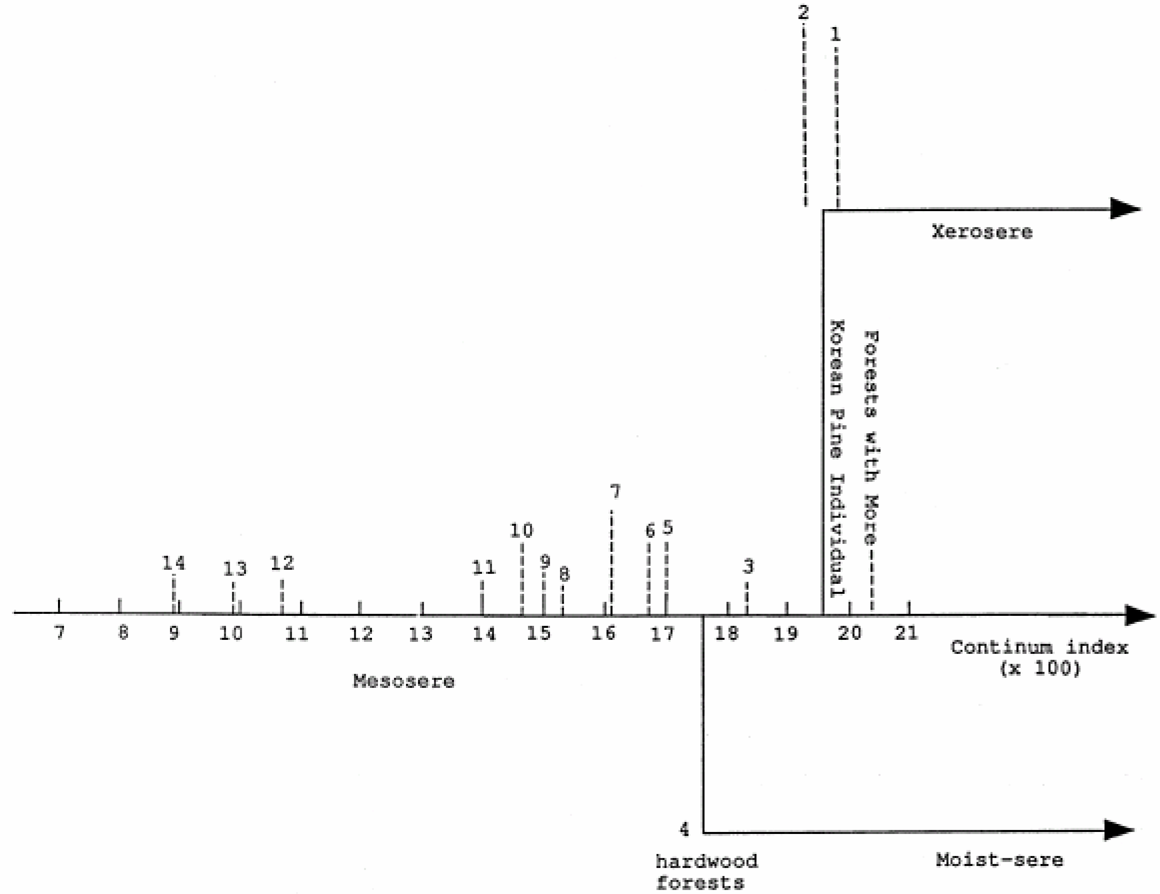


Figure 3.--Community Position on a single axis Ordination Diagram

We call management based on the dynamics of vegetation a "dynamic management system." This system is developed in three stages, as follows:

a. pioneer stage

R-selected species dominate. The secondary forest is the pioneer stage, and its development is controlled by ecological selection. The silvicultural principle applicable at this stage should be planting conifers and preserving deciduous trees. The preservation of all deciduous trees is favorable to the rapid renewal of vegetation.

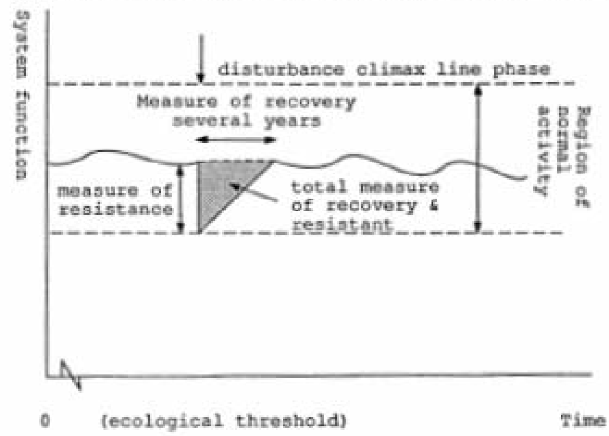
b. Transition stage

Under the control of biological selection, interspecies competition and adaptation are restricted by the bionomic adaptation strategy. Some intermediate types gradually invade the stand. During the transition stage, the silvicultural principle should be to manage in order to especially "attract" deciduous trees. Although many deciduous trees may reseed themselves naturally, it is important that the site be as receptive to those species as possible in order that there be sufficient numbers of deciduous trees for selection during the next stage of reforestation.

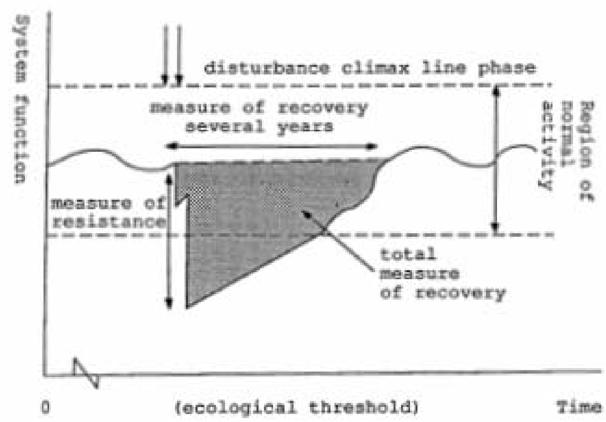
c. Succession stage

In this stage, the species establishing themselves on a reforested site have begun to interact as a plant community under the influence of syneclolgical selection. At this stage, selection of the deciduous trees is important, thereby preserving all the valuable deciduous species and increasing their selective, adaptive ability.

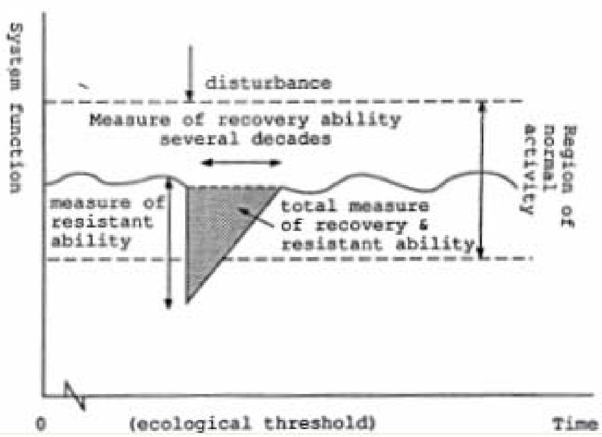
Figure 4.--Disturbance and Stability of Various Forest Types.



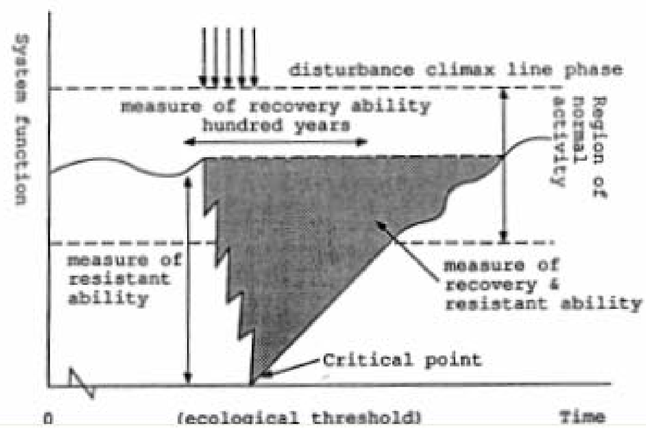
A. Virgin Forests { Resistance / Recovery } Stability



C. Overcut Forests { Resistance / Recovery } Stability



B. Derivative Forests { Resistance / Recovery } Stability



D. Secondary Forests { Resistance / Recovery } Stability

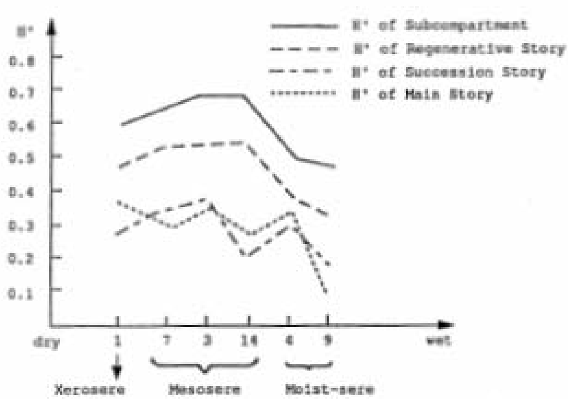


Figure 5.--Diversity index of every community type in different succession series.

REGENERATION OF DAHURIAN LARCH (LARIX GMELINI) IN THE GREAT XINGANLIN MOUNTAINS OF HEILONGJIANG PROVINCE, CHINA

Li Jingwen and Zhan Hongzhen

ABSTRACT: In Heilongjiang province, whose geographical area is about 46 million hectares, forests occupy about 16 million hectares or roughly 35%. The Great Xinganlin forest region located at the top of Northwestern Heilongjiang is estimated to be some 6.7 million hectares. Its forests cover about 73.4% of the area or about 4.9 million hectares. These forests contain some 281 million cubic meters of old growth volume, about 80% of which is larch. The annual allowable cut is about 4 million cubic meters. Since a large proportion of larch forest is in overmature sawtimber stands that offer little opportunity for future management because of their advanced age, relatively slow growth, and susceptibility to wind and insects, harvesting and regeneration practices developed in the Great Xinganlin mountains have been directed toward converting old growth to managed stands by clearcutting in strips and blocks or by shelterwood cutting. The regeneration, both natural and artificial, has not been studied in detail. How to regenerate these clearcuts has been the concern of many foresters. A variety of opinions have been suggested. In general, there are three approaches to be considered:

1) Natural regeneration - Larch is thought to be a shade intolerant species, the seed light and which is wind disseminated, and produces good seed crops every 2 to 5 years. It was recommended that regeneration of most larch forests should take advantage of the remarkable capacity of forest communities to maintain themselves by natural seeding, which must be associated with a well-designed logging plan. In fact, natural revegetation usually proceeds rapidly after disturbance, but stocking on the cutover area does not always reach a satisfied level despite an abundant supply of seed. Results from regeneration surveys showed that larch has some degree of shade tolerance since one-third of the sample plots were well stocked, mostly with advanced regeneration. This advanced regeneration is well-adapted to the environmental conditions. The amount of new regeneration present depended upon exposed mineral soil or disturbed duff and was usually mixed with undesirable kinds of trees and shrubs. Dependence upon natural regeneration to restore new stands without any other treatments would not be recommended since advanced growth is more likely to be damaged or destroyed in logging. To promote efficient regeneration of the new stand, seedbed preparation should be done.

2) Site preparation aids natural regeneration- Some investigators successfully treated clearcuts with scarification and burning, and advocated that site preparation should be a main method to restore stands in this region. This treatment is being used operationally on some forest farms. There are two general methods of eliminating or

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reducing the dead organic material of the forest floor. (1) Burning of piled slash: Burning is ordinarily done by pushing the slash into piles, and when it becomes safe enough, burn. Then the burned pile areas are scarified with a spade to create the appropriate environmental conditions for seed germination. (2) Scarification: The hand scalping method is usually used. The hand-scalped spot is not smaller than 1-1.2 square meters. Above-ground parts of plants are totally removed and organic material is mixed with the mineral soil with hand tools. The effects of these methods on regeneration are limited by a variety of factors: a supply of viable seed, a suitable seedbed, and environmental conditions compatible with germination and seedling establishment. Generally, regeneration often fails in the region, and most larch seedling mortality occurs during the first growing season, but the loses can be substantial during the first 5 years after germination. Therefore, these methods should be used in combination with logging. In the long run, artificial regeneration will become dominate as the intensity of forest management increases.

3) Forest planting - Both methods, mentioned above to enhance forest regeneration, are now the principal ones used in the region. Artificial reforestation has been used operationally on a small scale. Larch plantations occupy not more than 5% of the total regenerated land, a few of which have been successful. Recently, many managers have recognized planting to be efficient. Its significant advantages are: (1) Shortening of the period of establishment, (2) avoidance of dangers to which seed and new seedlings are exposed in the field, (3) freedom from restriction on harvesting techniques and (4) close control over the arrangement, composition, and genetic qualities of new stands etc. A few forest farms have established forest nurseries, seed orchards and the location of superior seed sources. Xinganlin's vigorous climate is continental, with a mean annual temperature range from -2 C to -6 C. Precipitation is generally less than 500 mm. More than half of this amount occurs as summer rains. The growing season ranges from 80 to 90 frost-free days. Forest soils are shallow and profiles poorly developed and covered with a thick undercomposed organic layer. Permafrost occurs sporadically in the south of the range, and is continuous in the northern part. It is necessary when planting to observe proper operational techniques and scientific cultivation, particularly giving the emphasis to the careful site preparation and selecting suitable planting stock raised from high-quality seeds. Planting material should be developed in containers. Wild stock is always inferior to nursery-grown trees. Its use, particularly for small plantations is often permissible owing to its low cost. wild stock should not be depended upon except when it is collected in the locality where it is to be used.

To restock these cutovers, the manager should first consider the cultivation of existing acceptable advanced regeneration before planning on subsequent restocking by site preparation or planting. Slash must be treated carefully to avoid unnecessary damage to advanced reproduction. Sufficiently large piles should be made so that burning is confined to the smallest area possible. If advanced reproduction is not adequate, the area must be regenerated by natural or artificial means after logging.

Timber production is only one of the key uses of larch forests in the Xinganlin mountains. They occupy areas that are also important for water yield, wildlife habitat, recreation, and scenic beauty. Because of increasing demands on forest lands from a rapidly expanding population and the limited resource available, management must consider multiple-use silviculture.

GENETIC IMPROVEMENT OF FOREST TREES AT HIGH LATITUDES WITH PARTICULAR REFERENCE TO LODGEPOLE PINE

Dag Lindgren, Anders Fries and Jan-Erik Nilsson

ABSTRACT: The flowering of lodgepole pine grafts of northern origin indicates that commercial seed crops may be collected in Swedish seed orchards within a few years. Scots pine pollen may decrease seed production, but not to an unacceptable extent. The possibilities for genetic improvement of lodgepole pine (Pinus contorta) for use in interior northern Sweden seem favourable.

Scots pine hardiness may be improved by short term tests. Research has been initiated to investigate if there are localities where especially hardy genotypes may be found.

INTRODUCTION

There are three main commercial species planted in northern Sweden: Norway spruce, Scots pine and lodgepole pine. For none of these is the genetic adaptation to conditions following planting at high altitudes and latitudes quite satisfactory. For Scots pine the local provenance has an expected survival of 15 - 35 % 20 years after planting on harsh sites (Eriksson etal. 1980). More northern origins have better survival, but are not available. Thus the situation is bad. Norway spruce may be a better alternative on some site types particularly in combination with radical scarification. Often it develops slowly and is damaged by snow blight. Snow breakage is also a problem in natural forests at high altitudes. Lodgepole pine has been thought of as a salvation, however, there is not much experience for the most extreme sites. The available experience is not as convincing for such sites when compared to the advantage of lodgepole pine on better sites. Furthermore there are theoretical reasons to doubt the superiority of lodgepole pine on the extreme sites, and thus there must be positive experience to justify its use.

There are actions taken by forest tree breeders, which will improve the situation, but we do not think that any activity initiated will result in a completely satisfactory situation. In this presentation we will concentrate on genetic research done at the Department of Forest Genetics and Plant Physiology, Umea, and the intention is not to give a complete overview of all activities.

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POSSIBILITIES FOR GENETIC IMPROVEMENT OF LODGEPOLE PINE

General Background

During 1970 and 1971 plus trees were selected in Canada. Seed from open pollination of the plus trees in the Canadian stands and twigs for grafting were imported. Clonal seed orchards were established with this material. (Some delay occurred because the scions were heavily treated for phytosanitary reasons).

In the later half of the 70's new plus tree selections were made. This time, for phytosanitary reasons, only seed was imported. Six seedling seed orchards covering around 80 hectares and around 20 progeny trials, distributed over the areas of intended use, have been established with this material. The seed orchards in this program are still very young. From a breeding point of view, this material constitutes the major gene pool for the future.

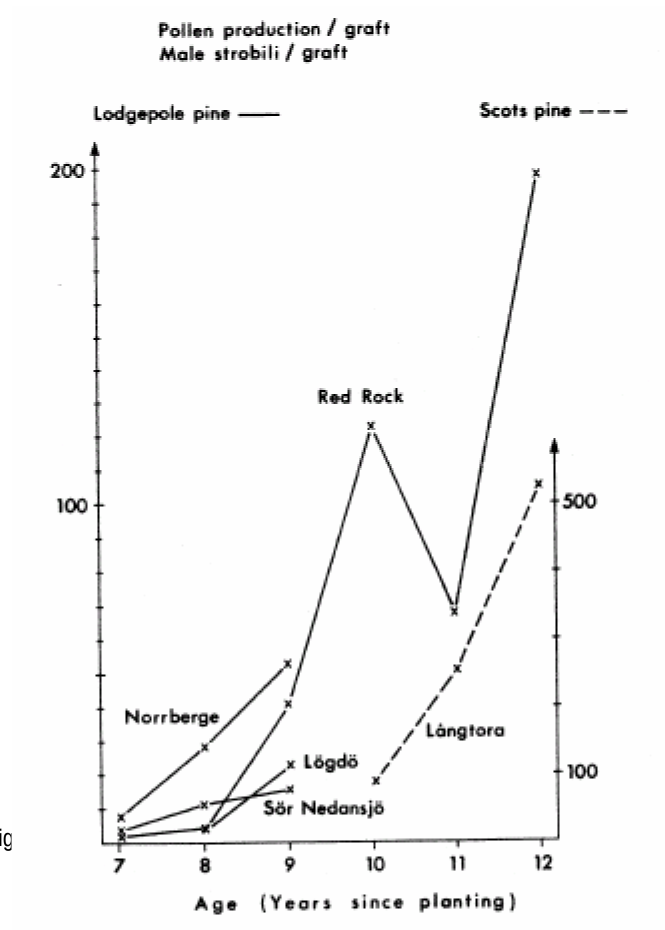

Figure 1. Number of male strobili per lodgepole pine graft. There are data from three Swedish seed orchards (Norrberge, Lögdö and Sör Nedansjö) and a Canadian clonal archive (Red Rock). For comparison data from a Scots pine seed orchard (Langtora is given. The scale is different for Scots pine, as the amount of pollen per strobilus is much bigger for lodgepole.

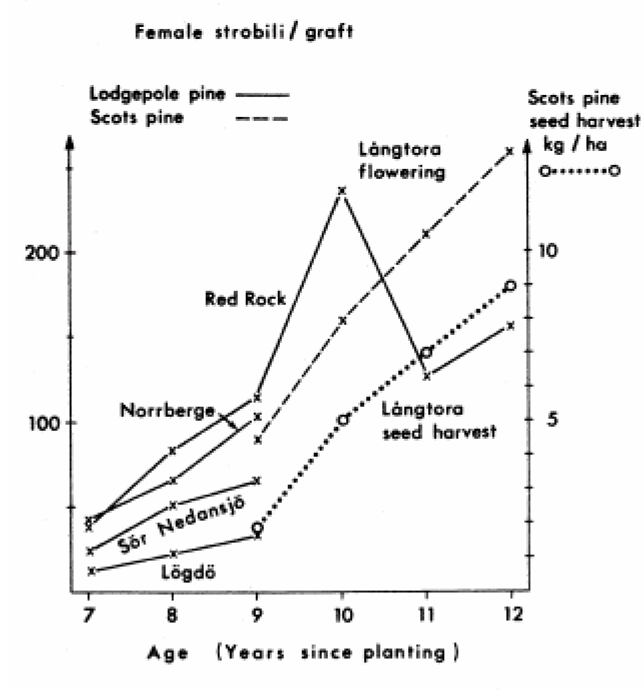

Figure 2. Number of female strobili per graft. For comparison the seed harvest of a Scots pine seed orchard is also given (pollination year).

Flowering In Seed Orchards

In Fig 1 and 2 male and female strobili production are plotted for a seed orchard of Scots pine (Jonsson et al. 1976) as well as for grafts of P. contorta. The objects are grafts in three seed orchards close to Sundsvall (Fries 1984), and grafts from the same plus trees in a clonal archive at Red Rock, British Columbia (Ying et al. 1985 and Andersson, personal communication).

Results and observations are compatible with an assumption that male as well as female flowering starts somewhat earlier in lodgepole than in Scots pine. There are other reports supporting the same view. Thus artificial crossing, which is a key factor in a breeding programme, can be started earlier with lodgepole pine. The same seems to be true for seedlings, which flower early in field trials. Actually, it was possible to carry out a rather extensive crossing program in a provenance trial at Ånge with limited difficulties in tree climbing. Due to poor flowering it would not have been possible to make crosses in the Scots pine trees of the same trial.

The number of male strobili is shown on a five time larger scale for lodgepole pine compared with Scots pine. There is much more pollen in a lodgepole pine male strobilus than in a Scots pine strobilus. A factor of around five seems to be a good quantitative estimate of this difference (Nilsson 1981).

For Scots pine it is believed that 100 male strobili per graft is sufficient for good pollination, although 500 is desirable to quench non-orchard pollen (cf e.g. Hadders 1972). To reach the level required for full pollination in a lodgepole pine seed orchard does not seem to be a problem (Fig. 1). Besides, the information in the figure, good pollen production is documented in other studies (Fries 1984, Nilsson 1981). Also undocumented information supports the theory that the number of male strobili will increase above 30 per tree, and quite probably reach values similar to those in Red Rock. The Swedish grafts are pruned to make it possible to use wire netting cages as protection against voles. This may cause a drop in early reproductive development in the Swedish lodgepole pine grafts. This was not the case in the Långtora or Canadian grafts.

As lodgepole pine is an exotic species there is not, and probably never will be, a serious problem with pollination by pollen from non-orchard sources. (However, non-seed-orchard pollen may decrease seed production, see below). This is particularly favourable for harsh northern localities, where non-orchard pollen, of insufficient hardiness, is a major problem for Scots pine. This facilitates a lodgepole pine breeding program for harsh areas.

The dimension of the Swedish lodgepole pine seed orchard programme is based on an assumption that seed production will be similar to Scots pine, and that around 100 cones per graft will be harvested. The female strobili of lodgepole pine occur mainly on primary branches, while strobili on secondary or tertiary branches are less common (Fries and Nilsson 1982). This, together with an observed low female strobili production in a provenance trial at Ange (Nilsson 1981), gave rise to some doubts that the lodgepole pine seed orchards will live up to expectations. The development of female strobilus production, as assessed in the three Swedish seed orchards investigated, seems to be similar to Scots pine in one case and considerably lower in two cases. Thus it is quite possible that the prognoses will be right, but there is an evident risk that they will not be, thus some kind of inventory is recommended during 1986, when full production is expected in several locations. One way of increasing seed production may be pruning to encourage more points where female strobili may develop (Fries and Nilsson 1982). Genotypes with a more northern origin are characterized by more abundant flowering. Thus, the best flowering of the three seed orchards is the one with the most northern origins. This is a very pleasing feature if a programme was to be ,initiated to produce a lodgepole pine with better adaption to harsh sites than what nature can offer. It may be, advisable to localize seed production units, whose origins are from south of 560, by locating such units further south than 620 in Sweden.

Can Scots pine pollen disturb the lodgepole seed production? Everywhere in Sweden there is Scots pine pollen in the air. Scots pine and lodgepole pine do not hybridize, but theoretically Scots pine pollen may by filling the pollen chamber and preventing fertilization by lodgepole, pine pollen. Scots pine and lodgepole pine pollen show no evident morphological differences. Therefore crosses were performed to investigate if lodgepole seed production might be decreased by Scots pine pollen (Table 1). Experiment A was described by Nilsson 1981, Experiment B has not been reported earlier.

From the results and discussion above it seems likely that more than half of the pollen cloud in a mature lodgepole pine seed orchard is lodgepole pine pollen. However, there are indications (Lestander and Lindgren 1985) that pollen from outside sources may sometimes

Table 1. Pollination of lodgepole with pollen mixtures.

Experiment A	Number of filled seeds per cone	empty seeds per cone	recovered cones
One pollination with lodgepole pine pollen	15.1	5.9	98
Two pollinations with lodgepole pine pollen	17.6	7.7	80
One pollination with Scots pine pollen followed by one with lodgepole pine	7.6	3.6	19

Experiment B	Number of Pollinated strobili	Recovered cones	Filled Seeds per cone	Per cent empty seeds
Pollination with lodgepole pine pollen	25	17	26.8	25
Pollination with a mixture of equal parts of lodgepole and Scots pine pollen	20	10	20.6	34

contribute more than expected and the lodgepole pine seed orchards are often rather small. Thus it may be possible that more than half of the pollen cloud may be of Scots pine origin.

Conclusion: The presence of Scots pine pollen may decrease production of filled seeds in lodgepole pine cones. However, it seems unlikely that this blocking effect is large enough to be a major obstacle to good seed yields of lodgepole pine seed orchards.

Genetic Variation Of Lodgepole Pine In Northern Sweden.

There is rather much experience on the provenance level for lodgepole pine (Lindgren 1983 and others). Interesting areas can be delineated on the map. The possibilities for making gains by provenance research are more or less fully exploited. The next step is to utilize the genetic variation within the good populations. The results from the first progeny-test in Sweden will be briefly described. It comprises open pollinated progenies from 69 Canadian plus trees from interior BC north of 550 and the Yukon. It is situated at Savar, lat 640, alt 10 m. The mean height of the trees was around 3.5 m at 10 years after sowing. For height the variance component for half sib families within origins was larger than that for areas of origin. This indicates that for long-term breeding we should preserve some material even from the non-top ranking populations in the interior BC and Alberta (excluding the most southern parts) and the Yukon.

Height growth declined for origins from altitudes above 800 m. Therefore, it does not seem advisable to search for high altitude seed sources for practical forestation. Genetic gain calculations indicated that seed orchards established in the 90's will increase volume production by 10 per cent compared to the present seed orchards. A comparison with a provenance trial in the neighbourhood indicated that the gain from plus tree selection may be 10 per cent for height.

Measurements of open pollinated progenies in another more southern trial, comprising plus, tree parents from 540 - 550, revealed similar results and similar predicted gains. Density and height growth of progenies were not highly correlated. Thus selection for height is not, likely to decrease density.

It may be concluded that there is a considerable genetic variation in lodgepole pine, and that there is potential to establish new and considerable better seed orchards utilizing already existing materials.

On harsh northern sites there is a considerable difference in performance between provenances of different northern origins, and it is not quite clear that the most northern are the best ones. Thus there are reasons to believe that the possibilities for improvement are at least as big in these areas as in milder ones.

Controlled Crosses

A program with controlled crosses has been performed in a provenance trial at Ånge. The main purpose was to see if gains can be made by hybridizing genotypes with different origins. Two field trials were established in spring 1984 and a third one was sown 1985 for planting in 1986.

A crossing program has been performed in SCA's grafted seed orchards close to Sundsvall. Crosses were done in 1982 and 1983, and additional crosses were made in 1985. For 1982 and 1983 some data are presented in Table 2. The origins of the parents are mostly very northern and the material constitutes the best breeding material available for the northern, interior part of Sweden. However, as the size of the founder population is only 70 and there are only around 18 unrelated families, the Institute of Forest Improvement has to increase the quantitative size of the breeding population. Our purpose is scientific, we want to produce information which will help future breeding.

Table 2. Statistics of lodgepole pine crosses 1982-1983

Nr of mothers	58
Nr of fathers	24
Nr of crosses	407
Nr of pollinated cones (female flowers)	8305

For comparison some, statistics from the Finnish breeding work with Scots pine during 1984 are given (Hahl 1984): 118 crosses, 45 000 female flowers, 13 seeds per harvested cone.

It seems possible to complete crossing schemes rather quickly and with a limited effort for lodgepole pine. Thus it is a species which will be relatively easy to breed using strategies including controlled crosses.

Table 3. Results of crosses of lodgepole pine.

	Lögdö	Norrberge		Sör Nedansjö
	1982	1982	1983	1983
Empty seed (%)				
Crosses	26.0	17.2	32.6	55.6
Selfings	98.0*	87.1	59.1	57.8
Number of filled seeds per cone				
Crosses	15.9	23.0	10.7	9.4
Selfings	0.33*	3.2	3.9	7.7
Abortion rate (%)				
Crosses	17.5	30.3	15.1	48.7
Selfings	39.1*	27.2	66.7	62.4

* Based on a single cross.

Selfing is not likely to be a major problem when designing lodgepole pine seed orchards.

Some Future Research On Contorta Genetics For Northern Sweden

Nursery study

The controlled crosses are under investigation in a short term test. The aim of this study is to get genetic parameters from full sibs for use in decisions on breeding strategy and tactics before results from field trials are available. Tests with summer freezing have indicated that there may be some family differences. It will be considered whether it is worthwhile to breed for this character.

Field trials with crosses

To give the genetic parameters required for later breeding decisions, as well as to study this "domesticated and naturalised" breed of the species.

Cutting propagation of full sib families and field tests with those cuttings.

To get more information on genetic parameters as well as to study if cuttings are a useful tool for breeding lodgepole pine.

POSSIBILITIES FOR GENETIC IMPROVEMENT OF SCOTS PINE.

It is well known that Scots pine provenances are characterized by better survival for more northern orgins. The survival is also increased, but to a lesser extent, by higher altitude. However, Scots pine stand seed, which gives desirable survival in north Sweden, is not available. Therefore, we try to get such improved seed by intentional breeding. The first step is to make seed orchards of clones selected in northern populations. The seed orchards are localized in areas where abundant flowering and good seed maturation is possible. However, the progenies from these clones are not expected to be more hardy than the corresponding provenances. Actually the seed orchard harvests may be less hardy, as there is some inflow of pollen from surrounding stands, which decreases the hardiness of the orchard seeds. It is possible to test for hardiness in Scots pine. In existing field trials there is considerable variation between progenies for survival. For breeding purposes a freezing test was designed (Rosvall 1982). Young seedlings were cultivated in a growing period with fixed night length and then exposed to gradually longer dark nights. Finally the seedlings were exposed to -100C for a few hours. The survival is expected to be a measure of fast hardening in the autumn and thus good survival in the field. In a study using full sib progenies Nilsson and Andersson (1985) found significant correlations between survival in field experiments and freezing tests.

In another study (Nilsson 1985, Nilsson & Eriksson 1985) freeze test results from open-pollinated progenies from clones in a clonal archive were compared with survival in a 20-year-old provenance test comprising stand-pollinated progenies from the same clones. Strong dependence on latitude of origin was found for both freezing tests and field tests. Lower, but mostly positive, correlations between survival in field trials and freezing tests were found within stands. However, it is still not known how useful freeze-testing is as a measure of differences in hardiness within a natural population. Nilsson also demonstrated that the discriminating power of the freezing test might vary with the conditions of plant production.

In the study of Nilsson and Andersson (1985) using 13 full sib families with good and 13 with bad survival after 10 years in four fields tests, the early freezing test was efficient in separating the bad field performers from the good ones. None of the bad survivors in field were among the 10 best ranked in the freezing test. Therefore, it seems likely that field survival can be considerably increased by selection for hardiness using this type of early test.

In a small trial with Scots pine grafts situated at latitude 660 Lindgren (1985) found that genotypes with high survival may be found within a population. On the other hand, there might be a risk that this increase in hardiness is bought at the cost of decreased growth capacity.

Another approach to increasing hardiness is to extend the search for hardy genotypes from ordinary forests to the few surviving trees above the timber line or at other localities with conditions so harsh that only very few trees survive (Nilsson & Aman 1985). The Department of Forest Genetics and Plant Physiology has established a clonal archive for future crossing programmes for testing the hypothesis that genotypes from these origins may contribute genes of particular value. Pollen from these genotypes was also collected and has been crossed using clones in existing clonal archives and seed orchards as mothers. Tests with these crosses will start in 1986.

It is certainly possible to increase field survival to a rather high extent by manipulating the growth rhythm by using freezing tests or other methods. However, trees also die or grow badly because of reasons not closely associated to growth rhythm, such as frosts in the summer, temperature fluctuations (particularly in spring), pathogens, wind and a combination of wind and drifting snow. Tolerance, or the capacity to heal damage, may be as important as avoiding damage by a proper growth rhythm (Stahl and Andersson 1985). The growth rhythm of a 1- or 2-year-old seedling and that of the same genotype at age 30 may not necessarily be the same.

It is possible to get considerable immediate gains by using methods like freezing tests. Probably, there is a limit to what can be obtained without checking 20 year old trees in field trials and it is advisable to be prepared to adjust the breeding decisions, currently based on freezing tests, when information from older trials (preferable based on crosses) becomes available. It is also desirable to keep some kind of "unselected" checks within the breeding programs, to be able to evaluate the effects of the breeding decisions in the future.

The present method of testing open-pollinated progenies from trees in the forest has considerable unmaturation and the pollen cloud may introduce uncertainties. It might be favourable if test results could be complemented with information about the mother tree. Such information may be:

* Growth rhythm of grafts of the mother.
* Some type of test of cambium damage of the mother (Stâhl and Andersson 1985). However, this may be difficult, cf Hagner (1980).
* The seed maturation. This is genetically controlled by the mother, and it seems likely it is correlated to the rhythm of other characters preparing the tree for the winter. (Proposal raised by Peter Krutzsch, personal communication).

ACKNOWLEDGEMENTS

Parts of the investigations presented has been supported by "Skogsstyrelsens forskningsnämnd" and some by "Statens râd for skogs- och jordbruksforskning" .

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Note: SLU = Swedish University of Agricultural Sciences

GPO 691-133/82057

Abstract

McHugh, Paul; Olson, Douglas; Schallau, Con; Lindall, Scott; Akhavi-Pour, Hossein; Maki, Wilbur. 1989. Alaska IPASS database preparation manual. Gen. Tech. Rep. PNW-GTR-233. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 79 p.

Describes the data, their sources, and the calibration procedures used in compiling a database for the Alaska IPASS (interactive policy analysis simulation system) model. Although this manual is for Alaska, it provides generic instructions for analysts preparing databases for other geographical areas.

Keywords: IPASS, policy analysis, impact analysis, input/output analysis, dynamic simulation, computer simulation.

MartInsson, Owe; Packee, Edmond C.; Gasbarro, Anthony; Lawson, Teri, coords. 1989. Forest regeneration at northern latitudes close to timber line. Proceedings, 7th annual workshop on silviculture and management of northern forests: 1985 June 16-20; Lulea, Gällivare, and Őstersund, Sweden. Gen. Tech. Rep. PNW-GTR-247. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 73 p.

The proceedings contains 13 papers presented at the workshop. The papers reflect work done in Finland, Sweden, Norway, Canada, and the People's Republic of China.

Keywords: Yield, boreal forests, latitudes (-site, regeneration (stand).

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