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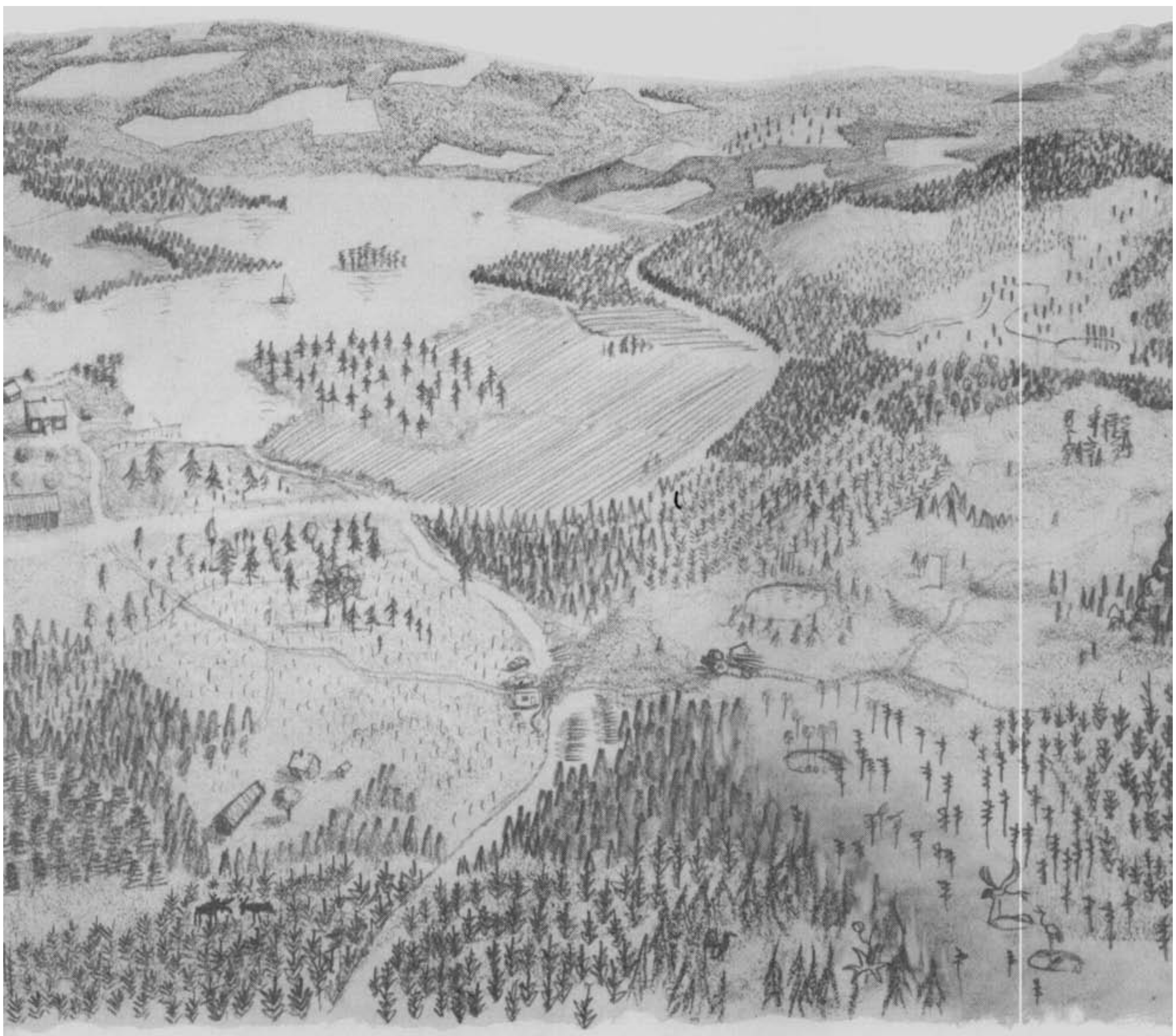
# Forest Regeneration At High Latitudes: Experience From Northern Sweden



# FOREST REGENERATION AT HIGH LATITUDES:

## Experiences from Northern Sweden

Edited by

Mayo Murray

The Proceedings of a Second International Workshop

Sponsored by

The Swedish University of Agricultural Sciences, Faculty. of Fore'stry

With the assistance of

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# INTRODUCTION

Anthony F. Gasbarro*

The problem of obtaining adequate and economical forest regeneration is of major concern among the managers of high-latitude forest lands. In 1979 forest researchers and managers from Scandinavia and North America held the first of three workshops to address this topic by sharing experiences and research from each county. The first workshop was held in Umeå, Sweden in August 1980. The papers presented during the second workshop are included in this publication. A third workshop will be held in Prince George, British Columbia, Canada in August 1981. These three scientific gatherings provide the basis for a joint U. S. – Canadian project to prepare a definitive technical manual on the regeneration of white spruce (*Picea glauca*) in Alaska and the Yukon Territory.

The workshop on forest regeneration held in Umeå, Sweden was sponsored by the Swedish University of Agricultural Sciences, The Institute for Forest Improvement, and the Swedish Logging Research Foundation. The major objective of the workshop was to provide an opportunity to observe research and practical management for forest regeneration in northern Sweden. The individuals responsible for organizing and coordinating the workshop were Professor Fritz Bergman, Swedish University of Agricultural Sciences, and Dr. Jan Remrod of the Swedish Forest Service. The workshop program and areas visited can be seen in Appendix I, page 37.

The North American foresters visiting Sweden also had an opportunity to participate in a post-workshop tour of parts of central and southern Finland to observe forest research and management activities. Dr. Sven Erik Appelroth, Senior Research Officer of the Finnish Forest Research Institute organized the tour and served as guide and interpreter. The program for the Finnish tour is shown in Appendix 11, page 39.

This publication was prepared through the cooperative effort of the School of Agriculture and Land Resources Management and the U. S. Forest Service Pacific Northwest Forest and Range Experiment Station. Sincere appreciation is expressed to the authors of the papers in this document.

*Project Coordinator, School of Agriculture and Land Resources Management, University of Alaska, Fairbanks.

# FORESTRY IN NORTHERN SWEDEN

Bo Axelson*

## BASIC FACTS ABOUT NORRLAND, AND VASTERBOTTEN

Sweden is divided into three geographical regions, namely Norrland, Svealand and Gotaland. Included in Norrland are four counties, one of which is Vasterbotten. Of the total productive forest area of Sweden, 23.5 million hectares, or 54%, is in Norrland. The structure of the ownership is as follows: state forests 27%, other public forests 5%, company forests 29% and other private forests 39%.

The total annual growth of the Swedish forests is about 70 million cubic meters ($m^3$). The growth per year per hectare for the country as a whole is 3 $m^3$ and for Norrland 2.2 $m^3$, while it is 4.6 $m^3$ in the south of Sweden (Gotaland). The lower productive capacity in Norrland results primarily from the shorter growing season due to the latitude and the higher altitude above the sea. In Vasterbotten, for example, the growing season near the coast is around 90 days, while it is only 50 days in the mountains.

Norrland has comparatively few inhabitants; the population of Vasterbotten is around 240,000, an average of 4 persons per $km^2$, with most living near the coast. Predominating occupations have changed considerably during the last 15 years (See Figure 1). Farming and forestry have decreased while public service, education, and medical care have increased. Regarding forestry, it can be said that development can be attributed to the fact that forestry has mechanized and has changed from part-time to full-time employment. It should be noted that the companies and the State Forest Service have always had rather good access to labor, even in the inner part of Norrland. Part of government policy has, for some time, been to stimulate people to settle down in this part of Sweden. In the middle of 1800, many people settled here and established small farms and villages. For these people, farming could not provide an adequate living and an additional occupation was needed. The only available work was in forestry in the winter and timberfloating in the summer. Most farmers also combined farming with forestry on their own forests, and this combination is still important.

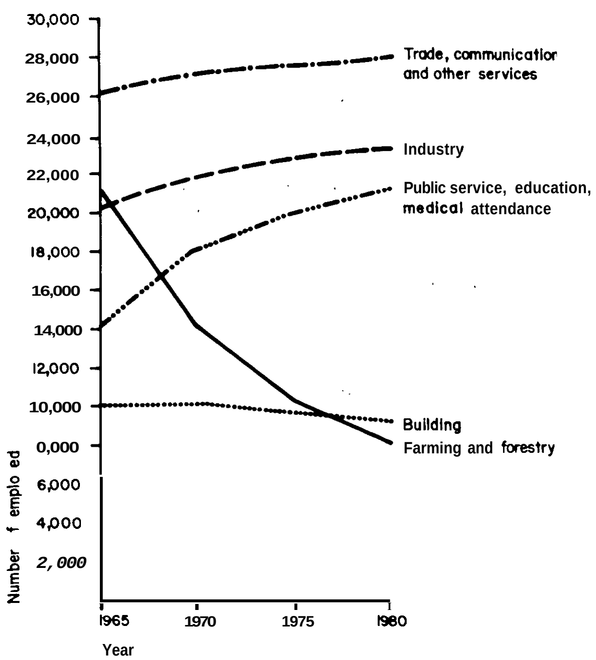


Figure 1.

Taking a look at the forests of Vasterbotten, it can be said that there is a surplus of forests older than 120 years, the normal rotation period in the north. The annual growth in Vasterbotten is about 6 million $m^3$ and the annual removal about 5 million $m^3$. Most of the transportation of the timber nowadays takes place on roads instead of floating. A network of forestry roads has been built, 15,000 kilometers in length, compared to the public roads which total less than 1,000 kilometers.

### Forest Industry in Vasterbotten

The location of timber and pulp activities appear in Figure 2. Most of the industry is located in the coastal region. During the last few years, it has been desirable to locate sawmills in the inner parts. of Vasterbotten because of the problems of unemployment there. In recent years, a new market for wood has been recognized for fuel purposes; this depends, of course, on the rising prices of oil.

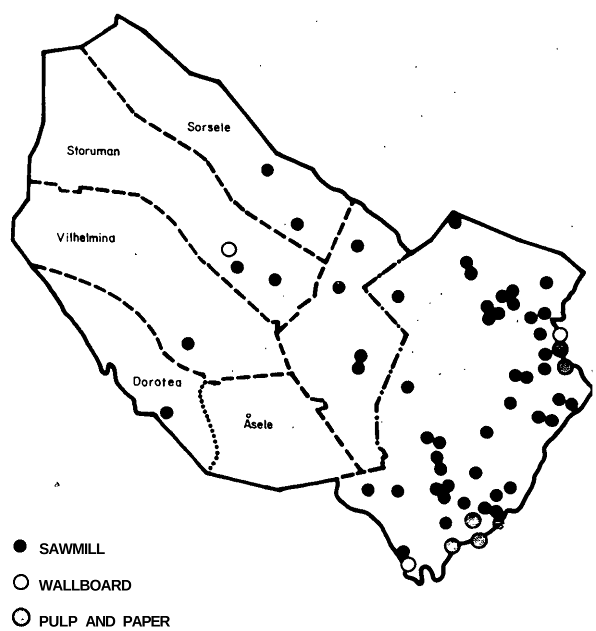


Figure 2. Sawmill, Wallboard, Pulp and Paper Industry in the County of Vasterbotten.

*Head of the County Forestry Board of Vasterbotten, Sweden.

## The Importance of Forestry and Forest Industry In Sweden and Vasterbotten

Forestry is of major importance to the country's economy and employment. Of total exports, just over 20% consist of forest products. Nearly 300,000 people are employed in this sector. In Vasterbotten, investigations have been made which tell us that about 15% of the population depend directly or indirectly on forestry and the forest industry; and, in the inner part of the county, the figure is as high as 50%.

## Forestry Policy

As forestry means so much to the economy of the country and to employment, a forestry policy is necessary. How the forests are managed is not only a matter for the forest owner, but is of major interest for the whole country. In 1903, the first forest law, in the modern sense, was passed. The law has been revised during the years, and in 1979 a new forest law was passed, effective January 1, 1980, (Appendix 1) and on a new forest policy (Appendix 2, page 8). For us in the north, the forestry policy means a lot because it provides for economic subsidies. Government aid is concentrated mainly in those areas of the country, Vasterbotten for example, where production conditions and economic prerequisities are the poorest (See Appendix I). In the budget year 1980/81, about 25 million Swedish crowns are allocated for economic subsidies in Vasterbotten.

## The County Forestry Boards

In order to implement the forestry policy, there is a county forestry board in each of the 24 counties in Sweden. The National Board of Forestry is responsible for coordinating the activities of the forestry boards, coordinating questions of seeding and planting, and supervising the measurement of timber.

The tasks of the county forestry boards appear in Appendix 2. A county forestry board is made up of a chairman the governor of the country), two members nominated by the government, three members nominated by the county council, and the county forest officer, who is the chief executive officer of the board. Activities as well as personnel are divided into sections: an administrative section, one or more silvicultural sections, a regeneration section, and a technical section for roads, drainage, and forestry planning. The silviculture sections include the largest and most important group of personnel, the county foresters, who are stationed in their respective districts and are responsible for the immediate contact with the forest owners. The work of the boards is financed mainly (more than 60%) by the customers, directly by service charges and indirectly by a forestry levy. Courses and advisory activities, certain general planning, law enforcement, and other administrative activities are financed by public funds. About 200 people are employed at the county forestry board in Vasterbotten: 9 forest officers, 90 foresters, 70 foremen and 30 office employees.

## APPENDIX I

## THE FORESTRY ACT

**A** new forest legislation was adopted by the Swedish Parliament in 1979. This legislation is based on the acts dating from 1903, 1923, and 1948. The Government has issued an ordinance and the National Board of Forestry has announced regulations concerning the application of this act. The act [went] into effect on 1 January 1980.

### General Provisions

A Summary Presenting the Aim of the Forest Policy

§ 1. By means of prope. utilization of their wood-producing capacity, forest land and forests growing on them should be managed in such a way as to provide a permanently high and valuable timber yield. This management should pay heed to nature conservation and other public interests.

§ 2. For the purposes of this act, forest land is defined as:

1. land which is suitable for the production of timber and which is not used to any large extent for other purposes;

2. land where the presence of forest is desirable to protect against sand or soil erosion or against lowering of the timber line.

   However, land lying wholly or mostly unutilized shall not be regarded as forest land if, by virtue of special circumstances, it is not desirable for such land to be put to use for the production of timber.

   Land shall be considered suitable for the production of timber if, on the basis of customary principles of assessment, it can produce an average of at least one cubic meter of wood per hectare per year.

§ 3. This act does not preclude the utilization of forest land for purposes other than for the production of timber.

§ 4. This act shall not be applied where its provisions conflict with regulations issued under the provisions of the Nature Conservancy Act and other laws.

### Establishing of Stands on Forest Land

§ 5. New stands shall be established on forest land:

1. where, after felling, or due to damage to forest, the timberproducing capacity of an area of land is not satisfactorily made use of;,

2. where land is unused;

3. where forest is so thin, or is composed of unsuitable tree species for the type of terrain to such an extent that its growth is considerably lower than the growth which is possible.

   Measures on the bases of the first paragraph above shall be carried out in cases covered by categories

1 and 2 without delay. In cases covered by category 3 measures will be carried out within a reasonable period of time.

§ 6. If a forest stand is over-aged, and the timber-producing capacity of an area is exploited to only a minor extent due to decay or natural thinning, the County Forestry Board may decide to force clear cutting and the establishment of a new stand.

§ 7. Establishment of new stands shall be carried out using methods of regeneration which may be necessary to assure the growth of new forest which is satisfactory in terms of density and of composition in general. Regulations on methods of regeneration, scarification, planting of seeds and seedlings/transplants, tending of newly planted areas, and other measures in the above respect are issued by the government, or by a public authority designated by the government.

§ **8.** Where required for silvicultural considerations, the government, or public authority designated by the government, may issue regulations prohibiting, or placing conditions upon:

1. the use of forest reproductive material of indigenous or of foreign origin, in establishing new forest stands;

2. trading with such material.

   Forest reproductive material is defined as seed, seedlings/transplants, and other regeneration materials intended for establishing new forest stands.

*$9*. Cleaning newly-planted and young stands of forest will be carried out when forests are so dense, or otherwise are in a condition that production of valuable timber is significantly hampered.

If such forests are near the age when thinning may take place, the County Forestry Board may, in special cases, allow early thinning to be carried out instead of cleaning.

§ 10. Forest owners are responsible for establishing and tending new stands.

§ 11. The County Forestry Board may, in special cases, grant exemptions to § § 5, 7 and 9.

## Cutting of Forests on Forest Land

§ 12. Cutting on forest land may not take place in any other form than:

1. cleaning or thinning which benefits the growth of the forests;

2. clear cutting which is suitable for establishing new stands.

§ 13. Clear cutting of forest may not take place until it has reached such an age that only a minor increase in its average production can be achieved if it is allowed to remain standing. Average production is calculated as the average annual growth since the establishment of the stand.

The government, or the public authority designated by the government issues regulations laying down the lowest permissable age for clear cutting for various tree species growing in various parts of Sweden, on land of varying site quality class.

In special cases, the County Forest Board may grant exemptions from the first paragraph above.

§ 14. Forest owners are responsible for clear cutting being carried out in such a way as to encourage an even age distribution of forest on their holdings.

The government, or public authority designated by the government issues regulations laying down what proportion of each area of forest land within a holding may be clear cut per annum, or per any other cyclical period employed.

In special cases, the County Forestry Board may grant exemptions from the first paragraph above.

§ 15. A holding is defined as that foresr land which lies within the borders of one municipality and belongs to one and the same owner, unless otherwise provided in the regulations issued by the government, or public authority designated by the government.

§ 16. The County Forestry Board shall supply, on request, advance notice of decisions as to whether a specific cutting is consistent with the requirements of § 13 or § 14.

§ 17. Forest owners are obliged, under regulations issued by the government, or public authority designated by the government, to inform the County Forestry Board of cutting to be carried out on their land.

## Forests Difficult to Regenerate and Protected Forests

§ **18.** The government may order for forests difficult to regenerate due to an unfavourable location, or needed as protection against sand or soil erosion, or to prevent lowering of the timber line, to be set aside as forests difficult to regenerate or protected forests.

§ 19. Cutting in forests difficult to regenerate and in protected forests may not take place without the permission of the County Forestry Board.

In connection with granting permission, the County Forestry Board may decide upon measures to limit or to minimize inconvenience and to ensure regeneration.

Permission is not required for cleaning or thinning which benefits the development of the forest.

## Insect Damage

§ 20. The government, or public authority designated by the government may issue regulations for combating insect damage and removal of damaged forests, or storage of timber, and other measures required to combat the creation of breeding grounds for insects.

Forest owners are responsible for ensuring that such measures are carried out. Other parties who have right of management over forest and timber are also responsible for preventive measures in connection with cutting and storage of timber.

Nature Conservation Aspects

§ 21. The government, or public authority designated by the government may issue regulations on the aspects of nature conservation which have to bc taken into account in forest management, for example in relation to the size and form of the clear cut area, establishing new stands, leaving of tree-groupings, and the stretchings of forest roads.

These powers do not include the authority to issue regulations which are so far-reaching as to severely handicap utilization of land currently in progress.

Supervision

§ 22. The National Board of Forestry performs overall supervision of compliance with this law and with the regulations published under the provisions of this law. The County Forestry Boards perform more detailed supervision of compliance at county level.

§ 23. The supervising authorities have the right to be supplied, on request, with the information and documents required for such supervision in accordance with this law.

§ 24. The supervising authorities may order or prohibit certain action where required to ensure compliance with this act, and with any regulations issued under the provisions of the act.

Certain action may by (*sic*) ordered or prohibited when it has become clear that the advice and directions of the public authority have not been followed. However, in urgent cases, or where there exists other special justification, such orders may be issued immediately.

In connection with a decision to order or prohibit certain action, the supervising authority may order a monetary penalty in case of noncompliance.

Should a person fail to comply with an order, the supervising authority may order the measure to be carried out at the expense of the person at fault.

§ 25. Should cutting result in relatively extensive and costly regeneration programmes, the County Forestry Board may, in connection with cutting being carried out, order guarantees to be furnished to assure completion of such regeneration measures.

Guarantees may also be required as a condition for permission being granted in accordance with § 19.

If guarantees are not furnished in cases as provided for in the first paragraph above, the County Forestry Board may issue an order prohibiting forest cutting on the holding concerned without the permission of the County Forestry Board.

§ 26. The government may

of § 8, Par. 1, or § ;

2. violates § 12, § 13, Par. 1, or § 14, Par. 1;

3. violates § 19, Par. 1, or any regulation on cutting issued under the provisions of § 19, Par. 2;

4. carries out cutting, where such action is prohibited under § 25;

5. fails to fulfil the duty of notification as laid down under the provisions of § 17 or

6. fails to comply with an order, or carries out certain prohibited action, where such orders are issued to ensure compliance with any regulation under § 21.

No conviction for liability will take place in cases of minor violations.

In the event of several persons being accessories to a deed as referred to in the first paragraph above (§ 27), Chapter 23, § § 4 and 5 of the Criminal Code will apply.

Persons who contravene orders prescribing or prohibiting, certain action under penalty of a fine will not be found liable under this act for deeds within the scope of those prescriptive or prohibiting orders.

§ 28. Timber from cutting which represents a violation of this act, or the value of such timber, shall be declared forfeit, unless this is manifestly unjust.

§ 29. Proceedings against a decision by the County Forestry Board under the provisions of this act will be conducted in the form of an appeal to the National Board of Forestry. Proceedings against a decision of the National Board of Forestry will be conducted in the form of an appeal to the government.

§ 30. The authority concerned may order for its decision to be duly observed, notwithstanding any appeal.

## APPENDIX 2

## SWEDEN'S NEW FORESTRY POLICY

(A Summary presented by the National Board of Forestry, June 1979)

### A NEW FORESTRY POLICY

Forests dominate Sweden's natural landscape. Woodlands comprise 23.5 million hectares or 57% of total land area. The forestry sector is of major importance to the country's economy and employment. Of total exports, just over 20% consist of forest products. Nearly 300,000 people are employed in this sector. The forest industry has grown rapidly and at normal levels of activity it requires about 75 million cubic meters of wood per year. 'l'his volume of demand cannot be met in the long run under the forest management program implemented to date, but instead requires more intensive silviculture. Conflicts between the interests of nature conservation and forest management have become increasingly common, among other things due to growing public awareness of environmental issues.

These conditions have demanded new guidelines for the country's forest policy. The previously applicable guidelines established by Parliament in 1948 were expressed, among other places, in the Forestry Act of that year. In recent years, the law has been amended to include rules on nature conservation aspects, measures to combat insect damage, and the requirement that forest owners inform the authorities of planned clear cutting. In addition, the national government has increased its economic subsidies to silviculture in northern Sweden and has regulated the expansion of the forest industry.

Forestry policy was studied by a government commission appointed in 1973, which presented a report entitled "Forests for the Future." After seeking the offical comments of involved organizations, the Government presented a bill to Parliament containing new guidelines for Sweden's forest policy etc. In May 1979, Parliament approved the new forest policy. It went into effect on January 1, 1980.

## THE AIMS OF FOREST POLICY

The Government and Parliament believe that the forestry sector will continue to be of major importance in the future. Forests are among the few renewable natural resources. They provide important raw materials and are of great importance to our prosperity. For this reason we must make good use of the products of our woodlands.

Forest management should assume a long-term perspective and be characterized by an ecological way of thinking. The Government and Parliament did not wish to specify a detailed forest production program. Instead, forest measures should continuously be adapted to and take into account other important national interests. At the beginning they should be based on the objective of achieving a wood production level of at least 75 million cubic meters per year. (See Article 1, Forestry Act.)

The following sections describe various METHODS used by public authorities to assure realization of forest policy aims.

## THE FORESTRY ACT

The Forestry Act provides a framework of fundamental public regulations for management of the country's forests. More detailed instructions for implementing these rules are worked out by a central administrative authority, the National Board of Forestry, in contact with various interest groups. They are presented in regulations and general recommendations.

### Field of Implementation

The Forestry Act applies to all woodlands in Sweden, and thus also the forests owned by the national government and the State Church. Woodlands are defined as land which has an annual production capacity of at least one cubic meter of wood per hectare and which is not used to any large extent for other purposes.

Exceptions can be made in special situations. The regulations on forest planting and cutting contained in the Act apply to woodlands, while those concerning insect damage and conservation aspects can also apply to other land. In this case, the purpose determines the field of implementation.

### Establishing of Stands

Requirements for establishing of stands have been tightened somewhat. But efforts should first be made to fulfill the previous requirements of the Forestry Act. To accomplish this, considerably better forest planting is required than is now the case.

Establishing of a new stand is supposed to take place either after clear cutting or after the felling of a forest which is damaged, thin, composed of unsuitable tree types or is over-aged and has a low growth rate due to decay or natural thinning. In addition, unused land is to be planted with forest, for instance permanently abandoned farmland. Meadowland etc. immediately adjacent to built-up areas does not, however, have to utilized for forest production.

Regulations are published on suitable methods of regeneration and on the use of forest reproductive materials. Employment of chemicals should be limited as much as possible, and DDT is not permitted. The current proportion of our forests made up of deciduous trees (hardwoods) should remain the same. Planting of Lodgepole pine should be limited to difficult regeneration areas of indigenous tree species.

Cleaning away of undergrowth in newly-planted and young stands of forest is necessary. Cleaning should be done in forests which are so dense that production of valuable timber is significantly hampered.

### Cutting of Forests

Cutting may only take place in the form of cleaning or thinning which benefits the growth of a forest, or in the form of clear cutting which is suitable for planting of a new forest. Protection is given to growing forests by permitting clear cutting only after a forest has reached a certain age. Furthermore, clear cutting is to be carried out in such a way as to encourage an even age distribution. This evenness requirement is applied to the land holdings of each forest owner within a given municipal district. But on small properties, older forests do not need to be rationed.

Forest owners are supposed to inform the County Forestry Board of plans for clear cutting. This procedure makes it considerably easier for the Forestry Boards to carry out their work of supervision, extension services, plant supplying etc., as well as following up the extent to which forest owners take nature conservation interests into account. Permission is required for cutting forests that are difficult to regenerate or which enjoy special protection.

### Nature Conservation Aspects

It should normally be possible to take nature conservation aspects into account within the framework of efficient forest management. The regulations based on the Forestry Act specify what aspects should be kept in mind.

Conservation matters affecting forest management are also covered by such laws as the Nature Conservancy Act and the Act on Preservation of Beech Forests. Conservation aspects which entail stricter limitations are regulated by the Nature Conservancy Act. Before plowing clear cut areas and carrying out certain clear cutting operations, the authorities must be informed so that consultations can take place under this Act. In the future, the requirement will also apply to plans for draining wetlands.

### Insect Damage

The regulations specify measures for combating insect damage, as well as preventive measures. The latter include rules on cutting of damaged forests as well as removal and storage of timber.

### Supervision, Responsibility and Appeals

Supervising of compliance with the law is performed by the National Board of Forestry and by the County Forestry Boards for their respective jurisdictions.

The previous long-winded adminstrative rules have now been replaced by considerably simpler ones. First of all, the authorities should try to reach an agreement with the forest owner. Where called for, the forest owner is to be provided with advice and information on the rules contained in legislation. If necessary, a forest owner can be ordered to plant trees on a clear cut area or be forbidden from clear cutting a growing forest. These decisions can be combined with monetary penalties. A person who violates the law and related regulations can be convicted and sentenced to pay a fine.

A forest owner can be ordered to furnish guarantees for carrying out large, expensive regeneration programs.

## FOREST INVENTORIES

National planning, planning of forest management and collaboration among forest owners require various background information.

Overall forest inventories ought to exist throughout the country. These should be carried out by the County Forestry Boards, mainly within the private forestry sector. The inventories should also be usable as background information for devising forest management plans for private properties. The national government is to pay for them.

To encourage active utilization of woodlands, it is very important for every forest owner to obtain his own plan. In particularly sensitive areas, the government should pay for the work of establishing nature conservation-oriented forest management plans.

## ECONOMIC SUBSIDIES

The measures required to fulfill the basic demands of the Forestry Act should, in principle, be financed by forest owners. Because the public authorities want to realize silvicultural objectives beyond these basic demands, a certain amount of national government subsidies may be justified. Grants may also be provided for construction of forest roads so that the network of such roads will be properly designed.

Government aid concentrates mainly on long-term measures and on those areas of the country where production conditions and economic prerequisites are the poorest. Employment considerations connected with regional development policy may also enter in. Most subsidies are used within so-called forestry development areas.

The following table specifies what measures may receive subsidies and what are the highest percentages of costs that may be covered by these grants. The national government, the Church and forest companies may only receive road subsidies if they are part-owners of a road company or if their road carries a large proportion of outside traffic. The national Board of Forestry publishes regulations on utilization of subsidies. Subsidies can also be given to forest areas damaged by Pine weevil in 1975-1978.

National Government Grants for Forest Management

| | | Maximum % of Costs Covered by Grants | | |
|---|---|---|---|---|
| | | Forest Development Area | | Other Areas of Sweden |
| Measure | | Inner Zone | Outer Zone | |
| Planting of forests on abandoned farmland | | 50 | 50 | 50 |
| Regeneration of forests after cutting of thin stands or stands with unsuitable tree species[1] | Private | 70 | 30 | 30 |
| | Others | 60 | | |
| Complete measures for establishing of stands | | 50 | 30 | 0 |
| Neglected cleaning | Private | 70 | 30 | 0 |
| | Others | 60 | | |
| Thinning of stands with low timber content or small sizes | | Deficit from cutting | | 0 |
| Draining of forests and wetlands | Private | 70 | 50 | 50 |
| | Others | 60 | | |
| Supplementary planting after damage by rabbits or field mice | First | 70 | 70 | 0 |
| | Second | 90 | 90 | 0 |
| Mass invasion by insects | | 75 | From case to case | |
| Construction, rebuilding and major improvement work on forest roads | | 75 | 60 | 60 |
| Forest management plans for private properties | | About 50 | | |

[1] Furthermore, subsidies are paid to deficit from cutting.

## SILVICULTURE FEE

It is reasonable for forest owners to contribute more to financing certain national government programs. The silviculture fee is thus being raised from 0.9 to 3.0 pro-mille [per thousand] of the forestry value of their property. Attentions should be especially given to forest research and development work applicable to basic research.

## EXTENSION SERVICES

Extension services (advisory services) to forest owners are an essential method of encouraging them to manage their forests in keeping with the government's policies. Advice and information may often serve a preventive purpose, so that for formal intervention under the provisions of the Forestry Act can be avoided.

The extension services are being examined in detail by a government commission on forestry administration, which is looking at the structure of the Forestry Boards and how they should carry out the practical implementation of the forest policy guidelines that have been decided upon. The commission's report [was] expected by the autumn of 1979.

## OTHER METHODS

The contractual activities of the County Forestry Board, on behalf of forest owners and public authorities – including silvicultural and cutting work – are important. They are also being examined by the forestry administration commission.

Research and development work and education are significant methods in forest policy. A sharply increased commitment to forestry research is being made at the Swedish University of Agricultural Sciences.

The national government also helps in various ways to improve the structure of properties.

Regulation of the raw material consumption of the forest product industry continues under the provisions of Article 136a of the Building Act. These issues are being examined, among others, by a study commission on forest industry policy.

Forest taxation also has an impact on forest policy In March 1979 the Government presented a bill on restructuring of the forest taxation system and a bill on temporary stimulation of forest cutting etc.

## THE FORESTRY ADMINISTRATION

### The National Board of Forestry and the 24 County Forestry Boards

The National Board of Forestry, with its office in Jonkoping, is a central administrative authority under jurisdiction of the Ministry of Agriculture. It is responsible for the practical implementation of the forest policy established by the Government and Parliament. Its work is carried out with the help of 24 County Forestry Boards, one in each county of Sweden.

The duties of the National Board of Forestry include directing and coordinating the activities of the County Forestry Boards.

The latter are regional bodies at county level. Most of their field work and contact with forest owners take place within about 270 local districts.

### The Tasks of the County Forestry Boards:

Activities Financed by Public Funds

- implementation of the Forestry Act
- administration of subsidies for silviculture, road construction etc.
- devising forest management plans
- participation in national planning
- extension services to forest owners and others
- information about forestry

Contractual Services

- supplying seed and plants
- performing tasks for forest owners – marking standing timber, forest management plans etc.
- assistance to other public authorities – relief work, nature conservation etc.

FOREST REGENERATION IN NORTHERN SWEDEN

Per-Ove Bäckström*

## INTRODUCTION

Today, the forests in northern Sweden are primarily regenerated artificially, particularly through planting. The regeneration is exclusively based on clear felling, which had its breakthrough in Sweden after the Second World War. As far as Sweden – or roughly the northern third of the country – was concerned, extensive final felling of low-yield creamed forests started around that time. The intention was to reintroduce high-quality forests in the areas concerned by means of artificial regeneration. The creamed forests had developed as a consequence of repeated exploitation felling of the most valuable trees. In wide areas, this was the final phase of an exploitation process that had been going on for a long time. By this time, these areas simply didn't contain any trees worth saving.

From the beginning of the 1950s, large clear-felled areas became a common sight in the northern landscape. These areas were to be regenerated artificially. The annual regeneration area for the entire country is shown in Figure 1. You will notice that for the 20 years following the beginning of the '50s, the area regenerated annually kept on increasing, but today it has levelled out at about 170,000 hectares. The large-scale restoration project for the Norrland forests, which started in the '50s, led to increased regeneration activities, followed by refinement of the regeneration techniques. This refinement is a continuous activity and is still going on.

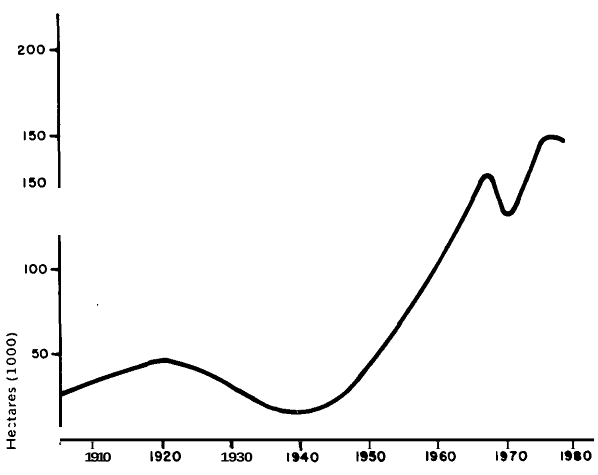


Figure 1. Artificial regeneration (ha/yr).

This means that we have experience from about thirty years of clear felling. During this period, the industrialized parts of the world have undergone technical development at a rapid pace. This has affected the development of forestry and its operating techniques, as well as society as a whole.

*Professor, Section of Reforestation, Department of Silviculture, Swedish University of Agricultural Science, The Faculty of Forestry, Umef, Sweden.

A brief rundown to show how the regeneration activities in Norrland have changed since World War II is presented here. First, there are a few key facts to keep in mind. During this period –

the area regenerated annually increased considerably every year;

the country went through an urbanization process that reduced the supply of labor for forestry operations, which are geographically dispersed;

the trend in the labor market is toward year-round employment and permanent jobs, making seasonal work less attractive;

labor costs have increased dramatically;

logging operations have been specialized. Those who work in logging are tied down to the machinery used. This means that you cannot easily move these workers to regeneration projects, not even temporarily.

In this review of the developments affecting forestry, I shall give particular attention to the changes in working techniques.

### The Seed Question

The regeneration program required large volumes of seed for seedling production and for direct seeding in the forests. To meet this need, intensive seed collection was carried out in years of good cone generation and seed ripening. Nevertheless, the seed question remained a bottleneck in Norrland, particularly at high altitudes. To tackle the problem of seed supply over a long period of time, a great number of seed orchards were established in the mid '50s. In the middle of the '70s, these orchards were producing so much seed that since then we have been able to meet our seed requirements for production of pine seedlings except in northern areas at high altitudes. But production from the seed orchards cannot cover the need for seed needed for direct seeding after soil scarification. In addition, the production of spruce seeds by these orchards is also insufficient.

### Production of Seedlings

Stepped-up forest regeneration also increased the need for seedlings. Consequently, our small forest nurseries were replaced by large centralized nurseries that could be more efficiently managed. Such nurseries were established by the forestry companies, the national Forest Service, and the county forestry boards. During the 1950s and '60s, they were all open-air nurseries for the production of bare-root seedlings. Since the beginning of the '70s, we have gradually gone over to container seedlings, and these are produced in plastic greenhouses. The entire environmental control in these greenhouses is now automated. In addition, it has been possible to mechanize many of the operations needed for the handling of the seedlings. The switch from open-air growing of bare-root seedlings to greenhouse production of rooted seedlings has reduced our labor requirements, and has evened out the seasonal fluctuation of these requirements. During the past 20 years, the nurseries have also been equipped with refrigeration systems, allowing them to deliver good seedlings during an extended planting season. About 70% of the seedlings set out in northern Sweden today are container seedlings, more specifically paperpot secdlings or what we call Kopparfors container seedling.

## Soil Scarification

As early as the start of this century, there were attempts to develop horse-drawn machinery for soil scarification. But, due to the uneven pulling load, this was clearly unsuitable for the animal. Toward the end of the '40s, units attached to tractors were developed, but there were no tractors that could operate efficiently in moraine terrain. So when the forest regeneration boom started in the '50s, there was no suitable machinery for soil scarification. Only two approaches were possible: manual scarification or controlled burning of the logging sites. In the '50s and the beginning of the '60s, large areas were burned every year. Rut, due to the large labor requirements and the need for good burning conditions, it became more and more difficult to combine burning with other forestry operations in which mechanization and detailed planning tended to set the pace of the work.

So the efforts to develop mechanized scarification techniques went on without respite. At the same time, off-road timber transport was being mechanized. This was actually the development that gave us off-road hauling machines that could be used to pull scarification equipment. This happened as we entered the '60s.

During the first half of that decade, machines were gradually taking over the scarification and smaller areas were burnt every year. When we went into the '70s, we were down to some 1,000 hectares a year. An additional reason why burning was almost abandoned was the criticism levelled at this technique and the growth of the environmental movement.

Up to the end of the '60s, patch scarifiers were exclusively used in Swedish forestry; but around that time harrow-type machines and deep cultivators were coming into use. As a result of the estensive research on soil scarification carried out in Sweden in the past seven years, we now have a variety of new and improved models. The patch scarifiers have been improved, and new scarifiers have been developed.

We are now working on active topsoil agitators and units for mounding of mineral soil. In view of the biological research results obtained from this project, additional development of scarification techniques can be expected in the next few years. During the past ten years, there has been a continuous increase in the use of scarification machinery for both artificial and natural regeneration.

## Planting

The most important forest regeneration technique in Sweden is planting. Seeding has been employed only to a modest extent for the past 30 years. In the beginning of the '50s, most planting was performed with notchers and augers, but as the techniques were refined, mattocks became more and more common. New tools came into use when we switched to container seedlings. They facilitated the physical work and resulted in improved performance. Today, the most common tool for setting out container seedlings is the planting tube. Even though the worker performance increased considerably when we switched to container seedlings, there has been a considerable increase in planting costs during the past two decades. In an effort to get out of this difficult cost situation, development of machinery for mechanized planting has been attempted. The first efforts in this direction were made as early as the late '60s at the Royal College of Forestry. During the '70s estensive analyses and studies of the prerequisites for mechanized planting were carried out by the Logging Research Foundation. This also encouraged a few Swedish machinery manufacturers to start development work on their own.

All this resulted in prototype units that have been tested in trial operations. But as yet, there is no planting machine in commercial operation in Sweden.

So what are the reasons why no practical results have been achieved in spite of these extended and intensive efforts? One reason is the technical difficulties involved in building a machine for coordinated scarification and planting in moraine terrain. Another important reason why we haven't made much progress is, as I see it, the fact that the rather limited market for these machines tends to restrain the manufacturers from making really forceful efforts. Even though the development of mechanized planting is now two years behind the plan prepared by the Logging Research Foundation when it started its research and development project in the early '70s, it is reasonable to expect a breakthrough for mechanized planting during the first half of the present decade.

## Seeding

During the 30 years I am reviewing here, only a small proportion of our forest regeneration activities has involved seeding. But in the past few years, interest in this method has increased quite a lot. One reason for this is the work on "protected seeding" using small plastic cones carried out at the university here in Umeå. Another has to do with the expectations of the type of seeding called drilling, carried out behind a continuously operating soil scarifier. A number of units for drilling in combination with scarification have also been developed in the past few years.

## Biological Result

The large clear-felled areas, forestry techniques such as burning and deep cultivation, and chemical techniques used to clean up the areas have all given rise to widespread concern. In particular, questions have been raised about the effects of clear felling at high altitudes and under heavy wind exposure. It is now clear that these misgivings were not totally without justification. The results of forest regeneration are not always as good as we might wish.

The difficulties of generating new forests are greatest in areas where the climate is least favorable, that is, the western parts of our interior regions, particularly at high altitudes. Several regeneration projects failed in these areas in the '50s and '60s. The primary reason for this was the fact the pine seedlings used did not have the proper provenance. So the rules on moving pine seedlings have been tightened. Today, we know enough about these things to be able to prevent the use of inappropriate seedlings based on their provenance. But since the provenance shifts are from north to south, and from high to low altitudes, we have no pine seeds of suitable provenance for the northernmost parts of Norrland and for high altitudes.

There are two other fields where we simply didn't know enough to prevent regeneration failures. One is the change of local climate brought about by final felling. The climatic effects in some of the clear-felled areas have been large enough to make regeneration quite difficult. In extensive areas in northern Sweden, we have to cope with weak, so-called *degenerated* soils. These are usually the result of repeated forest fires during the past century. The difficulties this entails for the regeneration activities were not always taken into account during the final felling.

We are now working on the solution to these problems. And with all the other efforts made to increase our knowledge about forest regeneration in general, we are fully justified in feeling optimistic about the future of Norrland's forests. Now, this does not mean that I think that all problems have been solved, but it does mean that with proper use of what we know, and with reasonable efforts, we should get reasonable results in the future.

## Research

During the period I have discussed, the resources of the research institutes have been successively expanded. Even so, the present situation in forest regeneration is such that we should, and we want to, do a lot more that our resources allow. Strengthened research and development efforts are needed across the spectrum. Let me end by bringing to your attention a handful of areas where I feel that increased efforts should be of special significance for forest regeneration in Norrland.

1. We must improve our understanding of the change in local climate brought about when a stand is clear-felled. We already know a lot about this, and this knowledge must be taken into account when final felling is planned and preparations are made for ‘regeneration.

2. We must improve our understanding of the opportunities to use scarification techniques for encouragement of seed germination and seedling rooting and growth. The long-term production effects of various scarification methods must be assessed.

3. The work on the development of seeding techniques should be kept up. If mechanized seeding can be economically and biologically successful, this should be a cheap regeneration method in areas where the problems of seed supply can be solved.

4. Considerable efforts are needed in seedling production. We need biologically adequate seedlings that can be used during an extended growing season, and can be adapted to various planting systems. Among other things, the seedling systems must be more efficiently adapted for mechanized planting.

5. In spite of the difficulties we have encountered, the work on mechanized planting must be kept up and, if possible, intensified. As I see it, mechanized planting is the most important opportunity for coming to grips with the cost increases in forest regeneration in a long-term perspective.

6. Efforts to solve the problem of seed supply are urgently needed. In particular, this concerns pine seeds for climatically difficult habitats. To meet future needs for forest regeneration materials for these habitats, the efforts on seed supply must be combined with breeding to improve the hardiness of our domestic species, as well as the possible use of imported species.

7. Birch and aspen present great problems in all regeneration work, due to their fast-growing stump and root shoots. At present we are not allowed to use chemicals in the fight against deciduous thickets. Similar restrictions against chemicals can be expected in the future. This means that there is an urgent need for research efforts aimed at the development of better methods for the fight against deciduous trees, both biological and chemical, since the costs for manual cleaning are becoming prohibitive.

SITE PREPARATION

Vadim Soderstrom*

## INTRODUCTION

If you are a good gardener, you know very well that you must treat the soil very carefully before planting or sowing in your garden at home. If you are a bad gardener, your neighbor perhaps is a better one, so you can study how he prepares to plant a tree, perhaps on a lawn.

He takes the grass away and digs a hole. He fills up the hole with some loose soil, perhaps turf of some other soil which can hold water as well as permit a good circulation of air and carbon dioxide. He mixes the soil in the bottom of the hole with nutrients. Then he plants the tree and makes a heap of bare soil around it. Why does a good gardener make so many preparations before planting?

The answer is that he wants to give the seedling or the tree a good environment, ***primarily*** so that it will be established as firmly as possible, and ***secondly*** so that it will grow as well as possible.

Why doesn't the forester treat his seedlings in the same careful way? The fact is that the forester – at least in Sweden – wants to use this very careful soil treatment before planting, but if one is planting about 2,500 seedlings per hectare (that is somewhat more than 1,000seedlings per acre) it will be a very expensive luxury.

### A Short View Back

In the beginning of the century, however, when labor was comparatively cheap, we made some very careful soil treatments before planting. Figure 1 illustrates one of the most intensive methods. On a plot, 40 by 80cm, they cut away the turf. Then they dug out the mineral soil from one half of the plot and put it in a pile on the other half. The turf then was laid upon the mineral soil pile in order to inhibit evaporation. The grass side was placed against the mineral soil. The method was called "planting in a mound" and was used in the beginning of this century. It was a safe method but also, of course, very expensive.

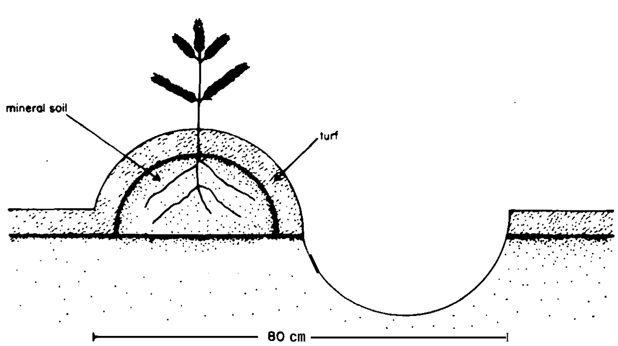


Figure 1.

*Professor, Section of Reforestation, Department of Silviculture, Swedish University of Agricultural Science, The Faculty of Forestry, Umeå, Sweden.

### Soil Treatment for What?

In Sweden we have used soil treatment of different kinds for three purposes, namely in connection with –

1. natural regeneration;

2. direct sowing;

3. pianting.

My intention is to speak mainly about soil treatment in connection with planting. However, I also want to say some words about soil treatment in connection with natural regeneration and direct sowing.

## SOIL TREATMENT TO FACILITATE NATURAL REGENERATION

In order to facilitate natural regeneration, we use some kind of scarification in patches or strips. The main purpose of this is to expose the mineral soil to the seed. Figure 2 (next page) shows the result of a regeneration study in stands of seed trees over the whole country. Each column represents the regeneration result expressed in plants/ha on a sample plot. The upper figure shows the number of plants on sample plots without scarification, while the figure below gives the number of plants where scarification has been done. The regeneration result has become considerably better with than without scarification.

This kind ***of*** site preparation has given very good results if the other conditions are good. For best results it is necessary that –

1. the climate be good enough for a good seed production;

2. the number of seed trees be 50-100 per hectare (20-45 per acre); use only pine;

3. the surface vegetation be sparse so that it doesn't disturb the seedlings.

Controlled burning in connection with natural regeneration has been used in Sweden to a very small extent.

## SOIL TREATMENT BEFORE DIRECT SOWING

For direct sowing, we also have used patch or strip scarification. Broadcast sowing on the undisturbed humus layer or after controlled burning, but without further scarification, has been used to a very small extent in Sweden. The main reason is lack of seed.

For only the past three or four years, we have been trying to sow seed in plastic funnels applied to the undisturbed humus layer. This method is still in the experimental stage, but some results are definitely promising. This method should be preferred on very difficult terrain sites, where any form of scarification is impossible.

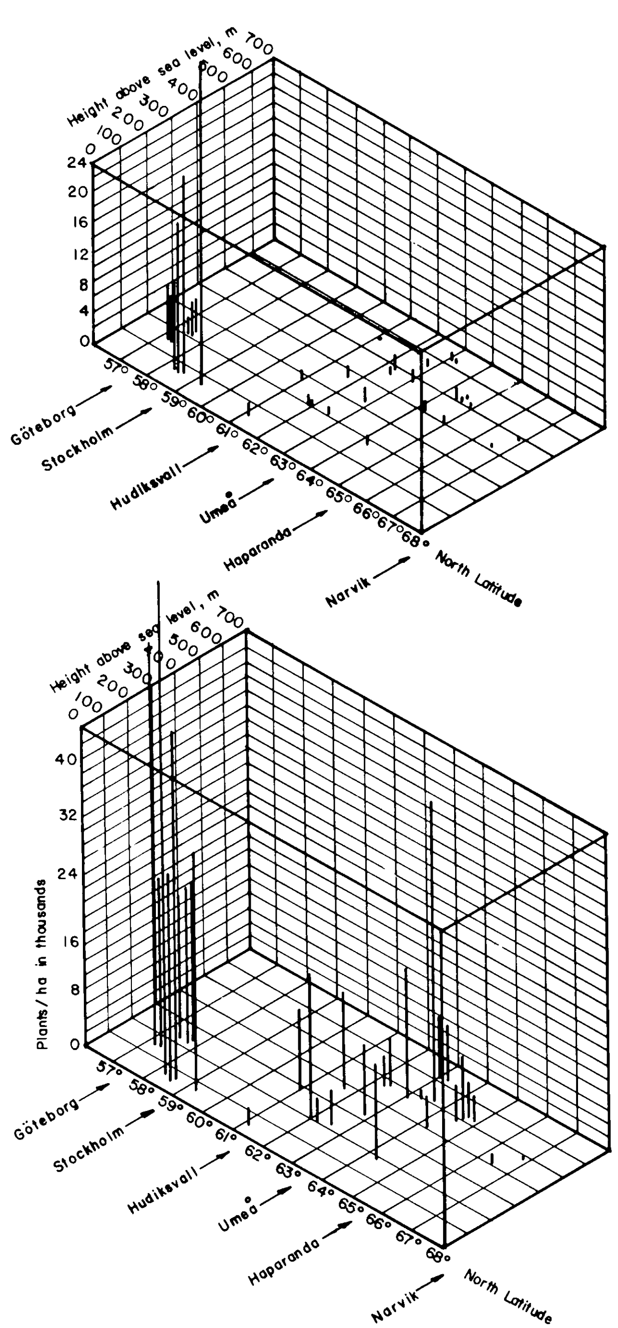


Figure 2.

## SOIL TREATMENT BEFORE PLANTING

### The Goal in Practice

**As** I mentioned earlier, the forester cannot prepare the soil as thoroughly as the gardener can. The forester has to find a method which –

1. is very cheap;

2. can be used on a large scale;

3. works.

The goal ought to be to make the soil treatment so good that every seedling gets a perfect place for establishing and growing. But in practice, the goal has to set much lower. We must try to get as many very good patches as possible. If we reach 80% very good patches on an easily treated soil, we ought to be very happy.

### Something about the History

**A** long time ago we scarified with hand tools especially constructed to remove the humus and vegetation layer in patches (30cm square) or strips (15 by 80cm). Our experience since that time indicates that a very simple scarifying gives a good result.

Since the beginning of this century, we have used a lot of different patch scarifiers. About 1950, we began using these tools on a large scale. At that time, we had some tools drawn by horses, which imposed a great cruelty to the animals as well as to men.

Then we began to use tractors, which permitted us to scarify on a much larger scale. Today we scarify about 200,000 hectares per year. Many patch scarifiers are still used. About 10 years ago, we started to use harrows. They make long, naked, mineral-soil strips about 30cm wide.

### Controlled Burning

During the period from about 1930 to 1965, we used controlled burning, especially in north Sweden, where the raw humus layer was especially thick and was broken down very slowly. About this time however, the labor costs grew very fast and mechanization in our forests increased rapidly. That meant that we didn't have workers enough for the controlled burnings.

### Plowing

The controlled burning on soil with a very thick humus layer was now replaced by plowing with very big plows. This method was a very large step forward. The soil was heavily damaged by this plowing, and public opinion was against it as well.

### Research about the Environmental Factors

About 1950, we began to discuss how to control the environmental factors. And we began to investigate them one by one.

Our research showed that –

1. the optimum water content in the ground was, especially on mineral soils, much lower than we had thought;

2. there will be a lack of oxygen on more soils than we had believed;

3. the soil temperature was much lower than optimum. For spruce, the optimum soil temperature is about 20°C, for pines as high as 25-30°C;

4. in the scarified patches the seedlings very often drowned, especially in the spring flood and after heavy rains;

5. it seemed very important that the soil be loose.

What importance, then, has the fertility of the soil? It is readily apparent that, during the establishment phase, the fertility of the soil has no importance at all. What is very important, however, is that seedlings are well fed in the nursery.

In the late ‘60s, when we began to use the plowing, we started investigating the environmental factors in connection with this kind of treatment. We found that the plowing gave a much better combination of environmental factors (see Figures 3, 4 and 5) than did patch scarifying as evidenced by plant height at age four years (see Table 1).

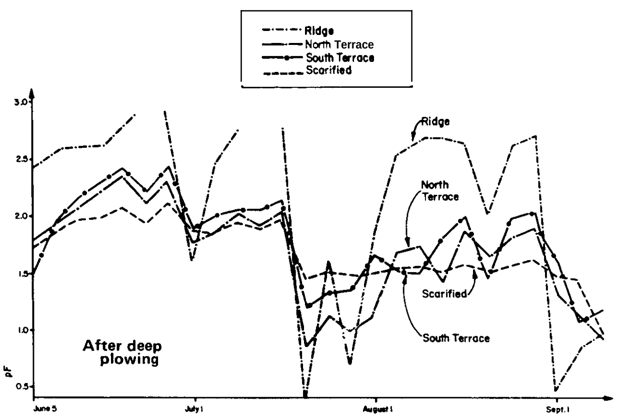


Figure 3. Soil moisture at 10cm depth, expressed as pF values* during the summer of 1973.
*The logarithm of the negative pressure (tension, or suction) head in centimeters of water. (Schofield, R. K. 1935. The pF of the water in soil. *Trans. Intern. Cong. Soil Sci.* 3rd 2: 37-48.)

Table. 1. Planting Experiment Established 1970. Planting Material: *Pinus silvestris* 2/1* bare-root.

| | Patch scarification | Deep plowing | | |
|---|---|---|---|---|
| | | Terrace | | Ridge |
| | | South | North | |
| Soil temperature at 10cm depth the summer of 1970, average °C | 13.6 | 13.4 | 15.4 | 17.4 |
| Height of plants 1974, cm | 43.6 | 46.5 | 54.3 | 60.8 |
| Plant survival, % | 92.5 | 89.0 | 91.5 | 90.5 |

*2/1: Two years in seedbed followed by one year in transplant bed.

But the plowing could not be used on a larger scale and not over the whole country. One reason I have mentioned is public opinion; the other is that plowing is such a radical operation in nature that there can be a risk of too much breaking down of the humus layer, which can result in too much leaching.

Then we tried to find some other methods for soil treatment. We guessed that mineral soil pits might best meet our needs. The first experiment we made was in southern Sweden in the spring of 1973. That year, the early summer was very dry, one of the driest we ever have had.

**As** you can see from Figures 4 and 5, the soil temperatures and soil-moisture curves corresponded well to those

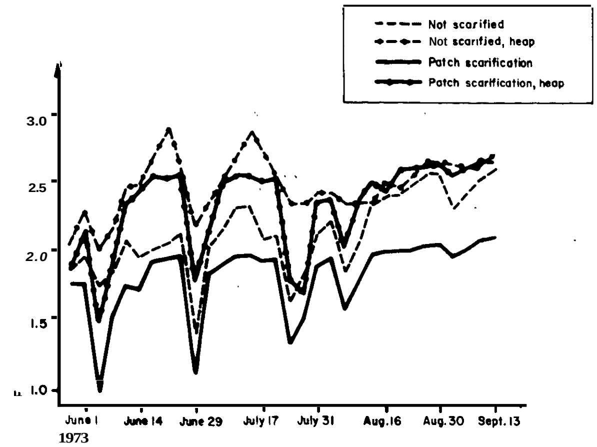


Figure 4. Soil moisture at 10cm depth, expressed as pF values during the summer of 1973.

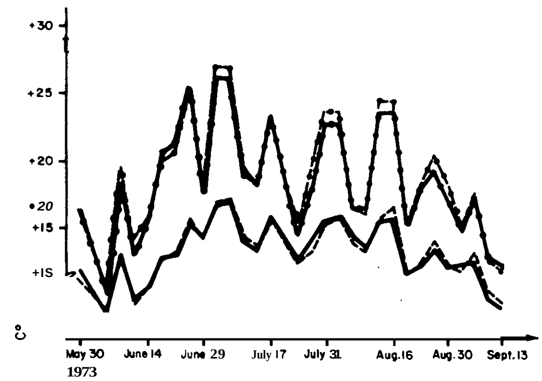


Figure 5. Daily maximum temperatures at 10cm depth during the summer of 1973.

after deep plowing. We got the highest soil temperature and the most favorable moisture and air conditions in mineral soil heaps put on mineral soil. We recorded the growth of nonlignified white roots 35 days after planting. The outstanding root-growth of the seedlings in heaps, mainly due to the high soil temperature and the moist air condition in the heaps, can be seen in Figure 6 (next page). These seedlings were very well established and the survival as well as the growth is much better for these seedlings compared with seedlings where other site preparation methods were used (Figures 7 and 8, next page).

To sum up, a good soil treatment, method provides –

1. high soil temperature;

2. a wel-drained microsite for the seedling;

3. high soil porosity which is not destroyed by the first rain;

4. scarification that does not leave seedlings standing so low in hollows that they will be covered by grass in the winter or be drowned by the spring flood;

5. Seedling surrounded by bare mineral soil, so that they will not be damaged by the pine weevil (*Hylobius abietis*).

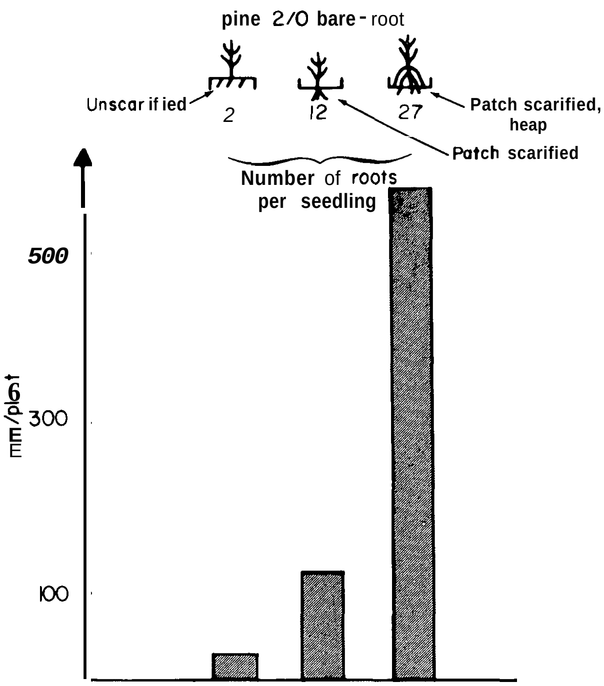


Figure 6. Root-growth 35 days after planting.

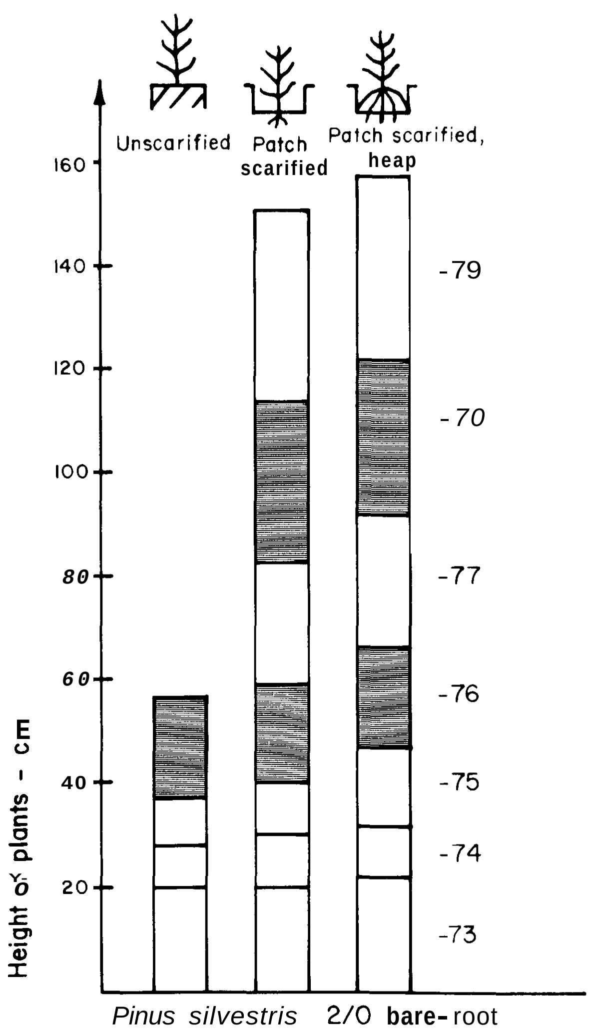


Figure 7.

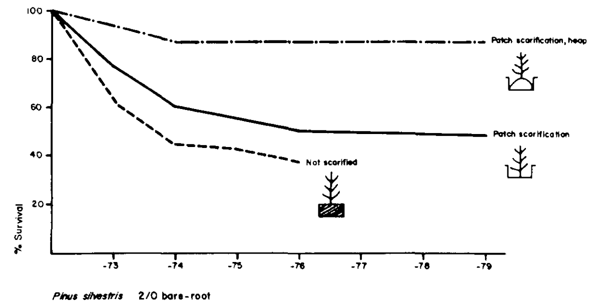


Figure 8.

# SEED AVAILABILITY, CONE COLLECTION AND NATURAL REGENERATION

Fritz Bergman*

## SEED AVAILABILITY

### Introduction

In this workshop, we are going to discuss the regeneration problems in northerly forest areas, particularly those encountered at high altitudes. In such forests, the availability of germinable seeds is determined by a number of interrelated factors. The cycle of flowering years and the weather during the actual flowering will determine the volume of cones available for collection in any given year. But the quality of the seeds in these cones is determined by the temperature conditions during the meiosis and during the extended seed-ripening period.

### Bud Initiation

Conifer buds are initiated during the growing season that precedes flowering. They are fully mature no later than at the end of the growing season (Barner and Christiansen, 1960, 1962) and often as early as the middle of the season (Sarvas, 1965). The buds can be identified on the basis of their location, shape, and size. They appear on the new shoots, i.e. in the youngest, peripheral parts of the crown, and are often bigger than the vegetative buds. The flower buds will hibernate just as the vegetative buds, and will continue to develop in the early spring when rising temperatures favor the resumption of physiological processes.

Each tree species has a characteristic cycle for the initiation of flower buds (Heikinheimo, 1932). A year of abundant flowering will produce large volumes of flower buds across wide areas, regardless of the site quality. In certain years, there may be no initiation of flower buds at all, but in most cases at least some buds will appear, although the intensity can vary depending on the region.

This means that the reason flower buds are initiated at varying times must be found in a factor that varies from year to year, but one which is more or less the same within a given region (Sirén, 1961). Obviously, one such factor is the climate, in particular the supply of energy, in this context manifested as air temperature. But precipitation and factors related to air temperature and soil moisture are also likely to be significant.

Several investigators (Hagem, 1917; Tirdn, 1936; Hustich, 1948; Hagner, 1958; Andersson,. 1965; Eriksson et al., 1975) have pointed out that the flowering cycle is largely determined by the temperature during the period when the flower buds are initiated. Brøndbo (1969 and 1970) and Remrod (1972) carried out experiments that confirmed this and showed that bud initiation in spruce grafts can be encouraged by means of plastic hoods that improve the temperature environment of the grafts.

Even though light conditions are similar over large areas, the alternation between light and darkness, photoperiodism, is highly significant to bud initiation due to the biochemical reactions it triggers in the plant (Garner and Allard, 1920, 1923, as quoted by Hillman, 1962). Forest trees can also react to changed light conditions by initiating flower buds (Stefansson, 1948a). In a 15-year provenance study in Ostergotland, Sweden, Johnsson (1955) found that pine progeny from the north tended to flower more abundantly as a consequence of the forced relocation to the southern part of the country where days are shorter.

According to a theory advanced by Klebs at the turn of the century (Klebs, 1904, as quoted by Klebs, 1913, **p.** 290), the so-called nitrogen carbohydrate quotient has decisive importance to the initiation of flower buds. An increase of carbohydrates, relative to nitrogen, will trigger abundant flowering and weak vegetative growth. One objective of the forced fructification techniques used in horticulture is to slow down the flow of assimilation products from the crown to the stem and roots. However, Bilan (1957, as quoted by Kramer and Kozlowski, 1960) found that increased light supply to the crown, caused by thinning, was more efficient than strangulation in adding to the flowering of loblolly pine, *Pinus taeda.* Kapper (1932) had previously established that among pines in southern Russia, 84-96% of the seeds were produced by the dominant trees in the stand. According to Heikinheimo (1932), 79-99% of the pine seeds came from the dominant trees. This is another indication that the trees need light, and possibly some other type of energy, in order to initiate female flowers.

The supply of nutrients from the soil is also significant to flowering and cone generation. In a study of individual trees, Heikinheimo (1932) found that the flowering of trees growing in poorer soils was less abundant than that of trees in richer soils. It has also been possible to initiate flower buds by supplying nutrients, such as a combination of nitrogen, phosphorous, and potash (Wenzer, 1953; Oxawa and Matsuzaki, 1955). In a Swedish experiment (Bergman, 1955), the flowering intensity of pine trees showed a considerable increase after fertilization with potash salt.

Sachs (1887, as quoted by Kramer and Kozlowski, 1960) suggested that there might be a flowering hormone, generated in the leaves, that triggers the creation of generative buds instead of vegetative buds. But no such hormone, called florigen, has yet been isolated. However, Dunberg (1974) believes that giberellins cooperate in the induction of spruce flower buds.

### Flowering and Pollination

To start flowering, a pine tree needs warm and dry weather. Depending on the weather, female flowering normally starts in the upper reaches of the crown half a day or a day earlier than in the other parts (Sarvas, 1962). Both the female and the male flowering will then go on without being much affected by the weather, unless prevented by extreme temperature and moisture conditions.

*Professor, Section of Reforestation, Department of Silviculture, The Swedish University of Agricultural Sciences, The Faculty of Forestry, Umeå, Sweden.

The female flowers are very sensitive to external influences. For instance, I have noticed frost damage on female flowers in seed orchards where the crowns are close to the ground, but they can also be harmed by frost in standing trees (Sarvas, 1962; Hutchinson and Bramlett, 1964; Krugman, 1966). Insect attacks can also cause wastage of flowers (Trädgårdh, 1939; Saalas, 1949; Schwerdtfeger, 1957; Annila, 1968, as quoted by Hagman, 1972).

Pollen volume and quality, as well as pollination conditions, are of significance to the success of the pollination. This is necessary to prevent the first-year conelets from being rejected, since the cones will not continue to develop unless they contain pollinated ovules. Unpollinated ovules will only develop seed wings. In addition, it is important that pollination result in successful fertilization, providing a viable seed.

Since pine trees, like all other conifers, are anemophilous, i.e. pollinated by wind-carried pollen, the weather during the actual flowering is highly significant for the size of the seed harvest. The pine pollen grain has two air cavities that facilitate dissemination. Upward air currents can carry the grains miles aloft, after which they can be spread over wide areas. If the wind blows in the same direction during the entire flowering season, there is a risk that only the seeds on the windward side of the trees will be pollinated (Sarvas, 1962). Unless an adequate volume of pollen reaches the female flower, the seed harvest will be reduced. This may be the case, for instance, after an extended rain period.

As unpollinated ovules degenerate, only their seed wings will continue to develop (McWilliam, 1959; Sarvas, 1962). The pollen can also be destroyed by rain, which saps its vitality and causes it to germinate. As Eklundh-Ehrenberg and Simak (1956) point out, "humid weather not only prevents the actual dissemination of pollen, as is already well known, but it also reduces the opportunities of fertilization by pollen already in place."

Sarvas (1962) has shown that the density of the pollen cloud is related to the number of rejected first-year conelets. A thin cloud produces more rejections. About 20 unpollinated ovules in a cone are sufficient to trigger a rejection. The cone harvest can be considerably reduced as a consequence. In one Swedish pine-seed orchard, certain clones lost up to, 95% of their first-year conelets (Bergman and Öhman, unpub.). A British clone bank reports a mean annual wastage factor of 35% of its first-year pine conelets (Brown, 1971).

Obviously, the quality of the pollen is also of great significance to the size of the seed harvest. In spruce and larch, low temperatures during the division of the pollen mother cell can result in pollen sterility (Anderson, 1954, 1965); Eriksson, 1968, 1970; Eriksson et al., 1970). Experimenting with spruce in a phytotrone, Jonsson (1974) found that the frequency of temperature-related irregularities in the pollen mother cell (PMC) varied with the severity of the climate at the original habitat of the spruce grafts from which the sample twigs had been taken. High temperatures can also cause irregularities during the division of the PMC (Andersson et al., 1969).

Brown (1971) showed that in grafted pine clones, the number of seeds (both good seeds and empty ones) declines with the frequency of nonviable pollen.

## Seed Development

The seed and the cone cannot start to develop until after fertilization has taken place. In south and central Sweden, fertilization in *Pinus silvestris* is likely to take place in the middle of June during the third growing season after flower-bud initiation (Håkansson, 1956). In Norway spruce, fertilization and seed ripening occur earlier, during the second growing season.

During the first phase of embryo development, the genetic factors will be decisive. Semilethal and lethal genes, the "genetic load," can abort the embryo at an early stage. The result of the abortion will be an empty seed (Dogra, 1967, Koski, 1971, 1973).

In the studies by Håkansson (1956) just mentioned, the embryos started to develop during the first days of July. This means that the period available for seed development is quite brief, consequently environmental influences will have a great impact on the final result. After all, the growth of the embryo and the endosperm is a consequence of genetically controlled processes whose reaction speed will, in the final analysis, depend on the supply of energy and nutrients during the summer months.

As early as 1917, Hagem showed that, to produce a germinable seed at all, a pine tree needs a mean temperature of at least 10.5°C during June, July, and August. To attain 60% germinability, it needs a summer temperature exceeding 11.7°C. Wibeck (1931) found that a mean temperature of 13°C during these three months is a prerequisite for good germinability, and that the 10.5°C isotherm for July-September fairly closely coincides with the borderline of the area where germinability is higher than 50%.

In a study of the relationship between temperature and growth, published in 1941, Mork, a Norwegian investigator, introduced a new concept called *growth unit*. This is a measurement of the heat effect, rather than the mean temperature, and it describes the relationship between the mean temperature during the six warmest hours of the day and the leading-shoot growth of the spruce tree. This mean temperature is about the same as that at 2 p.m. When the temperature reaches 8°, one gets one growth unit. With rising temperatures, the number of growth units will increase along an S-shaped curve. Several investigators (Bergman, 1960, 1976; Koch, 1968; Kardell, 1972) have found a close correlation between the summer weather, expressed in growth units, and the seed ripening in pine trees.

This method of forecasting germinability has been further developed by Alfjorden and Remrod (1975). The Swedish Meteorological and Hydrological Institute calculates the total amount of growth units at sea level during the period June 1 through August 31 every year (Figure 1, nest page). By using Figure 2 (nest page), one can reduce the number of growth units at sea level to the number at the altitude one is interested in. If one follows this value to the latitude concerned (Figure 3, next page), anticipated germinability can be found. This provides an opportunity to cancel all pine cone collection during seasons of poor germinability, or to organize such collection when the values seem more promising.

As we have seen, there is a close correlation between the temperature conditions during the summer of seed ripening and the development of the embryos. If there is no interference with this development, good germinability will result. An elegant and fast method of determining germinability by means of X-ray photography was introduced by

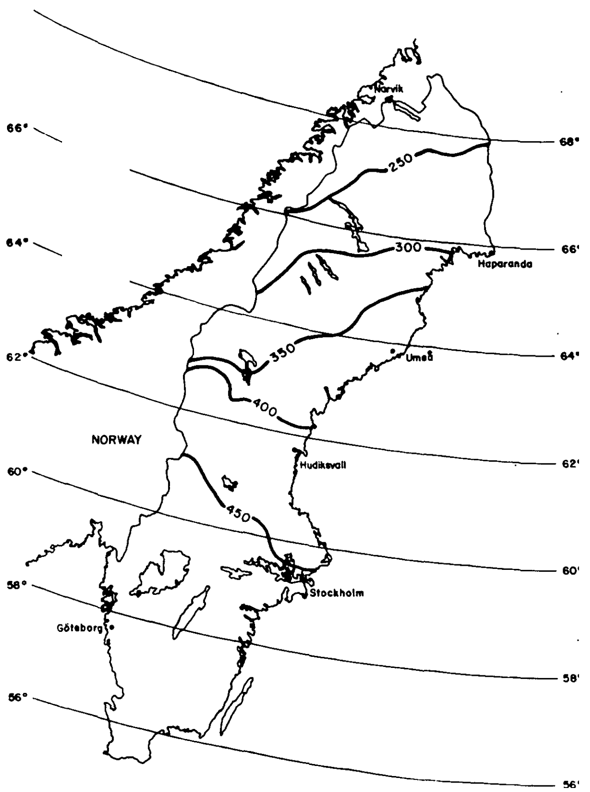


Figure 1. Sum of Growth Units 1/6 - 31/8 1975 at Sea Level (transferred from map submitted by author).

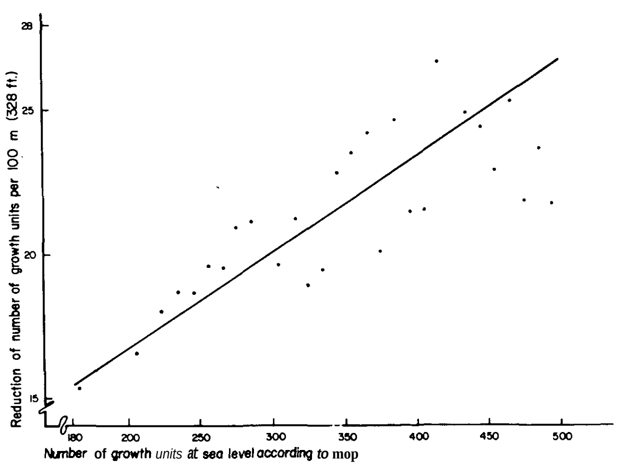


Figure 2. Diagram for reduction of the number of growth units at sea level to the number of growth units at the altitude of the area for cone collection. (After Alfjorden and Remrod, 1975.)

Simak and Gustafsson (1953a, b). The germinability in various endosperm and embryo categories can be calculated as shown in Figure 4. (Simak, 1966).

However, germinability can be seriously impaired by frost during sensitive phases of embryo development. In one interesting experiment, Simak (1972) subjected cones in various stages of development *in vivo* to temperatures below 0°C, averaging about -3.5°C for 2-3 hours. This exposure was especially harmful for seeds in the early stages of development. But it could also damage seeds that had concluded

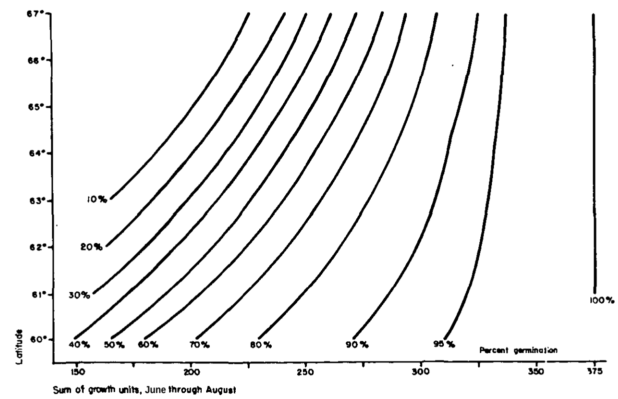


Figure 3. The correlation between the sum of growth units at a given latitude and the expected germination (%) of pine seed collected in this area. (After Alfjorden and Remrod, 1975.)

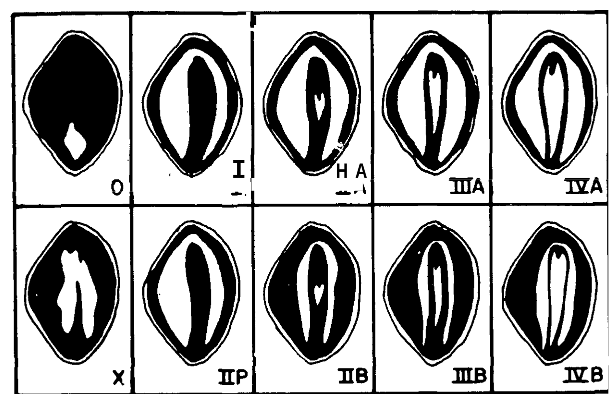


Figure 4. Scheme for classification of Scots pine seed according to Simak, 1966, p 416.

Seed classes:
0: Neither embryo nor endosperm (=empty seed).
I: Endosperm, embryo cavity developed but no embryo observed.
IIP: Endosperm, one or more small embryos the length of which does not exceed their breadth ("point embryos").
II: Endosperm, and one or several embryos, none of which longer than half of the embryo cavity.
III: Endosperm, and one or more embryos, the longest of which measures between half and three quarters of the embryo cavity.
IV: Endosperm, with one fully developed embryo, completely or almost completely occupying the embryo cavity, Diminutive embryo rarely occur.
X: Endosperm shrunken and of very low X-ray contrast. Embryo cavity poorly developed or not formed. No embryos observed. All seeds in early stages of development belong to this class, The class X has been used only in this study.
Endosperm: A: The endosperm almost fills the seed coat to capacity and absorbs the X-ray well. B: The endosperm only fills the seed coat incompletely and is often shrunken or otherwise deformed. The X-ray absorption is inferior to that of class A.
The germination percentage of the seed classes tested in Jacobsen's apparatus is: O, I, X and **IIP** = 0; IIA = ***50*, IIIA** = **88;** IVA = 99; IIB = **5**; IIIB = 43; **IVB** = 68.

their anatomical development, but were not fully developed physiologically. This led Simak to the important conclusion that "the reason behind the poor seed quality in northern Sweden is not only the low temperature total during the years of ripening as such, but also the frost that may occur during a sensitive development phase of the embryo, if the embryogenesis has been delayed." (Simak, 1972, pg. 24)

Seeds that have fallen behind in their development due to low summer temperatures can improve their germinability through *after-ripening*. Nordstrom (1950) established that green cones picked in the autumn and allowed to after-ripen at room temperature yielded seeds with considerably better germinability than cones picked in the winter. In other words, an improvement in ripening conditions occurring late in the year of ripening can, to some extent, offset the ill effects of delayed ripening during an unfavorable summer (Asplund et al., 1973; Kardell, 1973b).

Since temperature has such a great influence on the ripening process, the location of the cone in the crown can be highly significant, particularly during summers with abnormally low temperatures (Acatay, 1938; Bergman, 1976). Figure 5 shows an example of germination energy and germinability at the south and north sides of two sample trees during the autumn of 1956 and spring of 1957. **As** a consequence of the low temperatures during the summer of 1956, the germinability at the north side is between 40 and 60 percentage units lower than at the south side. The germination energy, the thousand-grain weight of the seeds, and the extraction properties of the cones are also poorer on the north side of the crown.

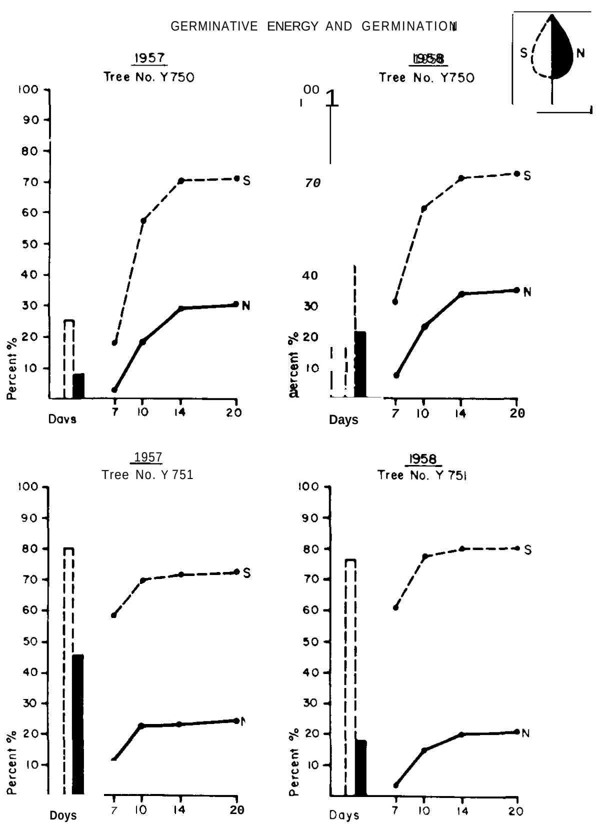


Figure 5. Germinative energy 7/20d (columns) and the rate of germination of seeds from the south (S) and the north (N) side of the crown of the sample trees Y 750 and Y 751. Sundmoberget. Collection November 5-7th 1957 and February 26-27th 1958.

Using Jacobsen's germinator, you can even see clear differences between seedlings from different parts of the crowns after only seven days (Figure 6).

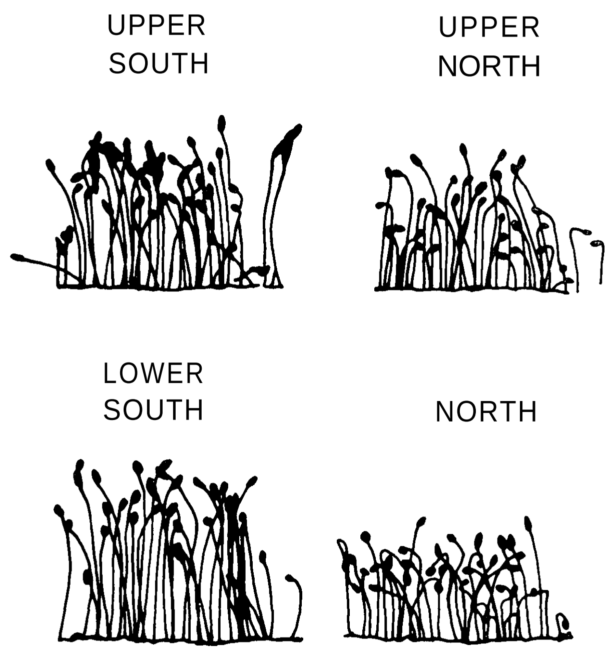


Figure 6. Seedlings originated from the upper south, upper north, lower south and lower north side of the crown after 7 days in Jacobsen's germinator.

**As** you can see, it is highly important that cones are collected only in years of adequate seed ripening. If they must be picked when poorer germinability is expected, collection should be restricted to the south sides of the crowns. This can be facilitated by felling the trees toward the north, exposing the south side of the crowns.

## CONE COLLECTION

### Background

Until recently, cones were collected primarily from the tree tops left over from logging operations. In northern Sweden, large-scale cone collection from standing trees has been carried out only once. At the moment, our seed orchards cover about 850 hectares, but this area will be doubled in the next generation. In 1977, Swedish seed orchards supplied 44% of our needs for pine seeds for plant production, whereas the spruce seed orchards did not cover more than 7% of the nurseries' needs. In consequence, we still have to import a lot of seeds, or collect them from logging waste.

### Cone Collection in Seed Orchards

#### Collection Platforms

Cone collection in seed orchards is facilitated by the fact that the ground is usually level, having no steep slopes. During the first 25-30 years, the height of the pine grafts can be kept down by pruning in order to make the crowns accessible for collection by means of various lifts.

One type of lift is a self-propelled power ladder. It is intended for operation in fairly flat citrus orchards, and its rather small wheels make it unsuited for operation in deep snow. The Israelis have developed two models of this type of lift: one with a lifting reach of nine metres and a smaller unit with a reach of 6.5 metres. Using this device in a pine-seed orchard, an experienced picker can gather about 150 litres (40 U.S. gals.) of cones during a seven-hour work shift.

There are several power ladders intended to be carried by tractors. One is a Swedish lift with hydraulically telescoping platforms that can surround the graft. Mounted on an ordinary farming tractor, the platform enables you to pick at a height of 6.5 metres, but mounted on a loader its reach will be just over 7 metres. Swedish authorities have approved the platform for use by two pickers, who will gather 300 litres (80 U.S. gals.) per work shift.

By substituting the platform for the bucket of a hydraulic excavator, you get a heavy carrier unit that gives you a chance to pick cones at a height of 9-10 metres. The market also offers lifts to be mounted on carts that can be pulled in off-road transport and allow collection at 9-10 metres with two people on the platform. One of these models can also be mounted on a heavy carrier, providing a reach of 12 metres.

### Collection Tool

When collecting cones in seed orchards, care must be taken to see that grafts are not damaged, since this can spoil next year's cone harvest. Mo och Domsjö AB, a Swedish forest company, has developed a collection tool consisting of a glove with a sharp edge. The edge will cut the cone stalk thus sending the cone into a collection bag carried in a belt around the waist. The glove can be adjusted for different cone sizes. For instance, it is highly suited for picking on Lodgepole pine.

## Cone Collection from Standing Trees

### General

Cone collection from standing trees is carried out primarily to secure the supply of seeds in areas where there is not enough logging waste to meet the need. Another objective of such collection may be to improve the germinability of a valuable seed harvest by collecting the cones early in the autumn and then using artificial after-ripening. In addition, genetic considerations might prompt collection from individual trees or stands especially selected for seed harvesting.

### Collection From the Ground

Winter collection has been tried. The picker moves along on skiis and uses a special tool attached to a 3-to-5-metre-long handle. This kind of picking was quite successful up to a height of 6 to 7 metres. With experience, it was possible to perform almost as efficiently as when picking from felled trees. However, the stand must be suitable for this kind of picking; preferably a young forest with an ample cone supply within 6-7 metres from the ground (Carlborg, 1961).

### Picking in Tree Crowns

A time study involving cone picking in a stand of pines, 18 to 20 metres tall, was carried out in northern Sweden during a year of high cone yields (Hagner and Bergman, 1961). The participants were highly experienced pickers using *Baumvelo* climbing irons of Swiss manufacture. These were used to reach the crown, after which it was possible to use the branches as support. The climbers were equipped with life belts and a lifeline running around the stem during all work in the crown. The actual collection started in the top of the tree and was carried out by hand without any special tools. Skiis were used to move from one tree to the next.

In trees with ample cone growth, the collection performance was comparable to that of skilled ground pickers. The collected volumes were highly dependent on cone size. With an average cone size of 120-160 cones per litre, the performance of the tested, skilled workers might reach 45-60 litres a day. The climbing time was between 15 and 23% of the total working time, while the actual picking took up most of the total time by a wide margin, normally between 75 and 80%.

## Cone Collection from Felled Trees

### Background

We cannot expect seed orchards to provide most of Sweden's need for seeds until a few years into the next century. Direct seeding of pine seeds is expected to increase in Sweden during the next few decades, thanks to the new combinations of scarifiers and mechanized sowing equipment.

A study carried out by Skogsarbeten (Gustafsson, 1980) shows that the demand for pine seeds collected from standing trees will increase from 2 tons today to 6 tons a year during the 1980s (Figure 7). Since only an insignificant share of this need can be gathered from standing trees, we will be left with logging waste as the primary seed source during the next few decades.

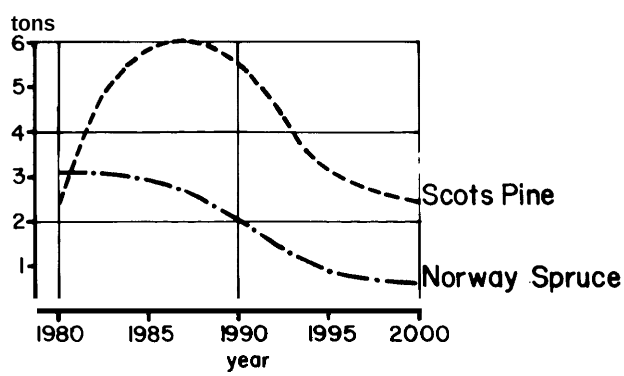

Figure 7. The total need of seed collection in stands in Sweden 1980-2000. (After Gustafsson, 1980.)

### Collection from Felled Trees

This is the traditional method, which provided most of the seeds used in artificially regenerated stands in the past. The trees were cut down by hand, and since the smallest usable top dimension was bigger than it is today, a substantial crown portion was left behind. Most of the cones are in the top,, and after the crown had been turned around it could easily be picked clean. A special hand tool was developed to improve collection efficiency: the SFI conepicker (Figure 8).

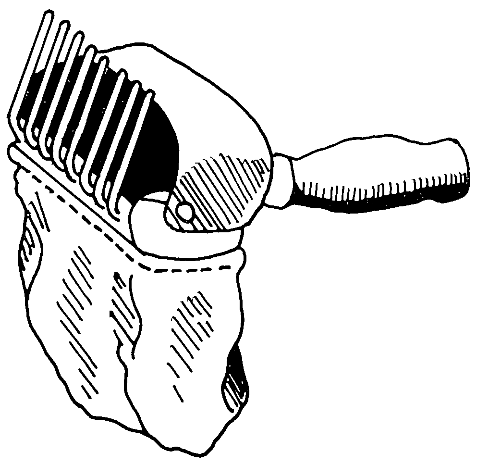

Figure 8. The SFI combrake. (After Gustafsson and Jakobsson, 1980.)

This tool increased performance by 20-30%. Hagner and Callin (1959) have presented tables that document the number of trees per hectare and the average number of cones per tree. In 1962, the same authors published corresponding documentation for spruce.

In Sweden today, the degree of mechanization of final felling is 60-70%. The mechanization is espected to continue during the next few years. By the end of the 1980s, the degree of mechanization of final felling is expected to reach 80%. This means that, in the future, a growing proportion of the cone collection must involve stands that have been felled by machines.

To get an idea of the collection opportunities after mechanized felling, Skogsarbeten carried out a time study of the collection work. Cone collection from entire trees behind a feller-buncher was first studied, (Figure 9). Efforts were made to fell the trees with the south side up, clearly separated from each other, and as gently as possible to keep

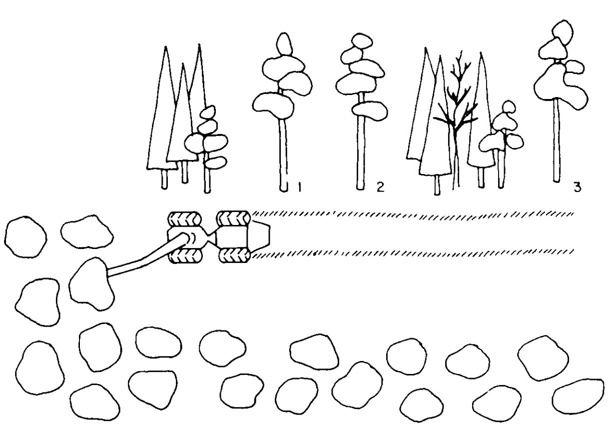


Figure 9. An example of the arrangement of trees with feller-buncher. Trees No. 1-3 were sample trees in the investigations. (After Gustafsson and Jakobsson, 1980.)

down cone wastage. A second phase of study involved cone collection in heaps of branch wood left behind by a limber-slasher (Figure 10).

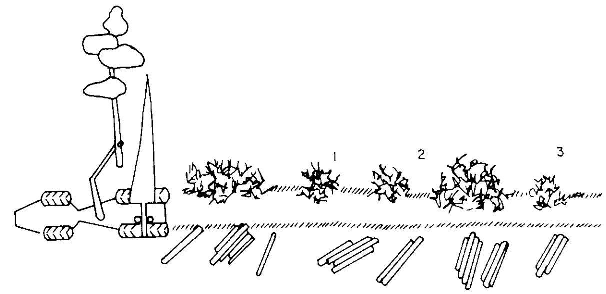


Figure 10. An example of the arrangement of the heaps of branches left behind by a limber-slasher. (After Gustafsson and Jakobsson, 1980.)

The results of the study indicate that, in many cases, there is an advantage to collecting cones behind logging machinery, since this allows you to prepare the collection more efficiently than after manual felling (Gustafsson and Jakobsson, 1980). Nor does collection in logging waste seem to present a problem, as long as the heaps are not of excessive size and do not contain too much slash from trees with a poor supply of cones.

### Future Prospects

As yet, there have been no attempts to mechanize cone collection in logging waste, or slash, in the Nordic countries. But the Canadians, among others, have tackled this problem even though technically and economically feasible approaches not have been reported so far. According to Gustafsson and Jakobsson, the problem is to find suitable routines for planning and organization of the collection activities. To encourage individuals to participate in manual collection, it might also be worthwhile to review the taxation rules applied to earnings from berry and cone picking.

## NATURAL REGENERATION

### Introduction

Natural regeneration, sometimes also referred to as self seeding, has traditionally been of considerable importance to forest regeneration. During the five-year period 1973-1977, natural regeneration was applied to about 30% of the regeneration areas in Sweden's large-scale forestry operations, i.e. crown forests and corporation forests, as well as almost half of the country's farm forests.

The normally used technique for natural regeneration is to leave a few seed trees behind after final felling. These trees are intended to seed the area. For this purpose they should be sturdy, storm-resistant trees with full crowns providing an adequate supply of cones.

Pine and birch have deep roots and are well suited as seed trees in open areas, fully esposed to the winds. Spruce, however, has superficial roots providing less reliable anchorage. For this reason, spruce self seeding is normally used only around the edges of a stand and in gaps. It can also be regenerated through natural regeneration under a fairly dense shelter of trees, retaining the basic stand characteristics.

The chances of obtaining good results from natural regeneration from seeds depend on –

1. seeding abundance
2. seeding quality
3. regeneration receptivity of the soil

These factors, in turn, are influenced by –

1. habitat climate
2. habitat geology
3. habitat water situation

Seeding

The quantity and quality of the seeding depends, as pointed out earlier, on the climate. Areas with high summer temperature and a long growing season will produce more high-quality cones and seeds. This means that the latitude and altitude of the regeneration area are of major significance to the success of the natural regeneration (NR).

Figure 11 shows cone production per tree (Scots pine and Norway spruce) in various parts of the country below and above 300 metres above sea level, respectively. As you go north, spruce-cone production tapers off faster than does pine, but this does not apply to habitats at high altitudes. Consequently, spruce trees at the 56°N latitude will produce more than six times as many cones than those at the 66°N latitude – as long as they are lower than 300 metres above sea level.

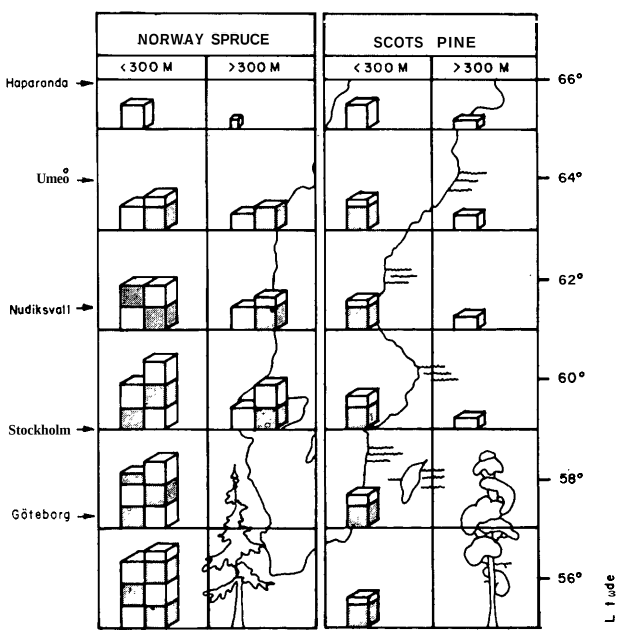


Figure 11. Relative cone production per tree in stands, related to cone volume at 66°n, <300 m.a.s.l. (After Simak, 1974.)

**As** already noted, cone generation is highly dependent on the weather at the time the flower buds are initiated, i.e. the year before flowering. This means that the production of seeds will normally be spread out more evenly in different years in habitats with a more favorable climate than is the case in habitats with a poorer climate. Even thous no specific cycle of rish seed years can be identified, such years are considerably more frequent in northern Sweden than in the south. It should be mentioned that the seed production in pine seed-tree stands is more even than that of spruce seed-tree stands. In addition to the poor storm resistance, this is another reason to avoid seed-tree stands of spruce.

The seed production per tree, and to some extent per area unit, can be increased by scattering the seed trees (Figure 12).

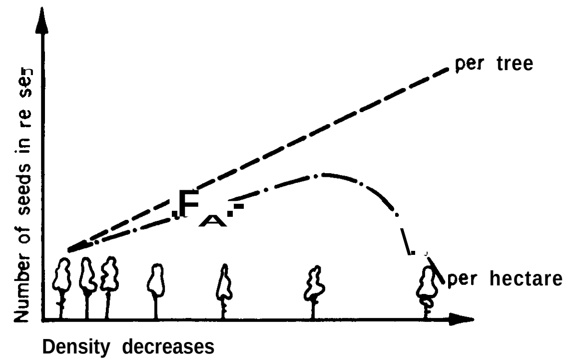


Figure 12. Seed production in stands with different density (x axis = density decreases, y axis = seed production increases). (After Simak, 1974.)

The seed production per tree will increase in proportion to the openness around the tree. This means that, in a seed-tree stand of modest density, the seed volume per hectare will be higher than in a dense stand. In a very scattered stand, however, the total production per hectare may be lower even though each tree may rpoduce more seeds individually.

In addition, the seed production per seed tree will be greater in proportion to the duration of the seeding (Figure 13). Spruce trees show a modest rise, pines considerably more, and birches display the most dramatic increase.

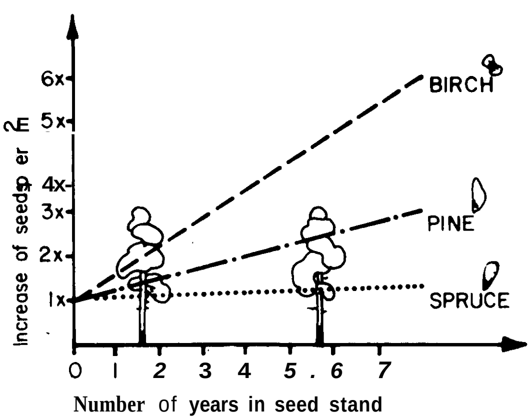


Figure 13. Increase of seed production/$m^2$ in a stand of seed trees compared with that in a normal stand (= 1x) during 8 years. (After Simak, 1974.)

Whereas the *seed volume* is largely determined by the temperature conditions the year before flowering, the *quality* will be determined by the temperatures during the summer and autumn when the seed ripens. In southern Sweden, seeds tend to ripen quite well, and show good germinability. But in the north, the seed quality is highly dependent on the temperatures during the summer of ripening (Figure 14). This diagram represents the germination percentage of mature pine seeds, gathered at various latitiudes and altitudes in northern Sweden during 1955-1956. The shaded part of the circle represents the germinability percentage.

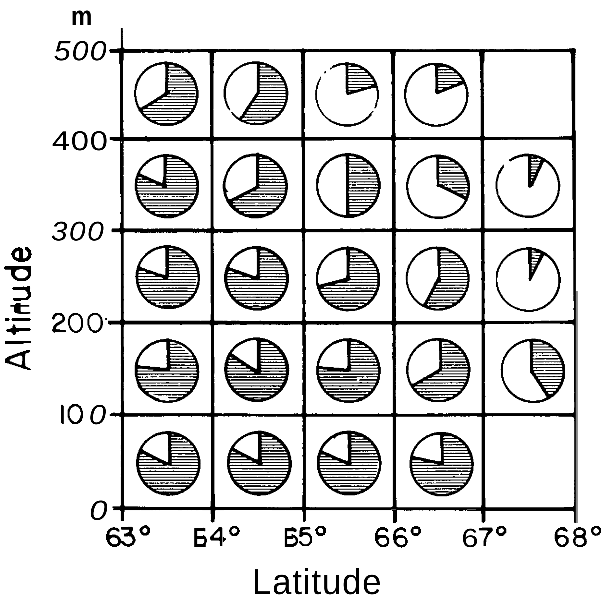


Figure 14. Germination percentage of filled Scots pine seed collected in 1955/56 in northern Sweden (whole filled circle = 100% germination). (After Simak, 1974.)

In northern Sweden, the seed quality can vary from one tree to the next. It will be better in seed-tree stands than in closed stands. In addition, the germinability of the seeds will be better on slopes facing south than on those facing north, and also – as we have seen – on the south rather than the north side of the tree crown.

Two successive summers with warm weather is a prerequisite for natural-regeneration success – one summer when the flower buds are initiated and one when the seeds ripen. At high altitudes in northern Sweden, the chance of this happening is quite small. For this reason, foresters have often applied an altitude limit above which they don't find it desirable to leave seed trees. At the 64°N latitude, this limit runs around 300 metres above sea level. It drops to a lower altitude as one goes north (Tirén, 1949).

A few words about *seed dissemination.* Spruce and pine cones open and release their seeds in early spring. Since the seeds are equipped with wings, they won't fall straight down but will be carried by the wind some distance away from the tree, Figure 15. But most of the seeds will not travel further away than 9-15 metres from the tree, maybe twice as far if carried by a strong wind. You cannot expect efficient seeding more than 20-31 metres away from a seed tree.

To obtain as even dissemination of the seeds and as rich seeding as possible, the practice in southern Sweden is to leave at least 50 seed trees per hectare. In northern Sweden, the figure is 80-120 seed trees per hectare.

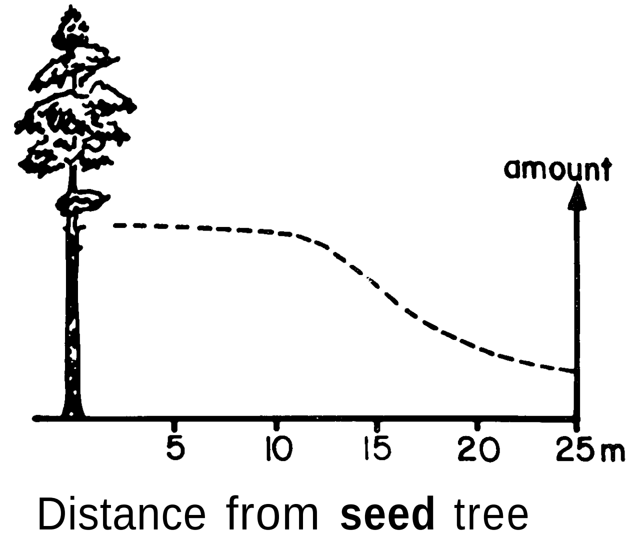


Figure 15. The seeding from a seed tree of Scots pine and Norway spruce decreases essentially with increasing distance from the seed tree (After Soderstrom, 1979.)

Scarification

The *soil receptivity* for regeneration primarily depends on the composition and abundance of ground vegetation, the thickness of the humus layer, and the moisture of the soil.

The number of seeds that can be received by the soil and start germinating is inversely proportionate to the density and vitality of the vegetation. In areas with a thick humus layer, the small seedlings will suffer from heavy competition for light, nutrients, and water (Figure 16). Thus,

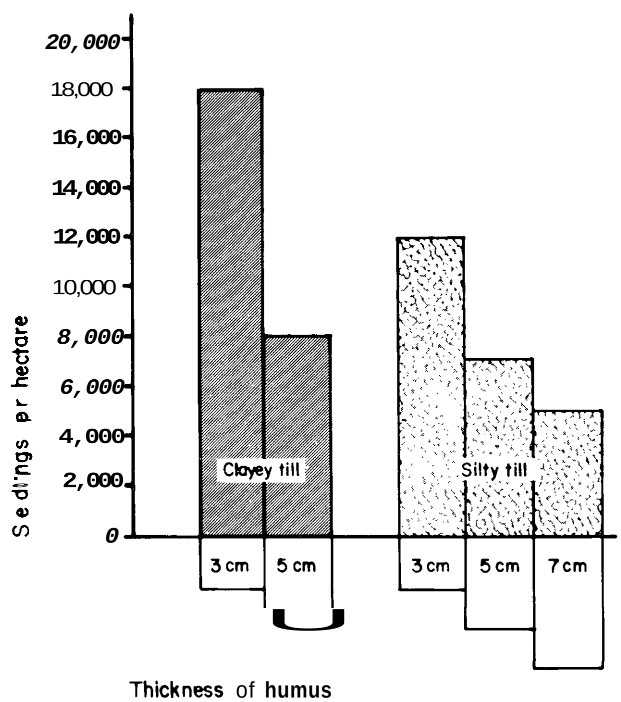


Figure 16. The number of seedlings per hectare at different thickness of the humus layer on two soil types (After Soderstrom, 1979.)

increasing lushness on the ground will reduce the regeneration opportunities. This figure shows the number of plants per hectare as documented in a study made by Soderstrom in central Jamtland **(1979).**

In southern Sweden, this is an impediment that is difficult to overcome in almost all good soils. If the ground vegetation consists of blueberries and lingonberries, you can obtain NR, provided that the seedlings are given some assistance. You simply tear up the humus layer exposing the mineral soil. This used to be done in a patchy sort of way, first with hoes, and later with plot-scarifying units. Today, the soil in seed-tree stands is most appropriately prepared with a scarifier of the harrow type (Figure **17).** This will leave an exposed surface that is much larger. Consequently, more seeds will be given a chance to germinate and develop into viable plants (Figure **18).**

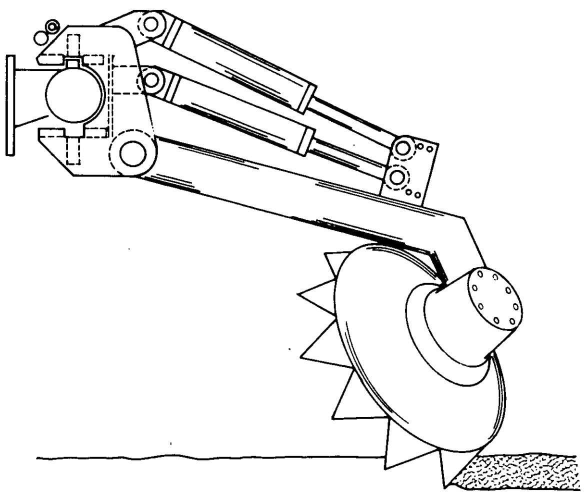

Figure **17.** Harrow-type scarifier.

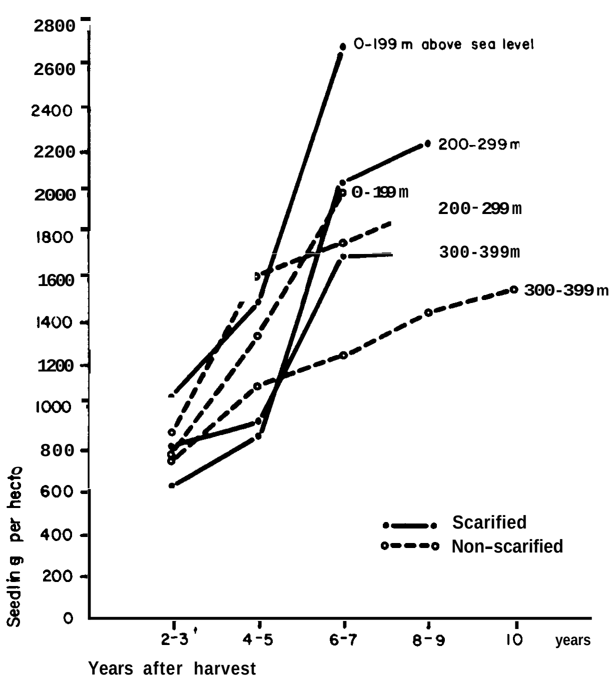


Figure **18.** The result of natural regeneration by means of seed *(Pinus silvestris)* in scarified and nonscarified stands. (After Bergman and Andersson, **1968.)**

It is important that the scarification of a seed-tree stand is carried out immediately before a good seed year. This is because it remains effective for only a few years. After six or seven years, the vegetation will have returned to the exposed areas. You are back to where you started, with heavy competition for the seedlings.

## Disposal of Seed Trees

When new plants have been established, the seed trees must be removed. If this is not done, the parent trees will eventually offer heavy competition for the water and nutrients. The result will often be spoilage of plants around the seed trees and gaps in the regrowth. At some distance from the seed trees, the plants will survive but will be held back in their development as long as the seed trees remain. This leads to uneven stocking of the natural regeneration. All this can be avoided if the regeneration area is carefully inventoried and the seed trees cut down as soon as the stocking is adequate.

## Summary

To sum up, in areas where both the climate and the soil are suitable for NR, one can create perfectly adequate natural regeneration and, as a result, viable new stands. The methods may be .further refined by additional research, speeding up and safeguarding the regeneration of our forests using the method provided by nature herself.

## BIBLIOGRAPHY

### Abbreviations Used in Bibliography

| | |
|---|---|
| AFF | Acta forestalia fennica |
| CIFF | Communications instituti forestalis fenniae |
| DFF | Det forstlige forsjdgsvasen i Danmark |
| KSLA | Kungl skogs- och lantbruksakademiens tidskrift |
| MNS | Meddelelser fra Det Norske skogsforsjdksvesen |
| MSS | Meddelanden frdn statens skogsforsoksanstalt (Statens skogsforskningsinstitut) |
| NST | Norrlands skogsvårdsförbunds tidskrift |
| SFS | Studia forestalia suecica |
| **SHS** | Skogshogskolan, Stockholm |
| **SST** | Skogsvårdsföreningens (Svenska skogsvardsf) tidskrift Sveriges skogsvdrdsforbunds tidskrift |
| TFJ | Tharandter Forstliches Jahrbuch |
| ZFJ | Zeitschrift fur Forst- und Jagdwesen |

Acatay, A. **1938.** Untersuchungen über Menge und Güte des Samensatzes in verschiedenen Kronenteilen einheimischer Waldbaume. – TFJ **89:5.**

Alfjorden. G., & Remrod. J. **1975.** Ny metodik for att forutsaga grobarheten hos tall- och granfro. – Institutet for Skogsforbattring, Skogstradsforadling. Information **3, 1975/76.**

Andersson, E. **1954.** Några data om pollenvariationen och pollenfertiliteten hos gran och tall. – Svensk Papperstidn **57** nr **7** och **18.**

– **1965.** Cone and Seed Studies in Norway spruce *(Picea abies* (L.) Karst. ). – SFS **23.**

Andersson, E., Ekberg. I., & Eriksson. G. **1969.** A summary of meiotic investigations in conifers. – SFS **70.**

Annila,. E. **1968.** Hyönteistuhoja tutkitaan ja torjutaan Metsantutkimuslaitoksen siemenviljelmilla (Insektskador undersoks och bekampas i Skogsforskningsinstitutets froplantager) – Metsalehti **40.2.**

Asplund, K., Lahde E. & Numminen E. 1973. Vajaasti kypsyneen mannyn siemenen kehitys kapyjen varastoinnin aikana (On the development of incompletely ripened seeds of Scots pine in cones under storage). – Folia Forestalia Institutum Forestale Fenniae 185.
Barner, H., & Christiansen, H. 1960. The information of pollen, the pollination mechanism and determination of most fovourable time for controlled pollination in *Larix*. – Silvae Genetica 9.
– 1962. The information of pollen, the pollination mechanism and determination in *Pseudotsuga menziesii*. – Silvae Genetica 11.
Bergan, J., & Skrøppa, T. 1975. Beregningsmetoder for vekstenhetssummer. – Meddelelser fra Norsk Institutt før skogsforskning 32.2.
Bergman, F. 1955. Forsok med tvångsfruktificering av tall, gran och bjork. – SST 53.
– 1976. Kott- och froegenskaper i skilda krondelar hos tall *Pinus silvestris* L. i norra Sverige (Characteristics of cone and seed from different parts of the crown in Scots pine, *Pinus silvestris* L. in northern Sweden). – SHS, Institutionen for skogsforyngring Research notes 68.
Bergman, F., & Anderson, B. 1968. Inventering av froträdsstallningar av tall. – Mo & Domsjo AB, Skogsbiologiska avdelningen, B:30.
– 1960. Något om fromognad och frobeskaffenhet hos tallen i Norrland. – Skogen 11.
Bilan, M. V. 1957. The stimulation of cone and seed production in pulpwood-size loblolly pine. D.F. dissertation. – Duke University, School of Forestry, Durham.
Brøndbo, P. 1969. Blomstringsinduksjon ved varmebehandling hos Granpodningar. – MNS 98.
– 1970. The effect of meteorlogical factors on the flowering intensity and cone of *Picea abies* in southeastern Norway. – Abstract i CIFF 74.6
Brown, I. R. 1971. Flowering and Seed Production in Grafted Clones of Scots Pine. – Silvae Genetica 20.
Carlborg, G. 1961. Kottplockning från stående trad. – NST 1.
Ching, K., & Simak, M. 1971. Competition among embryos in polyembryonic seeds of *Pinus silvestris* L. and *Picae abies* (L.) Karst. – SHS inst for skogsforyngring. Rapporter och uppsatser 30.
Dogra, P. D. 1964. Pollination mechanismas in gymnosperms. – Advan. Palynology publ. National Botanical Garden, Lucknow (India).
– 1967. Seed sterility and Disturbances in Embryogeny in Conifers with particular Reference to Seed Testing and Tree Breeding in Pinaceae. – SFS 45.
Dunberg, **A.** 1974. Occurence of gibberellin- like substances in Norway spruce *(Picea abies* (L.) Karst.) and their possible relation to growth and flowering. – SFS 111.
Eklundh-Ehrenberg, C., & Simak, M. 1956. Flowering and pollination in Scots Pine. – MSS 46:12.
Eriksson, G. 1968. Temperature response of pollen mother cells in *Larix* and it's importance for pollen formation. – SFS 63.
– 1970. Low-temperature induced irregularities in pollen mother cells of *Larix leptolepis*. – SFS 85.
Eriksson, G., Lindgren, K., & Werner, M. 1975. Granens blomningsgiolgi ett hinder for en rationell skogsträdsforadling? – SST 5.
Ferguson, M. 1904. Contribution to the knowledge of the life history of *Pinus* with special reference to sporogenesis, the development of the gametophytes and fertilization. – Proc. Washington Academy of Sciences 6.
Filzer, P. 1938. Das Mikroklima von Bestandesrandern und Baumkronen und seine physiologischen Rückwirkungen. – Jahrbücher für wissenschaftliche Botanik 86.
Gan, P. A., & Sartbajeva, M. K. 1975. Temperaturei olika krondelar hos trad på skilda altituder. – Lesonvedenije (Skogsodling) nr 2.
Garner, W. W., & Allard, H. A. 1920. Effect of the relative length of day and other factors of the environment on growth and reproduction in plants. – J. Agric. Res. 18.
– 1923. Further studies in photoperiodism, the response of the plants to relative length of day and night. – J. Agric. Res. 23.
Gunia, S., & Simak, M. 1968. Effect of damaging resin vesicles in the seed coat on the germination of Silver fir *Abies alha* Mill. seeds. – International symposium on seed physiology of woody plants. Institute of Dendrology and Kórnik Arboretum on the Polish Academy of Sciences.
Gustafsson, J. 1980. Behov av tall- och granfro i Sverige år 1980-2000 – en analys. – Forskningsstiftelsen Skogsarbeten, redogorelse 2.
Gustafsson, J. & Jakobsson, R. 1980. Kottplockning efter mekaniserad awerkning – en pilotstudie. – Forskningsstiftelsen Skogsarbeten, ekonomi 6.
Hagem, O. 1917. Furuens og granens frøsaetning i Norge. – Medd. Vestlandets Forstl. Fors. stat. 1, 2.
Hagman, M. 1967. Serological studies of pollen, and the incompatibility in forest trees. – XIV. IUFRO-Kongress Referate Section 22 – AG 22/24 III.
– 1971a. Hur tallkotten utvecklas. – Skogsbruket 6.
– 1971b. On self- and cross-incompatibility shown by *Betula verrucosa EHRH* and *Betula pubesscens EHR*. – CIFF 73.6.
– 1972. On some Factors Influencing the Yield from Seed Orchards of *Pinus silvestris* L. and their Interclonal and Intraconal Variation. – Forest Tree Improvement nr 4.
Hagner, S. 1958. Om kott- och froproduktion i svenska barrskogar. – MSS 47:8.
– 1962. Naturlig foryngring under skärm (Natural regeneration under Shelterwood stands. An analysis of the method of regeneration, its potentialities and limitations in forest management in middle north Sweden). – MSS 52.
Hagner, S., & Bergman, F. 1961. Om insamling av tallkott från stående trad. En orienterande undersokning. – NST 1.
Hagner, S., & Callin. G. 1959. Om insamling av tallkott. – NST 4.
– 1962. Om insamling av grankott (Über die Einsammlung von Fichtengapfen). – Skogen 22.
Håkansson, A. 1956. Seed development of *Picea abies* and *Pinus silvestris*. – MSS 46:2.
Heikinheimo, O. 1932. Metsapuiden siementämiskyvystä I (Referat: über ide Besamungsfahigkeit der Waldbaume. II.). – CIFF 24.
– 1948. Metsapuiden siementamiskyvysta. III. (Summary: On the seeding capacity of forest trees. III.). – CIFF 35.
Hillman, W. S. 1962. The physiology of flowering. Biology studies – New York.
Holmsgaard, E., & Olsen, C. C. 1966. Experimental induction of flowering in Beech. – DFF 30.
Hustich, I. 1948. The Scotch pine in northern-most Finland. – Acta Bot. Fenn. 42.
Hutchinson, J. G., & Bramlett, D. L. 1964. Frost damage to Shortleaf Pine flowers. – Journal of Forestry.
ISTA, 1966. International Rules for Seed Testing 1966. – Proc. Intern. Seed Test. Assoc. 1:1.
Johnsson, H. 1955. Försöksodlingar av tall. – SST 1.
Jonsson, A. 1973. Meiotic investigations on embryo sac mother cells of normal and desynaptic Norway spruce. – SFS 105.
– 1974. A study of the temperature response of pollen mother cells in Norway spruce. – SFS 116.

Kamra, S. K. 1968. Effect of different distances between water level and seed bed on Jacobsen apparatus on the germination of *Pinus silvestris* L. seed. – SFS 65.

Kamra, S. K., & Simak, M. 1968. Germination studies on Scots pine *(Pinus silvestris* L.) seed of different provenances under alternating and constant temperatures. – SFS 62.

Kapper, D. K. 1931. Samenertrag der Kiefer in Südrussland. – ZFJ LX III.

Kardell, L. 1973a. Tallfrostudier i Norrland 1. Studier over tallens *(Pinus silvestris* L.) fro- och kottmognad i sodra Vasterbottens inland. – Stockholm.

– 1973b. Tallfrostudier i Norrland 2. Lagringsforsok med norrlandsk tallkott (*pinus silvestris* L.). – Lund.

Klebs, G. 1904. Probleme der Entwickelung I bis 111. – Biologisches Centralblatt.

– 1913. Fortpflanzung der Gewachse. – Handworterbuch der Naturwissenschaften 4.

Koski, V. 1971. Embryonic lethals of *Picea abies* and *Pinus silvestris.* – CIFF 75.3.

– 1973. On self pollination, genetic load and subsequent inbreeding in some conifers. – CIFF 78.10.

Kramer, P. J., & Kozlowski, Th. T. 1960. Physiology of trees. – New York, Toronto, London.

Krugman, S. L. 1966. Freezing Spring Temperatures Damage Knobcone Pine. – U. S. Forest Service Research Paper PSW-37 Berkeley.

Kujala, V. 1927. Über den Bau und die Keimfahigkeit von Kiefernund Fichtensamen. – CIFF 12.6.

Lindgren, D. 1975. The relationship between self-fertilization, empty seeds and seeds originated from selfing as a consequence of polyembryoni. – SFS 126.

– 1975. Mannyn kavyn koko, siemensaanto ja siemenen laatu Pohjois-Suomessa (The size of pine cones, seed crop and seed quality in northern Finland). – CFF 86.5'.

McWilliam, J. R. 1958. The role of the micropyle in the pollination of *Pinus.* – Botanical Gazette.

– 1959. Interspecific incompatibility in *Pinus.* – Am. J. Botany 46.

Messer, H. W. 1958. Das Fruchten der Waldbaume als Grundlage der Forstamengewinnung. – Mitteilungen der Hessischen Landesforstverwaltung 1.

Mirov, N. T. 1967. The Genus Pinus. – New York.

Mitscherlich, G. 1971. Wald Wachstum und Umwelt. 2. Waldklimat und Wasserhaushalt. – Frankfurt am Main.

Mork, E. 1941. Om sambandet mellom temperatur og vekst. Undersøkelser av de daglige variasjoner i granens højdetilvekst. – MNS 27.

– 1944. Om bjørkefruktens bygning, modning og spiring. – MNS 8.

– 1957. Om frøkvalitet og frøproduksjon hos furu i Hirkjølen. – MNS 48.

Müller-Olsen, C., Simak, M., & Gustafsson, A. 1956. Germination analyses by the X-ray method: *Picea abies* (L.) Karst. – MSS 46: 1.

Neumann, F. P., Schantz-Hansen, T., & Rees, L. W. 1964. Cone scale movements of Jack pine (*Pinus banksiana* Lamb.). – Minnesota Forestry Notes 142.

Nordstrom, L. 1950. Tallfrö for Norrlands hojdlagen. Ett forelopande meddelande. – NST 3.

Nyman, B. 1963. Studies on the germination in seeds of Scots pine *(Pinus silvestris* L.). – SFS 2.

Opsahl, W. 1952. Om sambandet mellom sommertemperatur og frømodning hos gran. – MNS 40.

Ozawa, J., & Matsuzaki, S. 1955. Promoting of the fruiting of Japanese larch. – Rep. Hokkaido Branch G.F.E.S. 4.

Remrod, J. 1972. Forsok med blomningsstimulering i en granfroplantage. – Foreningen Skogstradsforadling och Institutet for skogsforbattring. Arsbok 1972.

Renvall, A. 1914. Ein Beitrag zur Kenntnis der sog. partiellen Variabilitat der Kiefter. – AFF 3: 1.

Rummukainen, U. 1975. Mannyn kapysadon ennustamisesta. (On forecosting the cone crop of Scots pine). – CIFF 84.6.

Runqvist, E. W. 1968. Meiotic investigations in *Pinus silvestris* (L.). – Hereditas 60.

Saalas, U. 1949. Suomen metsahyonteiset (Finlands skogsinsekter). – Porvoo.

Sachs, J. von 1887 (1960). Lectures on the physiology of plants. – Oxford University Press, New York.

Sarvas, R. 1955. Investigations into the flowering and seed crop of forest trees. – CIFF 45.7.

– 1962. Investigations on the flowering and seed crop of *Pinus silvestris.* – CIFF 53.4.

– 1965. Metsapuiden vuotuinen periodi (Skogstradens årliga period). – Suomen Tiedeakat. Esit. ja Poytak.

– 1968. Investigations on the flowering and seed crop of *Picea abies.* – CIFF 67.5.

Scamoni, A. 1938. Über Eintritt und Verlauf der mannlichen Kiefernblüte. – ZFJ 6.

Schwerdfeger, F. 1957. Die Waldkrankheiten. – 2 uppl. Hamburg och Berlin.

Simak. M. 1955. Samengrösse und Samengewicht als Qualitatsmerkmale einer Samenprobe (*Pinus silvestris* L.). – MSS 45:9.

– 1957. The X-ray contrast method for seed testing Scots pine – ***Pinus** silvestris.* – MSS 47:4.

– 1960. Influence of cone size on the seed produced *(Pinus silvestris* L.). – MSS 49:4.

– 1972. Låga temperaturers inverkan på embryoutvecklingen hos tallfrö ***(Pinus** silvestris* L.). – SHS Inst for skogsforyngring. Rapporter och uppsatser 36.

– 1973. Polyembryonal seeds of *Pinus silvestris* in arctic regions. – **SHS** Inst for skogsforyngring. Rapporter och uppsatser 45.

– 1974. Fromangd och dess beskaffenhet vid skogsfornyelse. Importance of Quantity and quality of seed in Forest Regeneration. – SST 1.

Simak, M., & Gustafsson, A. 1953a. Rontgenfotografering av skogstradsfro. – Sltogen 5.

– 1953b. X-ray photography and sensivity in forest tree species. – Hereditas 39.

Sirkn, G. 1961. Skogsgranstallen som indikator for klimatfluktuationerna i Norra Fennoskandien under historisk tid. – CIFF 54.2.

– 1948a. – Arsberattelse over Foreningens for växtförädling av skogstrad verksamhet. Stockholm.

Soderstrom, V. 1979. Ekonomisk skogsproduktion. Del 2. – Föryngring. – Boris.

Tirén, L. 1935. Om granens kottsattning, dess periodicitet och samband med temperatur och nederbord. – MSS 28.

– 1949. Om den naturliga foryngringen på obranda hyggen i norrlandsk granskog. (On natural regeneration on unburned cutting areas in Norrland spruce forests). – MSS 38:9.

Tradgardh, I. 1939. Sveriges skogsinsekter. – Uppsala.

Wenzer, K. F. 1953. The effect of fertilization and injury on the cone and seed production of Loblolly Pine seed trees. – Journal of Forestry 51.

Wibeck, E. 1919. Det norrlandska tallfroets grobarhet. – MSS 17.

– 1928. Det norrlandska tallfroets grobarhet och anatomiska beskaffenhet. – NST 1.


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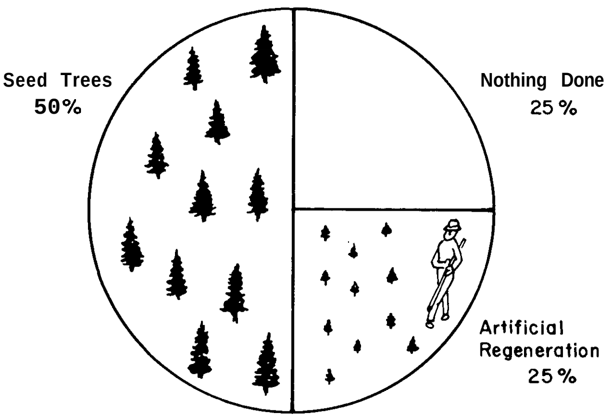
DIRECT SEEDING

Mats Hagner*

## DIRECT SEEDING – A COMMONLY USED METHOD

Direct seeding is not a common regeneration method. In fact, artificial regeneration in general is uncommon in northern Sweden (Figure 1). The National Forest Survey, 1973-77'has shown that forest land owners prefer natural regeneration, and seed trees have been left on 50% of the clear-cut areas. Artificial regeneration is carried out on **25%** and nothing done on the remaining quarter. We know from earlier surveys that a portion of the untreated area will be artificially regenerated at a later stage, but the time lag between clear cut and regeneration is fairly long. Within the area which was artificially regenerated, planting was carried out on about 97%, while direct seeding was used on only 3%.




| | Seed Trees | Artificial Regeneration |
|---|---|---|
| Class B1 Plants 0.1-1.3 meter | | |
| Total no. plants | 8000 | 8000 |
| Total no. coniferous plants | 3000 | 1900 |
| Main Crop Plants | | |
| Per cent of area with less than 1500 coniferous plants/ha | 52% | 62% |
| Former tax. period 1964-69 | 28% | 27% |

Figure 1. Northern Sweden 8 years after clear cut National Forest Survey 1973-77.

The quality of the regeneration was low (Figure 1). It is desirable to have more than 2000 main crop plants per hectare. The survey cited above shows that there were less than 1500 conifers per hectare on 62% of the artifically regenerated area. Of the area in which seed trees were used, 52% was understocked. Figures from a former taxation period show that the quality of regenerations seems to have declined.

While the number of conifers was too low, the total number of plants was fairly high, 8000, showing that the number of deciduous plants was high.

*Professor, Department of Forest Service, University of Umeå, Umeå, Sweden.

I am convinced that the main reason artificial regeneration is not more widely practiced in northern Sweden originates in a fear of costs and administrative problems. Facts presented by forest owners to the contrary are not persuasive.

A drastic change can be implemented only by the introduction of much more simple and less expensive artificial regeneration methods. Direct seeding is one.

### New Methods for Direct Seeding

Early in 1950, direct seeding was performed in spots scarified manually with a hoe. Around 1960, spot scarification with tractors was introduced. **As** the germination is very low unless the seeds are placed upon exposed mineral soil, scarification has been critical to the success of direct seeding. With a spot scarifier pulled by a tractor, one normally reaches **4%** exposed mineral soil. It is, therefore, recommended that planting density approximate 100 seeds/spot which would amount to 1 kg seed/hectare. This is 30 times as much seed as is consumed when the area is planted with plants produced in forest nurseries producing containerized stock. As a seed shortage exists in northern Sweden, one can easily see why we had to abandon the conventional spot seeding.

The harrows developed during the 1970s expose about 25% of the mineral soil (Figure 2). The seeds can be spread over an area four times larger than if a spot scarifier were used. A much higher number of microsites can be tested. A density of 0.3 kg of seeds per hectare seems to give adequate

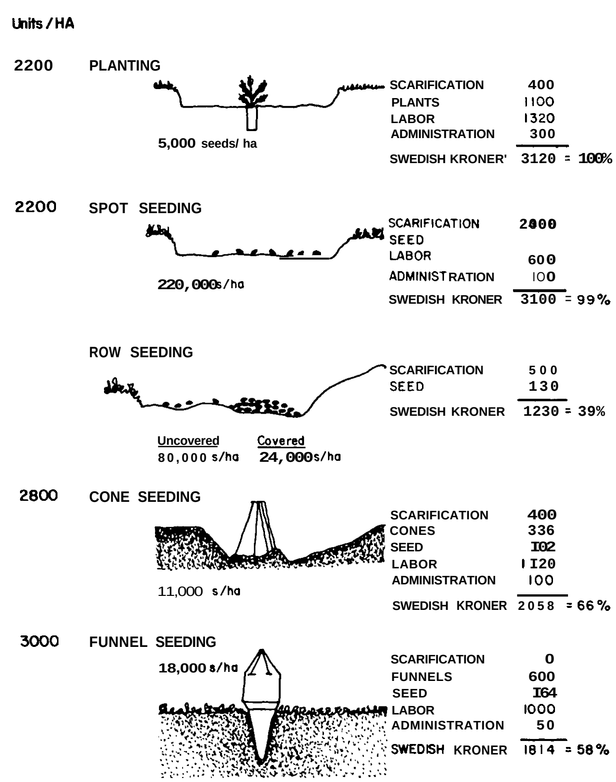



Figure 2.

results. However, this is still ten times as much as is used in connection with planting. From extensive field tests of gravel on top of the seeds, we know that the seed consumption with "covered seeding" after scarification with a harrow could be restricted to 0.1 kg per hectare.

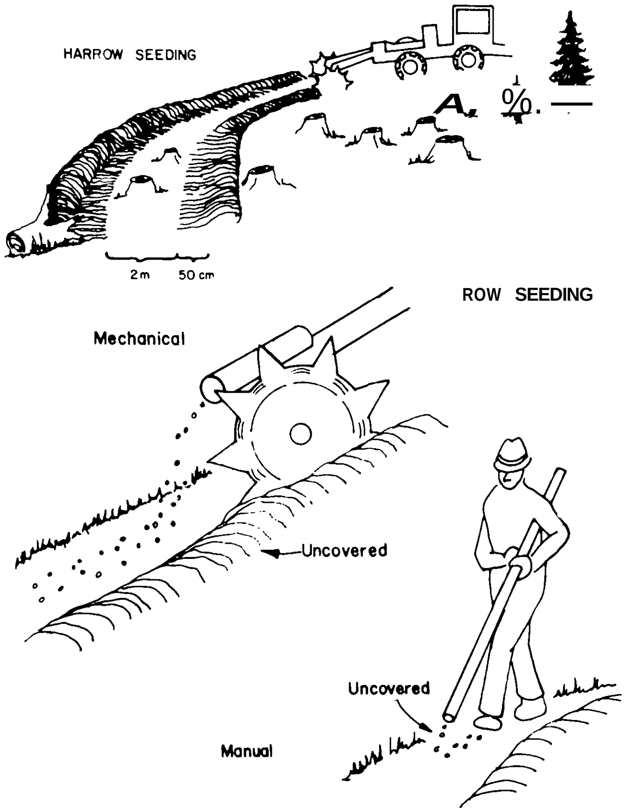



Figure 3

Seeding after-harrowing, called ***row** seeding,* without coverage has been used on a practical scale in northern Sweden for two years. The seeds are spread by a seeding device on the harrow or manually (Figure **3**). Manual seeding can deliver the seed to the better microsites, thus reducing the seed consumption to 75% of that required for mechanical seeding. **A** normal seeding rate per man per day is 2 hectares.

To date, there is no device available for covered row seeding.

*Cone seeding* has been used on a practical scale for about five years. Plastic cones, 8 cm high, are placed on top of four seeds (See Figure 4.) The seeds must be placed on bare mineral soil and the lower edge of the cone must be tight to the ground. To obtain results comparable to those achieved with planting, 25% more cones than plants must be distributed on a given area. Seed consumption seems to be double that required in connection with planting.

*Funnel seeding* is a method very different from cone seeding. In this case, scarification is not necessary. Vertically divided plastic shelters are pressed down into the humus layer (See Figure 4.) The inside of the shelter contains nothing but the seeds which are placed on top of the compressed humus in the bottom of a hole 8mm in diameter. The germination takes place in the bottom of the shaft which is about 5cm deep, measured from the surface of the moss

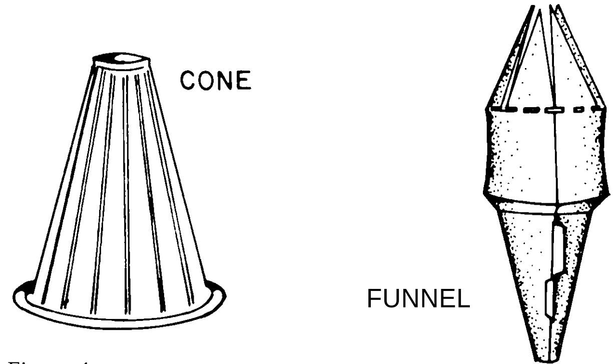



Figure 4.

layer. It does not seem to matter whether the tip of the funnel penetrates the mineral soil or stays within the humus. The portion of the plastic shelter left above the moss layer has been designed to prevent litter from falling on top of the seedlings and to prevent the pine weevil from reaching the seedlings. In this last respect, the design has not proved entirely effective.

During the last four summers, more than 200 field tests have been conducted throughout Sweden. Seed germination has been 50-80% and the first development of the seedlings is good on most sites at all locations. However, the survival of small seedlings is highly dependent on factors pertaining to the microsite – thick grass for example. The growth of the seedlings in such grass is generally better than that for seedlings on bare mineral soil.

In the Umeå region, 64°N latitude, we recommend that the forest owner use 30% more funnels per hectare than plants, 3000 funnels for this region. He should place 6 seeds in each funnel.

Summarizing the costs for scarification, plants, labor, and administration, the modern, direct-seeding methods seem to be cheaper than the conventional planting (Figure **3**). Uncovered row seeding is less than half as expensive. Seed consumption is of course the big problem. The methods requiring scarification are limited to the 70% of Swedish forest land area which can be reached by tractor. The remaining areas are either too rocky, steep, or situated behind wet bogs.

Weed problems are common on fertile sites. Small conifer seedlings often succumb below a dense weed cover. However, we have found that after clear cutting a dense stand, the weeds do not thrive until the third summer. On fertile sites in southern Sweden, funnel-seeded spruce has reached an average height of 15cm by the end of the second growing season. This is why we here in northern Sweden are enthusiastic about the possibility of using funnel seeding on fertile sites as well.

Choice of Microsite in Connection with Funnel Seeding

With regeneration methods in which scarification is not required, a choice of microsite can be adopted. In a test in which funnels were placed in a mathematical random spacing, we registered the quality of microsite on a scale of 0 to 9 (See Figure 5, next page.) The trees (Scots pine) were **3** years old and were covered with a box during the evaluation of the site. **A** very good site was "elevated, sunny and warm."

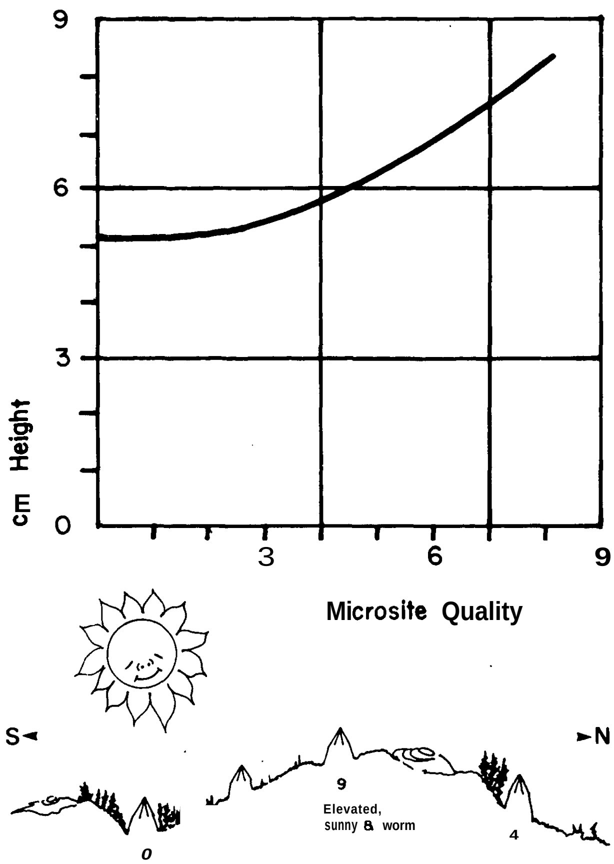



Figure 5. Funnel seeding 1977 seedling ages 3 years.

A regression analysis shows that trees on a good micro-site grow 60% taller than those on a very bad site, and 40% taller than a seedling on an average microsite.

Time Lag – Between Clear Cut and Artificial Regeneration

The National Forest Survey shows that the average time lag between clear cutting and artificial regeneration in the northern half of Sweden is 4.5 years. Theoretically the normal time lag should be 2 years (Table 1). When regeneration is carried out the year after the scarification, which is the case with planting and cone seeding, the time lag should be limited to 1 year. Funnel seeding should be carried out in the first spring after clear cutting.

Table 1. Time Lag Between Clear Cutting and Various Methods of Artificial Regeneration.

| | Time lag (summers after clearcut) | | | |
|---|---|---|---|---|
| Method | 1 | 2 | 3 | 4 |
| Planting | | Scarification | Planting | |
| Cone Seeding | | Scarification | Seeding | |
| Row Seeding | | Scarification<br>Seeding | | |
| Funnel Seeding | Seeding | | | |

In many old tests, where planting is compared to spot seeding, the difference in development between seeded and planted trees seems to be equal to the age difference of the seedlings. If direct seeding is performed at the same time as planting with 2-year-old plants, the planted trees seem to stay two years ahead in development of the seeded ones. The rotation age is thus increased by two years with direct seeding.

While cone seeding carried out at the same time as planting seems to increase the rotation age by two years, mechanized row seeding should increase the rotation age by only one year. Funnel seeding should not increase the rotation age at all, since seeded trees would be two years old by the time planting would normally occur.

Increase the Density of Young Stands

As was pointed out in Figure 1, the density in stands in northern Sweden is very low. This has caused low volume production and low saw-timber production because of heavy branches. Voles, moose, and various other agents cause losses of stems. Regeneration methods employed in the future must permit a forest owner to create denser stands with lesser costs.

There are also valid reasons to adopt methods which enable the forest owner to use two species simultaneously. We have studied stands created from 1920 to 1945 by direct seeding with a mixture of 60% pine and 40% spruce seed. The spruce seems to survive on most microsites while pine does not survive in wet depressions. In these stands, older than 30 years, spruce trees are the biggest and are established on fertile depressions, while pine, somewhat smaller, is the dominating species on dryer, less fertile, hills. However, the distribution of species is so complex that one could never foretell exactly where the spruce or the pine would do best. Therefore, I am quite convinced that we should increase the production in our forests by the simultaneous use of several species. Our Swedish spruce mixed with pine is a good combination, but of course this is just one possibility. Lodgepole pine (*Pinus contorta*) mixed with black spruce (*Picea mariana*) would be another very interesting possibility.

Gain by Selection Among Producing Stems in the Stand

In a provenance test with twelve-year-old Scots pine, we grouped the stand into clusters of four neighboring plants. We then estimated the production of the stand at age twelve and for age twenty. We determined what effect selection at age twelve would have upon the volume production of the stand. With no selection at all, the incremental increase in volume production at age twenty would amount to 100%. Had we removed the smallest tree in each group of four at age twelve, thus reducing the number of trees in the stand by 25%, the volume increment at age twenty would have amounted to 117%. Likewise, removing the two smallest trees in each group and reducing the number of trees in the stand by 50% would have resulted in a 136% incremental increase in volume production in the entire stand.

Had the removal of the trees actually been carried out, it would not have affected the relative sizes of the remaining trees as those trees which were growing fastest and were the largest in each group at age twelve were also the largest at age twenty. There were no great differences between provenances.

I am well aware that this is a theoretical example; we did not actually remove the trees at age 12. There is a lack of complete genetical correlation between the development between ages twelve and twenty and between 60 and 100 years. The early starters will lack in growth later on, for example. Nevertheless, the positive effect will certainly remain for a considerable portion of the rotation age, thus proving that there must lie a substantial gain in total volume production encouraged by a selection at a fairly young age. This is to say that one could estimate a higher production from stands which are created by selection out of young stands with inadequate spacing.

## Precommercial Thinning

Some of the seeding methods described produce trees established very close to one another. The Swedish forestry law suggests that culling should be performed in densely seeded spots before seedlings have reached the height of 1 meter. To study the necessity of this, I recorded the growth in a plantation nine years old. The stand was created by planting containers with widely varying numbers of plants. I recorded the total number of seedlings in each container and the number of dominating plants. The result is somewhat puzzling as the growth of a dominating seedling seems to be enhanced by the other trees in the same container (Figure 6). Some roots were excavated and the root systems of different trees were found to be intermingled. The trees seemed to have grown firmly together. This should be studied more carefully because one explanation for this performance could be an exchange of hormones between the trees. Judging from this study, I don't think an especially early cutting seems necessary if the stand will be thinned at the height of 2-3cm, which is the usual practice.

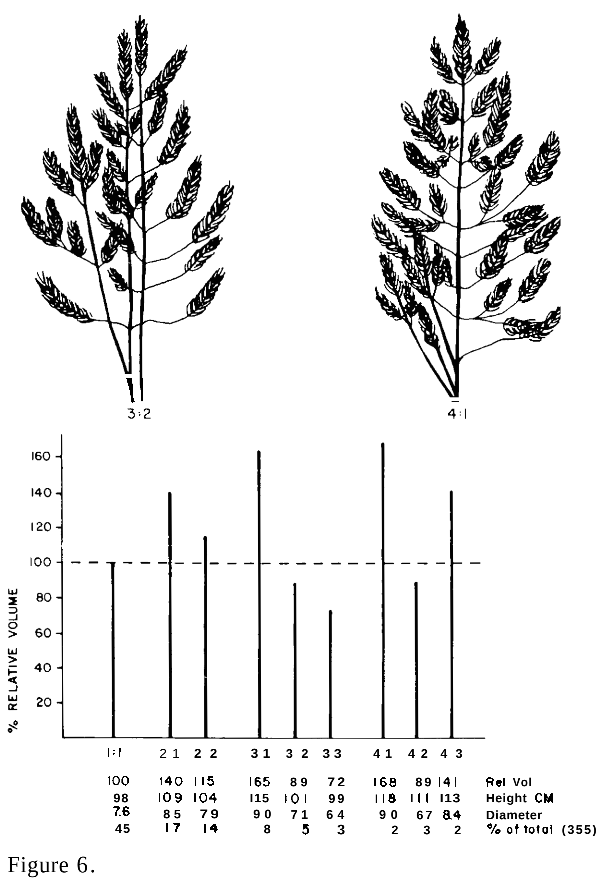



Figure 6.

## Conclusions

The use of artificial forest regeneration in northern Sweden is limited. From a national economic point of view, artificial regeneration should be used on a much larger portion of the clear-cut area and the time lag between clear cutting and regeneration measures should be shortened. The high costs of planting in combination with laborious administration are the main obstacles hindering the land owners from using planting. Several direct-seeding methods are available which combine administrative simplicity with low costs. However, the seeding requires two to ten times as much seed as is used for production of nursery stock. Lack of seed forced the foresters to abandon direct seeding in the 1950s and lack of seed production is not increased. Accordingly, research should be emphasized on increased production as well as decreased seed consumption in connection with direct seeding.

With direct seeding –

1. the seedling density in the yound stands could be increased and the effect of selection explored;

2. the effects of attacks of moose, voles, and pine weevil (*Hylobious*), are limited;

3. simultaneous mixing of 2 or 3 species could be used;

4. tree stability is increased by natural root development.

The use of direct seeding in Scandinavia will increase because it furnishes simple ways for establishment of dense and robust regenerations combined with low costs. On a long-term basis, I find direct seeding in the humus layer, without scarification, the most valuable method to explore.

APPENDIX I

INTERNATIONAL WORKSHOP ON FOREST REGENERATION ON NORTH LATITUDE FOREST LANDS

AUGUST 25,1980

| | |
|---|---|
| 10.00 - 11.00 | REGISTRATION – Swedish University of Agricultural Sciences, Faculty of Forestry, Umeå. |
| 11.00 - 14.00 | INTRODUCTION<br>"Welcome to the North"<br>Gustaf von Segebaden, Decanus |
| 12.15 - 13.15 | Lunch |
| | Forestry in Northern Sweden<br>Bo Axelsson, County Forester |
| | Forest Regeneration in Northern Sweden<br>Per-Ove Backstrom, Professor |
| 14.00 - 17.00 | TECHNICAL SESSION |
| | Site Classification and Site Productivity<br>Jan-Erik Lundmark, Docent |
| | Site Preparation<br>Vadim Soderstrom, Professor/Jan Backe, Forester |
| 15.00 - 15.15 | Coffee |
| | Seed Availability, Cone Collection and Natural Regeneration<br>Fritz Bergman, Professor |
| | Direct Seeding<br>Mats Hagner, Professor |
| 17.00 | Bus to Hotel Wasa |
| 19.00 | Dinner at 'Hantverkshuset'<br>Host: The Swedish Forest Service |

AUGUST 26,1980

| | |
|---|---|
| 07.15 - 08.00 | Breakfast, Hotel Wasa |
| 08.00 | Bus to Savar |
| 08.15 | TREE IMPROVEMENT AND PLANT PRODUCTION<br>Visit to the Institute for Forest Improvement, Northern Research Station, Savar |
| | Tree Breeding Problems and Programs |
| | Seed Handling |
| | Plant Production Systems |
| | Practical demonstrations by invited manufacturers |
| 11.30 - 12.30 | Lunch, Savar<br>Host: Institute for Forest Improvement |
| 14.30 | Bus to Piparbole |
| 14.30 - 16.30 | PIPARBOLE NURSERY |
| | Modern Commercial Large Scale Production of Forest Tree Seedlings |
| | County Forestry Board |
| 16.30 | Bus to Hallnas |
| 18.00 | Dinner, Hallnas |
| Evening | INFORMAL DISCUSSION |

AUGUST 27, 1980

| | |
|---|---|
| 07.30 - 08.00 | Breakfast, Hallnas |
| 08.00 - 10.30 | FOREST REGENERATION TECHNICS, Hallnas,<br>Equipment and machines for site preparation, seeding and planting used in the Nordic countries. |
| | Practical demonstrations by invited manufacturers. |
| | Arranged by the Swedish Logging Research Foundation. |
| 10.30 | Bus to Lycksele<br>Excursion |
| 12.30 - 13.30 | Lunch, Lycksele |
| 13.30 - 18.30 | Excursion, continued |
| 19.00 | Dinner, Hallnas |
| 20.00 | Film |

AUGUST 28,1980

| | |
|---|---|
| 07.30 - 08.00 | Breakfast, Hallnas |
| 08.00 | Bus to Vindeln |
| 08.00 - 12.30 | THE EXPERIMENTAL FOREST OF SVARTBERGET<br>Field excursion to selected young and old regeneration experiments |
| | Faculty of Forestry |

| | |
|---|---|
| 13.00 - 14.00 | Lunch, Hallnas |
| 14.00 - 17.00 | WORKSHOP SESSION<br>Chairman: James V. Drew, Dean and Director, University of Alaska<br><br>Presentation, discussion and refinement of outlines of the various chapters for the future bulletin on forest regeneration. |
| 16.30 - 17.30 | Dinner, Hallnas |
| Evening | WORKSHOP SESSION, continue |

AUGUST 29,1980

| | |
|---|---|
| 07.30 - 08.00 | Breakfast, Hallnas |
| 08.00 - 11.30 | WORKSHOP SESSION, continue<br><br>End of discussion, future work, final statements |
| 11.30 - 12.30 | Lunch, Hallnas |
| 12.30 - 14.00 | Bus to Umeå |

APPENDIX II

FINNISH EXCURSION

PROGRAM FOR VISITING NORTH AMERICAN FORESTERS

1980-08-29, 09-02

Leader Mr. Sven-Erik Appelroth

| | |
|---|---|
| 1980-08'29<br>Friday | 23.00 Arrival from Umeå to Vaasa by boat. Transit to Hotel Central by bus. Night at Hotel Central. |
| 1980-08-30<br>Saturday | Breakfast at Hotel.<br>Visit to cutting place at Vaasa archipelago. Long distance transport by bundle floating. Metsaliitto-Yhtyma company, Mr. Jukka Salenius.<br>Luncheon and dinner on the way to the Forest Field Station Hyytiala, University of Helsinki. |
| 1980-08-31<br>Sunday | 8.30-9.00 Breakfast at Hyytiala.<br>9.00 Getting acquainted with the activities of Forest Field Station. Visit to Arboretum. Excursion to the regeneration areas of State Forest District Korkeakoski. Luncheon on the way. Visiting Tampere and Hameenlinna. Night at Hotelli Rantasipi, Hyvinkaa. |
| 1980-09-01<br>Monday | 7.45-8.15 Breakfast at Hotel.<br>9.00-11.30 Getting acquainted with the Foundation for Forest Tree Breeding in Finland, Haapastensyrjä Tree Breeding Station, Mr. Pentti Tyystjärvi (M. Sc. For.)<br>11.30-12.00 Luncheon at Haapastensyrjä.<br>12.00 Getting acquainted with Työväline forest site preparation machines and chippers. Transit to Hotel Vaakuna Helsinki. Night at hotel. |
| 1980-09-02<br>Tuesday | Free program in Helsinki, departure at Helsinki-Vantaa airport. |

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.



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