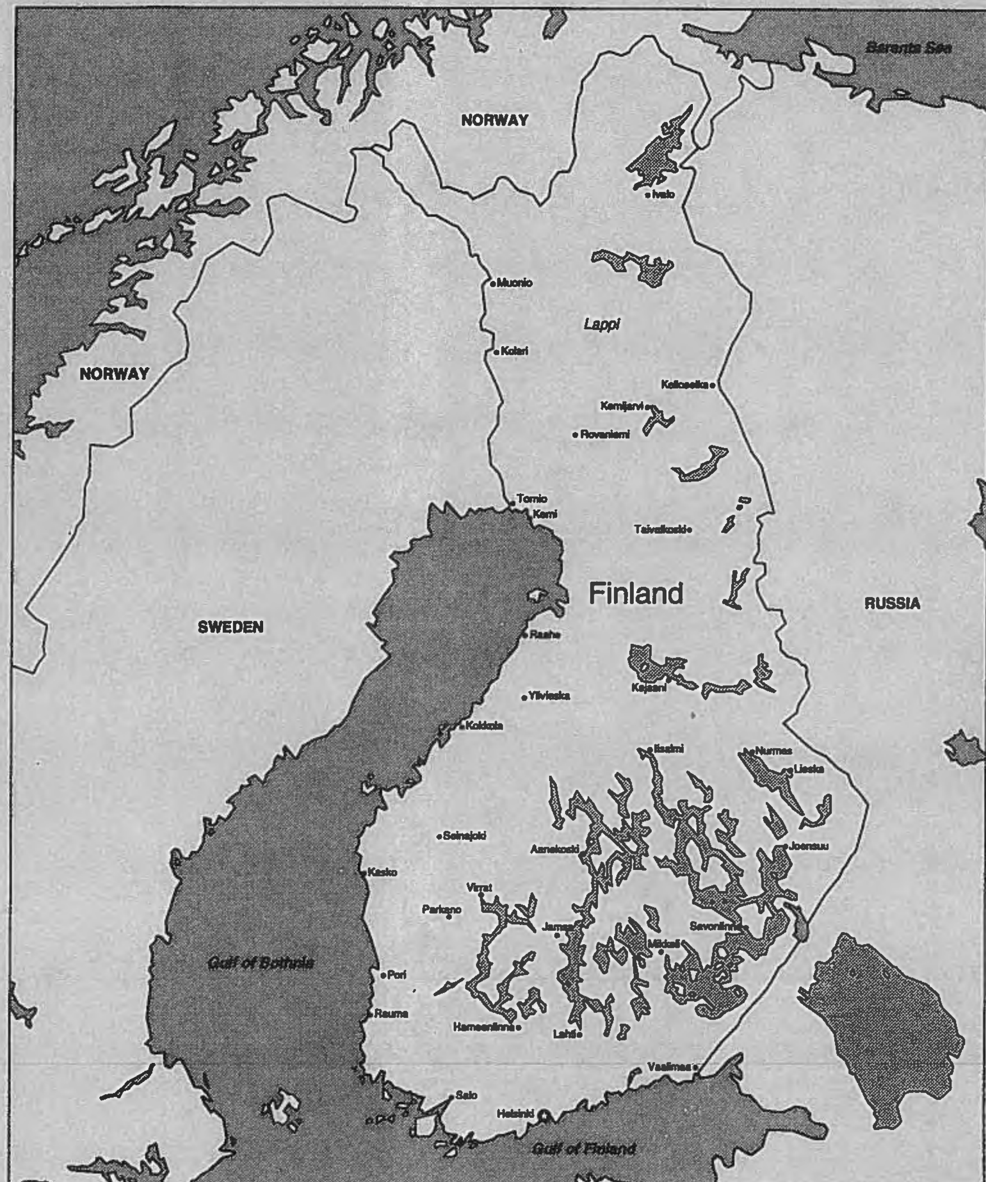
Northern Forest Silviculture and Management

1987 IUFRO Working Party S1.05–12 Symposium Proceedings



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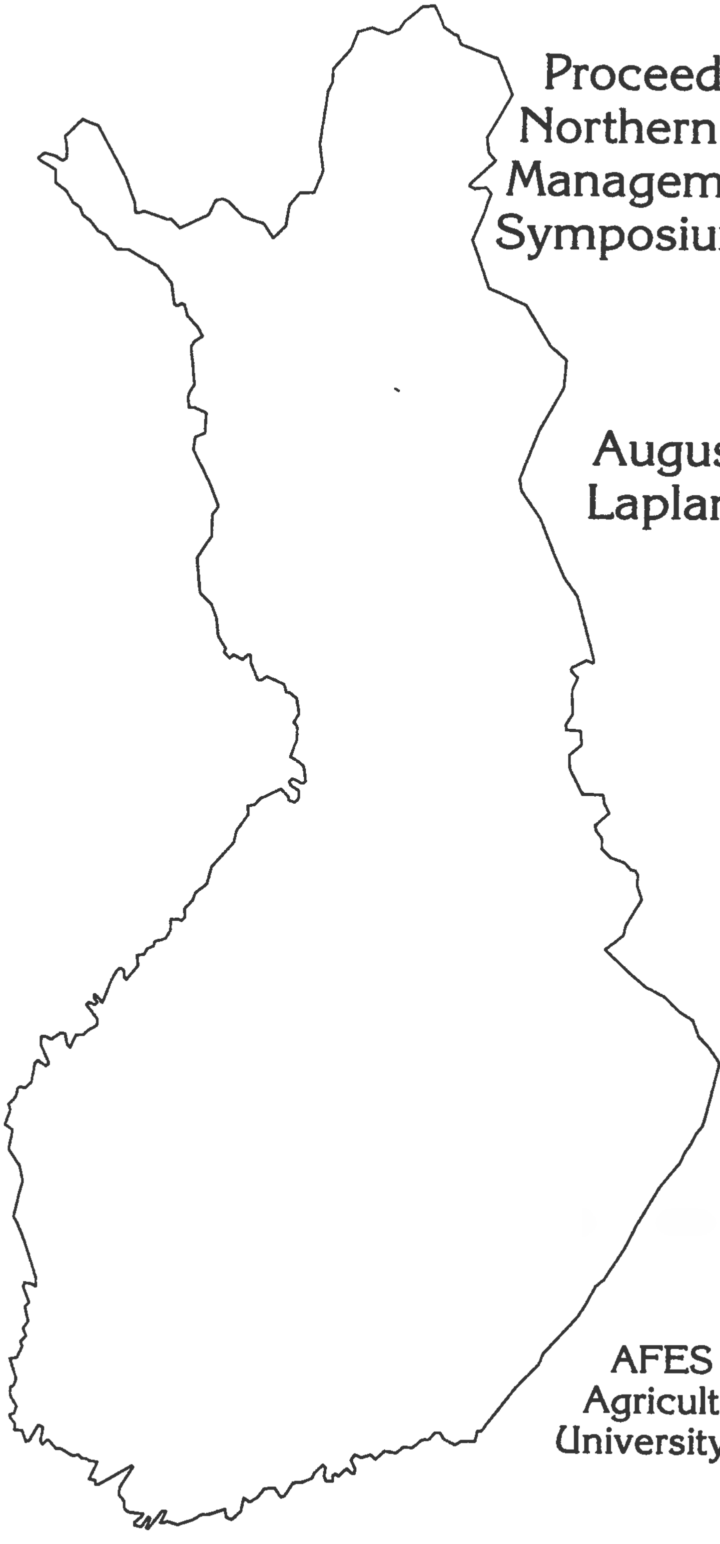

Proceedings of the 9th IUFRO
Northern Forest Silviculture and
Management Working Party S1.05-12
Symposium Proceedings

August 16–22 1987
Lapland, Finland

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Agricultural and Forestry Experiment Station
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Edmond C. Packee–Technical Editor

PREFACE

This volume contains the proceedings from the Ninth Meeting of the IUFRO Working Party, S1.05-12 held in Finnish Lapland, August 16-22, 1987. The event attracted participants from nine countries: Canada, Finland, Germany, Great Britain, Norway, The People's Republic of China, Russia, Sweden, and the United States.

Rovaniemi and north to the end of the forest; this is what one remembers most easily of the ninth meeting of the Working Group. There was more however. There were the excellent and informative papers; field discussions about silviculture, forest ecology, management, and policy considerations; and a great deal of camaraderie amongst professionals and new found friends—friendship spanning three continents: Europe, Asia, and North America.

Truly, the gathering was one of collective wisdom concerning the Northern Forest—collective wisdom as exemplified by the "Hat of the Four Winds!" From the coffee or tea in the old-growth forest or the young plantations, we were in the "green crown" of the north, the Northern Forest.

But back to the "Hat of the Four Winds." What a chase that must have been trying to find a genuine one. Finnish forestry scouts scoured all of Lapland so we are told. On the last day, in the far north of Finland across the river from Norway, in a genetics trial plantation, with the pouring rain, there was Ed Packee, wearing a garbage bag like many others. Unlike the others, however, Ed's garbage bag was not cut out for his arms; he was hostage to the environment. Then came the concluding event. Ed was presented with the quest of the chase, the "Hat of the Four Winds." The "Hat" holds much for a forester, symbolizing the environment in which we work and think. It symbolizes our lives. The "Hat of the Four Winds" is truly a symbol of the wisdom we, as foresters, need. No matter where we are, the wisdom comes from the north, the south, east, and the west.

The symposium would not have been successful without the efforts of more than 100 individuals. For their support and cooperation, we wish to thank all of the practitioners of forestry in Finnish Lapland and especially, chairman Paavo Onnela; director Jukka Ylimartimo; district foresters Alpo Eeronheimo, Mikko Hyppönen, and Pertti Veijola; and forest technicians Risto Junttila and Tarmo Mattila. The role of the organizing group was also decisive. We thank Sven-Eric Appelroth, Kaarina Niska, Aulis Ritari, Mauri Timonen, and Martti Varmola for their efforts. The proceedings were technically edited by Helena Poikajärvi, who also acted as the treasurer. The symposium was financially supported by the Ministry of Agriculture and Forestry of Finland.

Fairbanks, Alaska and Rovaniemi, Finland, December 1987
Edmond C. Packee and Hannu Saarenmaa

POSTSCRIPT: Initial funding for publication of this proceedings, through the University of Alaska Fairbanks, was thought to be secure in 1988. Such was not to be the case. Consistent budget cuts and associated funding losses delayed printing. Because of the quality of the papers and the information, it was important to have the proceedings published. In April 1995, Dr. James V. Drew, Dean of the School of Agriculture and Land Resources Management, UAF, and Director of the Alaska Agricultural and Forestry Experiment Station secured funds for a limited printing. I personally apologize to the many authors and supporters for the long delay.

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1 June 1995

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OPENING REMARKS

Aarne Nyyssönen[1]

It is a great pleasure for me to welcome you, all the participants of the symposium, on behalf of IUFRO and the Finnish Forest Research Institute. Since I may be the only participant of this symposium who was present at the first occasion in this series of the gatherings of the people interested in northern forests, I wish to greet you also in that capacity. The symposium was held in Fairbanks, Alaska, 10 years ago in September 1977. "North American Forest Lands at Latitudes North of 60 Degrees" and "High-Latitude Forestry" were used as titels in that time.

Among some 200 participants of the first symposium there were only four men outside of the United States and Canada. In the appendix of the proceedings of the symposium was included a report on "Forestry Potential in Interior Alaska", prepared by a Scandinavian group of forest scientists (Braathe, Holmen and Nyyssönen). The group had been invited by the United States Forest Service to undertake a tour in Alaska in the previous July. The purpose of our report was to provide the State of Alaska and the U.S. Forest Service with an analysis of the Interior Alaska forest lands as compared with Fennoskandia. The emphasis was in various problems of productivity, utility and management concerning current and future demands of forest commodities, but attention was also given to the total environmental aspects of those northern lands, including wildlife and recreation.

The sponsors of the first symposium were University of Alaska, Alaska Humanities Forum, U.S. Forest Service and Bureau of Land management, with the following cooperators: Alaska Federation of Natives, Joint Federal-State Land Use Planning Commission for Alaska, Society of American Foresters and Forestry Section of the Department of Natural Resources of the State of Alaska.

It may be of interest to notice that the list given above does not include IUFRO, our present parent organization. But due to a strong need to continue the cooperation on northern forestry problems and to extend it to the other continents, IUFRO soon came into the picture. We are proud that we now can celebrate the 9th symposium.

I have been asked by the Chairman of the Working Party to provide some information about IUFRO and its goals. The main aim of this union which will soon be 100 years old is to promote international cooperation in scientific studies embracing the whole field of research related to forestry, including forestry operations and forest products. In particular, its functions are exercised by

- facilitating exchange of ideas among individual research workers throughout the world,
- creating and maintaining contacts between Member Organizations and by encouraging the establishment of common programmes of research and cooperation in their execution,

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- promoting the dissemination and application of research results,

- cooperating with national and international organizations of a scientific, technical or cultural nature and more specifically with the Food and Agriculture Organization of the United Nations (FAO),

- working towards the introduction of a uniformity of nomenclature and for standardization in matters such as information storage and retrieval, and

- arranging periodical meetings, often combined with excursions.

Members of IUFRO are the research organizations, not countries nor individual research workers. There are about 600 member organizations in about 100 countries, among them 12 from Finland. The most conspicuous form of IUFRO activities are the world congresses held normally at five-year intervals. However, the activity proper takes place in about 250 groups - subject, project and working groups. The supreme authority responsible for regulating the affairs of the Union is the International Council; I have represented Finnish member organizations in the Council since 1967. The Executive Board of about forty members meets annually.

Since 1981 the orientation of cooperation took a new dimension when the World Bank and FAO came to the Kyoto Congress asking: would it be a time for reappraisal of forestry research priorities in developing countries? A review of research needs had indicated that traditional forestry research was not making a sufficient contribution to rural development, existing institutional arrangements were inadequate to meet the needs for promotion of research and that the resources allocated to research in developing countries were inadequate.

As a follow-up to the recommendations given by the Congress, the IUFRO Executive Board hired a special coordinator for developing countries to assist in planning practical measures. The special program has succeeded in organizing workshops, disseminating information, stimulating research activities, and gaining acceptance and support among forestry professionals, research institutions, and governments in developing and developed countries, as well as among bilateral aid agencies and international organizations.

In the Yogoslavia Congress last year the International Council of IUFRO took an important step to institutionalize the special program. The council authorized and directed the executive board to take all necessary measures, consistent with IUFRO's statutes, to establish an International Council for Forestry Research and Extension (INCOFORE) whose task shall be to promote and foster forestry research and extension in developing countries. The proposed budget for INCOFORE for this five-year-period is USD 8 million. It is likely that also a Finnish financial support will be available for implementation of the program.

After these references to IUFRO and its goals I should like to give you brief information about existing research institutions in the field of forestry and wood science in Finland (see Table).

FOREST RESEARCH INSTITUTIONS IN FINLAND

Forestry	Finnis Forest Research Institute Universities (Helsinki, Joensuu) Research Council for Agriculture and Forestry Work Efficiency Association Foundation for Forest Tree Breeding Metsäteho (Efficiency in Forestry)
Wood Science	Helsinki University of Technology Technical Research Centre of Finland Finnish Pulp and Paper Research Institute

Society of Forestry in Finland

We may notice that in addition to two groups of research institutions there is the Society of Forestry which is a kind of contact organization for all the forest research in this country.

It can be roughly estimated that the total number of research workers in these organizations is around 400, and in forestry research alone some 300 with an annual research budget of some FIM 130 Million. About two thirds of the total budget and manpower in forest research are accounted for by the Forest Research Institute which was established in 1917. The number of scientists at this institute is almost 200. Total personnel is about 700, but including temporary assistants the annual input is in the order of about 1000 man-years. About one half of the people work at the central unit in the Helsinki area and the other half elsewhere. There are 8 research stations in different parts of the country. The surface area of research forests and nature conservation areas administered by the institute is 140 000 hectares.

The main activity of these institutions, forest research, involves publishing and extension activities. In addition, the Forest Research Institute is charged with official duties in the fields of forest statistics, forest taxation, inspection of pesticides and registration of regeneration materials. The Institute also needs to prepare reports requested especially by government agencies. Another important activity is international cooperation.

A rather big group of the participants of this symposium work at our Forest Research Institute. We are here in order to implement one of the Institutes tasks mentioned above, international cooperation. But I think this is a common goal to all of us. At the same time, I think this symposium also fills all the prerequisities to meet the goals of IUFRO. There is a comprehensive program with several sessions and field tours ahead of us, thanks to the preparations done by many persons. I wish every success to the symposium.

NORTHERN BOREAL FOREST RESOURCES, THEIR UTILIZATION AND ECOLOGY
"THE EVERGREEN CROWN OF THE GLOBE"

An introductory paper

Kullervo Kuusela

1. FOREST AND MAN

Forests, the largest and most diverse single terrestrial ecosystem, and man have a common destiny. The first human beings and numerous successive generations have been part of the forest in a way that the largest mammals are considered to be today. Man gathered and hunted for his food in the forest and other nearby ecosystems, he sheltered himself with grasses, leaves and timber, he warmed himself and cooked his food by burning wood, and from wood he crafted his tools, utensils and weapons.

For thousands of years man was a true member of the forest ecosystem. He changed it little, probably less than the biggest animals such as elephant and mammoth. What he took he gave back as consumption residues to the nutrient cycle of the nature. He may have set destructive fires for chasing animals or accidentally from his primitive hearths, but lightning did the same. Whatever the origin of an ancient wild fire it was the beginning of a new round of successive plant and animal communities and a source of renewed diversity.

Of the principal forest zones: boreal coniferous, temperate mixed and broadleaved, evergreen mixed, tropical dry, and tropical moist; primeval man favoured those in the warmer climates where life was less arduous. In these forests there were also plenty of edible seeds and fruits and the fauna was rich.

The relations between man and forest changed profoundly when man learned to cultivate crops and raise cattle on cleaned land. Selective breeding increased the productivity of the crop species. Man became independent of the capricious gifts of the nature. Thanks to clothes, houses, utensils and weapons he could endure more extreme climates. His numbers increased, he felt himself the master of the plants and animals and commenced to invade more and rigorous environments.

However, even in these early stages of development man favoured the temperate and warm zones more than the two extremes, Boreal coniferous and tropical rain forests. The Boreal climate was too cold and the soil too infertile and the tropical ecosystem too profuse to surrender to the first agriculturists except in isolated niches.

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New skills to prepare metals and tools from them further increased man's domains. Still the northern podzolic soils and jungles were stronger than man with his axe and primitive plow in the time of muscular power. The growing human population concentrated in the warm temperate zones and in those dry sub-tropical and tropical areas where soils were fertile and the shortage of water could be compensated for by irrigation. In this stage of development the temperate forests were severely destructed and redused by agriculturists and cattle raisers.

The exploitation and destruction of the temperate forests reached its peak during the early stages of the industrial revolution when machine power replaced muscular power in production and transport. During this period two thirds of the European forests were cleared into fields, pastures and dwelling sites. Almost all of the natural forests vanished from the Mediterranean region and in large areas of South and South-East Asia as well as bulk of them in North and Latin America between the tropical rain and the Boreal coniferous zones.

In over-populated Europe, even in time of muscular power man had colonized large areas of the Boreal zone. The first colonizers lived on hunting, fishing and scanty crops of shift-cultivation and raising cattle. Trade with furs and other crops from nature was of great value. During good periods the population increased but in bad periods crops often failed and the population was reduced by hunger and diseases. For several hundred years industries such as tar extracting and charcoal burning, small scale mining, boat and shipbuilding improved the standard of living in the Boreal region of North Europe.

In the 20th century scientific technology, cheap energy, machines, and improved health services created a geometrical rate of growth of the population. Consumers increased, living standard rose and basic needs had to be satisfied by more fields and pastures, constructional timber, sawn wood, pulp and paper. The destructive exploitation of forests swept over the continents. Boreal forests also became the prey of the unsatiable human race.

Man succeeded to establish permanent and growing settlements adjacent to the Boreal coniferous belt by using machine power; scientific agriculture with drainage, fertilizers, insecti- and pesticides; cultivated pastures; plant and animal breeding. Only under European conditions of land-shortage with regard to the increasing number of people large parts of the Boreal zone was colonized. In Alaska, Canada, the bulk of the European Soviet Union and Asia the principal parts of the Boreal belt are outside of the inhabited areas proper. But the forests of these areas became an important timber source for mankind.

In the industrialized countries with high living standards there is at least a temporary balance between the remaining forests and other land uses. Efficient agriculture and cattle raising have produced surplus food in many of these countries. Large areas of marginal fields and pastures have been afforested, and the forest area is increasing in many countries and in Europe as a whole.

The forest area of the Boreal zone is stabilized or increasing. Exploitative logging without proper regeneration measures and wild fires, however, decrease the area of the coniferous tree stands and change them into the first stages of successions forested by broadleaved pioneer trees. Parts of the original coniferous forests may change after logging into paludified peat sites. Only in Nordic Countries Norway, Sweden and Finland, and in limited areas in the other Boreal countries forestry is based on sustained-yield silviculture and regeneration of tree stands after final cutting.

The forest situation is quite different in sub-tropical and tropical zone of the developing world than in the Boreal zone. There, the population is increasing. There is a desperate need for more fields and pastures and for more fuel wood and other household timber. The severe shortage of fuelwood is expected to be approximately 1 000 mill. m^3 per year around 2000. The destruction of forests by shifting cultivation and reckless logging for industrial timber is continuous. The annual decrease of forests is 10 to 15 mill. ha. The destruction of forests leads to erosion, floads, silting water tables and to other hazards to the environment.

In the 20th century mankind has reached an explosive stage of technological development. Man has become a force of geological magnitude capable of destroying his ecological environment by combining science and technology in the industrialized production of commodities and energy, including electronics and nuclear power. Manking has a potential to multiply the world sweeping ecological changes he has brought about so far.

The increase of carbon dioxide in the atmosphere and of airborn pollutants is feared to lead to fundamental changes in climates and ecosystems. The sagacious and industrious human being has reached a stage where he is capable to degenerate the very roots of his life.

2. BOREAL FOREST RECOURCES AND THEIR UTILIZATION

The Boreal coniferous zone is a homogeneous vegetation belt around the North Pole. There is no precise estimate of its area because it belongs to various states and administrational units which also include other forest zones. An approximate estimate of forest in the zone proper is 850 mill. ha, which is 29 % of all forests and 73 % of the coniferous forests of the world. Its share of industrial wood removals is 33 % and of industrial coniferous removals 35 %.

The high economic value of the Boreal forest stems from its good quality for coniferous sawnwood and fibre and from the homogeneous structure of the tree stands. The climax stages of tree stands comprise of often only up to 3 more or less similar conifers. The harvestable crop per hectare is great in spite of the small annual increment of stem volume.

Frozen ground and snow cover in winter and floatable waterways in summer favoured logging and transport of timber in the time of muscular power. Except in mountains, the terrain and soils are easily operable from the point of view of constructing forest roads and using tractors. Soft peat lands restrict logging in the summer but can carry vehicles and equipment in the frozen season.

In Boreal regions the forest resources per capita have been and are still much greater than the world average. The area of exploitable closed forest per capita varies from 2 to 9 ha and annual removals from 1.4 to 8.9 m³, timber assortment volume under bark. The world averages are 0.44 ha and 0.66 m³. Boreal countries have much more harvestable wood per capita than they need for their own consumption. For example, in Europe, excluding the Soviet Union, the consumption of forest products corresponds to 0.75 m³ of roundwood per capita while the removals are 6.4 m³ /capita in Canada and 5.9 m³/capita in Nordic countries.

Men capable of living in rigorous climate have had to possess considerable physical qualities to over-come the hard living and working conditions. They have attained the knowledge and skills to harvest and process wood into a great variety of commodities. The boreal zone has become and remains one of the most important global suppliers of timber and processes products.

Forest resources

The Boreal forests cover much of Alaska, Canada and the Soviet Union as well as Nordic countries. Resource information compiled in the late 1970's and around 1980 are presented in Table 1.

The total area of forest and other wooded land of these regions is 1 474 mill. ha, of which closed forest is about 1 120 mill. ha, and exploitable closed forest 802 mill. ha. Large areas of these regions belong to the temperate zone, however. About 20 % of the Soviet forests, coastal Alaska and British Columbia, although these latter two areas are dominated by conifers, are outside the Boreal zone proper. The southernmost parts of Canada, Norway, Sweden and a narrow strip of south-western coast of Finland also belong to the temperate mixed forest zone.

Shares of the forest resources from the world total (Fig. 1) compared with the share of population demonstrate how rich the boreal countries are in forests. Shares within the Boreal regions and growing stock and net annual increment per hectare of exploitable forest are as follows:

	Alaska	Canada	Nordic	USSR	Total
			per cent		
Population	.	8	6	86	100
Forest and other wooded land	3	30	4	63	100
Expl. closed forest	1	27	6	66	100
Growing stock	1	24	5	70	100
Coniferous	1	24	5	70	100
Net annual increment	.				
Coniferous	.	27	13	60	100
Growing stock m³/ha	287	107	91	125	119
Net annual increment "	0.79	1 68	3.27	1.40	1.58

It should be noted that even though the growing stock volume per hectare is smallest in Nordic countries the net annual increment of this region is by far greatest. In the case of the Soviet Union the area of exploitable closed forest obviously consists only of forested land. If about 120 mill. ha of land capable of growing closed forest, but at the moment treeless or under scrub forest following final fellings and wild fires, were included in exploitable closed forest, the net annual increment per hectare would be 1.15 m^3 in the Soviet Union. The Canadian exploitable closed forest land includes 22 mill. ha of land more or less treeless, following final cutting, forest fires and other calamities.

Removals of timber

Removals of timber in under bark volumes of harvested timber assortments are presented in Table 1. The shares of the world removals, the shares of the Boreal totals, and removals per hectare of exploitable closed forest are as follows:

	Alaska	Canada	Nordic	USSR	Total
	percent of world totals				
Removals	0.1	5.2	3.5	12.2	21.0
Coniferous	0.3	11.9	7.3	25.4	44.9
Industrial timber	0.2	10.4	6.6	19.7	36.9
	percent of Boreal totals				
Removals	0.5	24.8	16.6	58.1	100.0
Coniferous	0.5	26.5	16.4	56.6	100.0
Industrial timber	0.5	28.3	17.9	53.3	100.0
Removals m^3/ha	0.69	0.71	2.11	0.67	0.76

Nordic removals per hectare are about three times greater than in other Boreal areas.

Annual removals were increased from the beginning of 1960's to the first half of 1980's, if removals at 1980 equal 100, by 30 percentage units in the world as a whole and by 35 units in Canada (Fig. 2a). In Nordic countries removals increased up to 1975 but then decreased to the level of the beginning of the 1960's. In the Soviet Union the removals decreased by about 8 percentage units around 1975 and have since remained on the 100 percent level.

The world removals of coniferous assortments and industrial wood have increased less than the total removals and removals of industrial wood. This is explained by the growing need for fuelwood and increasing removals of non-coniferous assortments in the developing countries. In the industrialized Boreal countries the consumption of fuelwood and removals of non-coniferous assortments have decreased.

Increases in the removals of industrial wood stagnated around 1980. This is partly explained by the increasing consumption of saw- and veneermilling residues and the use of waste paper for pulp, particle and fibre boards.

There is some evidence that the timber resources within reasonable distances of the forest industries in Canada and the Soviet Union are exhausted and there are increasing difficulties to economically satisfy the need for timber from forests farther away. In Nordic countries the removals are 15 to 20 percent smaller than removals on the basis of sustained yield. The bulk of the forests there are in private ownership and the owners are not willing to utilize them fully. Nordic forest industries have for about 15 years been dependent on timber imports which have covered 10 to 15 percent of their needs.

Production of forest industries

Production of forest industries in the Boreal regions of Canada, Nordic countries and the Soviet Union around 1980 and the share of totals of the world production are presented in Table 2 and the country shares of the world production in Table 3. These countries produced 53 percent of mechanical pulp and newsprint, 38 percent of sawnwood and 35 percent of the products of basic forest industries.

Proportional shares of countries are:

	C	N	S	F	NC	USSR	Total
				percent			
Sawnwood	26	1	7	5	13	61	100.0
Wood-based panels	25	3	10	8	21	54	100.0
Mechanical pulp	52	6	13	16	35	13	100.0
Chemical and other pulp	38	2	21	15	38	24	100.0
Total basic industry	31	2	12	9	23	46	100.0
Newsprint	64	4	11	11	26	10	100.0
Writing and printing paper	24	5	17	34	56	20	100.0
Other paper and p.broad	20	3	23	14	40	40	100.0
Total paper and p.broad	38	4	17	16	37	25	100.0

Canada is a great producer of sawnwood, mechanical pulp and newsprint, the Soviet Union produces much sawnwood and wood based panels and Nordic countries produce much paper and paper board, especially writing and printing paper in Finland.

Production per capita figures (Table 4) demonstrate that forestry and the forest industries are of greatest importance to Finland, Sweden and Canada. In proportion to population, the production of paper and paper board is much smaller in the Soviet Union than in other Boreal countries.

Value of forest exports and imports

The total values of forest exports and imports and the values per capita, and the shares of totals in world trade are presented in Table 5 and the shares by products in Table 3. Boreal countries account for 47 percent of the world exports and 5 percent of imports. The share of sawnwood exports is 55 percent, wood pulp 66 percent and paper and paper board 53 percent.

The export of forest products is of the greatest importance to Finland, 942 $U.S. per capita. The corresponding value for Sweden is 596 $U.S. and for Canada 403 $U.S.

Efficiency of forestry

In spite of the international attemts to standardize the units of measurements and methods in surveying forest resources there are still many inaccuracies which make it difficult to compare the figures of one country with another. Some conclusions are, however, obvious.

In the following review the recorded net annual increment and removals per hectare around 1980 in Alaska are marked as 100. The corresponding estimates for other areas in proportion to the Alaskan values are:

	Net annual increment	Removals	Percent of removals from net annual increment	
			total	coniferous
Alaska	100	100	86	158
Canada	209	103	74	68
Nordic countries	409	306	81	85
Norway	328	200	65	76
Sweden	442	329	80	83
Finland	396	316	86	90
USSR	175	97	62	64
Total	198	112	63	68

The net annual increment and removals per hectare are far greatest in Nordic countries. Possible reasons for this are discussed in the part of this paper concerning forest ecology.

In the Boreal region of European Soviet Union (Fig. 1) the proportional value of removals was 97 at the end of 1970's. In this region the removals are reported to exceed the net increment by 26 percent. The overcut has been greatest in the administrational regions in the Boreal zone proper. For some time, the aim of Soviet forestry policy has been to move logging to Siberia and the Far East where there are large virgin forests. However, even in Siberia the forests near railways and floatable and navigable rivers have been heavily exploited.

In Canada the removals can be increased if the net increment of the total area of exploitable closed forest is taken as the ceiling of the allowable cut. The forests in use so far have been heavily exploited, and there are difficulties in moving logging to the remaining virgin forests far away from the forest industries and populated areas. If the current level of production is continued, the mill prices of wood can be expected to rise and the quality of wood to decrease.

In Nordic countries the removals, though much greater than in other Boreal areas (Fig. 1), have been smaller than the net increment by 35 percent in Norway, by 20 percent in Sweden and by 14 percent in Finland. These countries have lost, at least temporarily, their ability to fully utilize their timber resources.

In all Boreal countries, the coniferous tree stands are exploited proportionally more than the non-coniferous ones. The obvious reason for this is the small size, higher logging costs and lower value of non-coniferous trees. If the unexploitable non-coniferous trees are not cleared away as a silvicultural measure in the regeneration areas, and if large parts of the overcut areas are left to regenerate naturally by pioneer tree species, the productive value of forests will decrease.

3. ECOLOGY

Ecological conditions

The boreal coniferous forest is a homogeneous vegetation belt around the North Pole. Temperature is the most influental environmental factor determining its geographical location. The northern boundary of the zone is approximately on the July 13 °C isotherm. Marked departures, however, are coused by mountains and oceans, maritime and continental climatic influences. The southern boundary coincides with the July 18 °C isotherm. Conditions drier than average push the zone northwards.

The Boreal zone can be divided into continental, high-continental and maritime parts. The continental climate dominates most of it. Winter is long and cold. Abundant snow lasts 5 to 7 months. Considerable variations of the monthly mean temperature is a marked feature. Desiccating winds and temperature of -20 to -40 °C, or even colder, can be lethal for trees in the northern parts of the belt.

Warming in the spring is rapid but there is a great variation in the time photosynthesis begins. Summer weather is comparatively warm but it can be very changeable. The vegetation period lasts 100 to 150 days, 90 to 160 days in most extreme conditions. The mean temperature of the warmest month is +10 to +20 °C.

The annual precipitation varies from 400 to 600 mm, with the maximum of it falling during the summer months. The relative humidity is 50 to 70 percent in July and August. Climate is humid and water moves generally downwards in the soil.

During a year the range of the mean temperature is 20 to 40 °C and the maximum range can be 60 to 70 °C.

In the high-continental climate the winter is very long, extremely cold and dry. The mean annual temperature is -7 to -10 °C. The range of the mean monthly temperature can be more than 40 °C. The maximum range of temperature is 80 to 100 °C and the lowest temperatures can be -50 to -60 °C. The mean temperature of the coldest month can be colder than -25 °C. Summer is short and comparatively warm. Mean temperature of the warmest month is +10 to +20 °C. However, frost is possible every night even in summer.

Precipitation is generally smaller than in the other parts of the zone. Because of cold winter and thin snowcover there is permafrost in large areas. As an example of the capricious weather, in the Western Sibiria the annual presipitation varies from 350 to 600 mm of which 80 mm can fall in one storm.

In the maritime part of the zone the range of climatic extremes is smaller. There is more snow. Winter is comparatively mild and summer often cool. The temperature of the warmest month is +10 to +15 °C and of the coldest +2 to -3 °C. The annual precipitation ranges from 400 to 800 mm or more in some coastal areas and much of it falls during the winter.

Because of glacial action the parent soil material is generally less fertile than in the temperate zone. Glacial and alluvial sands and gravels dominate with morains. Podzol is the most common soil profile in the cold and humid climate. Podzolization process is fastest in sandy glacial outwashes. In more fertile sites podzolization proceeds at a slower rate. These profiles are nearer to brown forest soils than podzols proper and are often referred to as brown podzols.

Sites are inclined to paludify and change into peat-forming mires in conditions where drainage is impeded.

Coniferous trees are well adapted to Boreal conditions. They can reduce their transpirational water-loss to a very low level during the winter when water is unobtainable from the frozen soil.

In the spring, when temperature allows photosynthesis, the conifers are able to profit by it earlier than deciduous trees which have to grow leaves before photosynthesis can commence. Thus deciduous trees waste a part of the short growing season.

The deciduous trees have also to use a greater part of their net primary production to maintain foliage than the conifers. They renew their foliage once every year while the evergreen conifers renew their needlemass during 4 to 7 years.

Because of these competitive advantages the taller growing and longer living conifers can over-top and, with their greater biomass, out-compete the broadleaved trees. This also explains the greater timber production of conifers compared with broadleaved trees on similar sites.

In rigorous wether conditions near the northernmost boundary of the zone and in forest tundra, however, the coniferous evergreens can not endure the desiccating winds and bitter coldness. Under such conditions some broadleaved deciduous trees and shrubs such as birch, aspen and willows are more competitive than conifers. Growing slow and low, leafless in winter and partly inside the snow and regenerating by vegetative sprouts, they can overcome the cold weather and desiccating winds and form sparse stands.

In the most rigorous conditions of the Eastern Siberia and the Far East, two conifers, Dahurian larch (Larix dahuria) and its associate, dwarf Siberian pine (Pinus pumila) can survive and form the forest boundary against the tundra. They are shallow-rooted, low-growing, and often creep along the ground. The Dahurian larch combines the competitive qualities of both coniferous and deciduous trees.

In addition to the climatic and edaphic factors, the location, height and orientation of the mountain ranges and the location of seas have effected the composition of the plant species which have had to retreat and re-advance during the glacial and inter-glacial periods.

Plant-species compositions are comparatively similar in the North American, European and Asian formations of the Boreal formation-type. As a rule, the same plant genera occur and prevail in environmentally corresponding areas throughout the Boreal belt. However, there is a marked difference in the number of dominating tree species in North America, in Nordic countries, in the European Soviet Union and in Asia. The number of tree species is greatest in North America, and greater in Asia than in Europe. The location of the mountain ranges and seas in Europe have been a barrier for advancing tree species during the inter-glacial periods.

In North America, including the coast of Alaska and British Columbia, there are six principal coniferous tree genera and the number of species is 24. In the Boreal North America proper the corresponding numbers are 5 and 11.

In Nordic countries there are only 2 coniferous genera and 2 species and in the European Soviet Union 4 and 4. The corresponding numbers in Asia are 4 and 16; the number of species increasing from west to east.

The genera Betula, Populus and Alnus are pioneers in the Boreal tree stand successions. They belong to climax stages on water sides, wet lands and some mire types, and are associate species in stands dominated by conifers.

Natural and human dynamics in forests

The current state and future development of Boreal forestry are results of both natural and human dynamics. Principles guiding the dynamics of forest ecosystems are also the basis for studying and understanding the disturbances in forest ecosystems caused by human activities. Forest ecosystems attempt to adjust to these disturbances by definite natural reactions and when disturbances cease the ecosystems revert to the natural development.

The natural and human dynamics are illustrated by selected features of the forests of Finland with few references to other Boreal areas.

Plant-community successions and climatic climaxes

Boreal plant-communities are very young when compared with the tropical rain forests which have changed little over the last million years. During the glacial period, ice advancing from the north swept away all plants, animals and soils. After the ice retreated there appeared a completely inorganic surface of the parent soil material: bare rock, smooth boulders, glacial and fluvial sands and gravels, morains and fluvial loam and clay plains. The pre-glacial drainage system was destroyed and the new terrain was poorly drained, studded with ponds and lakes. Large areas were from the beginning susceptible to development into peat forming mires.

Plant and animal life started to invade the land rising from water after the retreating ice. Colonization and further development are usually described by a succession of plant communities, although the description could equally be focused on the characteristics of animal communities, microclimates or soil processes (Fig. 3).

Colonization stages on inorganic bare site are called primary seres. The first pioneering community comprises algae and lichens which can anchor themselves on the rock and boulders, take water when it is available and withstand desiccating periods. Pioneering communities create primitive soil from inorganic and organic particles, and prepare the site for more demanding plant and animal communities.

The secondary community also consists of mosses able to store water. This accelerates soils-forming processes with water-retaining layers, thus making the habitat less susceptible to drought. Microbes and animals co-operate with plants in soil-forming processes.

In the third stage turf-forming annual and ephemeral grasses (e.g. Festuca ovina) and in the fourth stage low-growing shrubs invade the site and create a thick soil layer.

In the subsequent stages trees dominate. At first, broad-leaved pioneer species with lightweight seeds transported by wind. Shrubs and trees create ameliorated micro-climate. Climatic extremes are reduced, the number of plant and animal species increase and forest soil profiles start to develop.

In the final stage, the deep-rooted, long-living climax tree species and the ground vegetation tolerating the shade of trees dominate the site. Species from earlier stages rarely survive under climax conditions. This is because the most competitive trees have shade tolerating seedlings which nevertheless outgrow shade-intolerant pioneer trees. The result is a climatic climax where, at least in theory, the plant and animal community is in balance with all environmental factors.

However, the climatic climax may not be permanent in the sense that it is an unchanging system where there is a balanced mixture of regenerating, growing and dying trees and other plants. Left undisturbed by wild fires and other calamities the climax tree-stand may finally give way to smaller and greater openings in the crown canopy thus giving a chance for a new seral development. Another interference to a climax tree-stand may be caused by degenerating nutrient cycle, paludification and the change of a poorly-drained site into mire.

Arresting factors, e.g., temporarily impeded drainage, may change the direction of a seral development into a subclimax community. When the arresting factor is removed, the subsere continues towards the true climax.

In natural Boreal conditions without effects caused by man, wild fire and some other calamities destroy climatic climaxes and start new seral successions towards climaxes. A very heavy fire may cause more or less bare site conditions where the successions restart from smaller plants than trees.

Plagioseres and plagioclimaxes are additional developments of plant-communities caused by the protracted actions of man and his domestic animals. Shifting cultivation with regular rotations and forest pasturing have maintained plagioseres. A heavy stock of reindeers, for example, and silviculture maintain forest structures different from natural forests.

Natural tree-stand successions

On lands exposed by the retreating ice cap some 10 000 - 12 000 years ago there developed two basically different types of soils, a mixture of mineral particles and humus on mineral sites and pure organic soils on peat lands. On lands where topography, impeded drainage and precipitation exceeding evaporation favoured paludification and peat-forming, mires were abundant.

About a third of land in Finland is now covered by peat. The share of mires increases towards the north. In Northern Ostrobothnia 60 to 70 percent of land is under mires. Moss and shrub vegetation dominates and tree stands are composed in most cases by small, stunted and bushlike scattered trees.

Before man, wild fire was the iniciator of treestand successions and the rejuvenator of forest ecosystems. On driest glacial sands and gravels the rotation of wild fire was 40 to 60 years and only on fresh morains, loams and clays the plant-communities could develop undisturbed for more than about hundred years.

A simplified scheme of the tree-stand successions on mineral sites is presented in Fig. 4. Some additional and partly hypothetical comments are needed to supplement the sheme.

As stated earlier, temperature during the growing season restricts most the gross primary production of tree stands. Gold weather retards the decomposition of the plant residues. On poor podzol soils, insufficient nutrients restrict the gross primary production more than the insufficiency of solar radiation, temperature and water.

The more assorted the soil parent material is and the less it includes clay particles, the greater is the susceptibility of sites and tree stands on them to fire. In natural conditions the rotation of wild fire is so short that on most of these sites there has been never a true climatic climax-stand. Because spruce is much more susceptible to fire damage than pine, pine is generally considered as the climax tree on alluvial sands and gravels.

On the poorest sites pine is also a pioneer tree. Birch, aspen and alder as pioneers invade open sites after fire or any other calamity. On morains and more fertile sites spruce is the climax tree.

Mixed forests and stands dominated by broadleaved trees can form climax stands on watersides and wet lands.

Without wild fire and human disturbances tree stands would developed into climaxes. Spruce would dominate on almost all sites except possibly the poorest sands and gravels. Spruce undergrowth together with spruce dominated crown-layers would shade-out all other tree species from the site until a calamity or the death of overmature large trees created openings and open land for other tree species to form pioneer stands.

There is evidence that under climax conditions the site begins to degenerate: mosses increase in the ground vegetation; the raw humus layer becomes thicker; nutrients available for trees, especially nitrogen, decrease; the site looses its fertility; paludification increases in conditions of poor drainage and the site may change into mire.

On the most barren sites and expecially near the northern forest boundary heavy fires can damage the thin humus layer to such extent that the site looses its fertility and becomes for a period of time unable to carry closed tree stands. During historical dry periods fire has moved the northern forest boundary long distances to the south.

Climatic climaxes of spruce may represent a degenerated nutrient cycle and lower site quality compared with conditions where repeated wild fire interrupts the advancing degeneration. Burning rejuvenates the soil and increases also the active nitrogen resources because of the symbiotic fixation by alder and some pioneer shrubs.

As an extreme example, in a black spruce stand the total storage of nitrogen in the humus and soil can be 1 722 kg/ha, of which there is only 37 kg or 2 percent available for trees which take up annually 15 kg and return to the soil in the form of litter an equal amount.

Tree stand successions under human disturbances

Most of the Boreal forest belt has been and remains outside the main zones of human settlement. Only in Nordic countries has man extensively settled in the Boreal zone and developed there a modern industrialized society. Virgin forests outside silviculture and timber production consist of smaller and smaller areas. Soon virgin forersts will exist only in national parks, other reserves and limited areas outside profitable logging. Even these may no longer be virgin proper, as they are protected from wild fires, and also suffer from airborn pollutants.

Human activities can be studied and analyzed inside the frames of the scheme presented in Fig. 5. During several hundreds of years the Boreal forests have been under the influence of the developing types of economics with correspondind functions of forests and dimensions of timber production.

The first human settlements and their economies a and b, Fig. 5, did not significantly change the natural forest conditions. There is some evidence that nomadic pasturalists with their reindeer stocks introduced deliberate forest fires to improve the pastures and thus modified to some extent the northernmost forests. The first colonizers increased rather than restricted forest fires and corresponding tree-stand successions.

The era of shifting cultivation, pasturing in forests, extracting tar and charcoal, the growing consumption of wood for houses, fuel and many other household purposes, and boats and ships (2c in Fig. 5), flourished up to 19th century and thoroughly changed the virgin forests within the reach of muscular power and floatways into plagio seres dependent on human activities.

Although the number of people was much smaller than now, man penetrated everywhere, except the most barren watersheds and eastern and northern wilderness. In the north, permanent settlements extended along river valleys to beyond the Arctic Cicrle.

It has been estimated that shifting cultivation has covered 4 mill. ha of forest land. Human activities increased forest fires. The bulk of the spruce forests were pushed away from the most fertile sites. The rotation period of shifting cultivation was from 20 to 40 years. Between agricultural cropping of 2 to 4 years, the sites grew mostly alder, birch and aspen. In large areas of Southern Finland and along the Gulf of Bothnia large-size construction timber was a rare commodity.

This stage of economic evaluation supported a population of only about 1.5 mill. When crops failed, tens of thousands of people died of hunger and diseases. However small the population, men exhausted the timber resources, which reached a minimum in the second half of 19th century.

Mining, extracting metals from the ore and shipbuilding industries were great consumers of wood. Because of an imminent shortage of exploitable timber, laws were enacted to restrict the cutting of forests. Initially, sawmills driven by water-power were suspected to be a cause of the destruction of the forests. The establishment of steam sawmills was permitted in 1857.

Steam-power, produced by burning wood, was introduced to increase production. It overcame the distances of timber transport. Steam and waterways became the means to transport timber from inland to factories and coast and timber and processed products to export markets.

Exports made possible imports of raw-materials, machines and foodstuffs which enabled the population to grow and to increase more diversified production.

The green gold of Finland was discovered. The sawmilling expanded strongly in the 1880's. The value of forests increased by another large step after wood-fibres started to be used as the raw-material for paper. The first pulp-grinding machine was started up in 1860, the first kraft pulp mill in 1880 and the first sulphite mill in 1885. The economy switched trough type 2d to 2e (Fig. 5).

During the time of sawmilling dominance there was market demand only for large-dimensioned trees which were felled by selection cutting. This finally led to poorly productive residual tree stands, many of them of spruce on barren sites. The growth of pulp and paper industry resulted in demand for all timber assortments and permitted the carrying out of silvicultural thinnings, regeneration cuttings and the rational growing of timber.

Although the consumption of timber by the forest industries increased strongly, industrialization brought about a start on the improvement, regeneration and increase of forest resources. At the same time, the wasteful practices of shifting cultivation and tar burning were discontinued. Forest fires became effectively controlled. Fuelwood was replaced by coal, oil and electricity. The use of wood as building material declined.

Industrialization resulted in a major structural change in wood consumption. The proportion of wood used by industry out of the total stemwood drain was about 2 percent in the 1850's, 20 percent in 1900, 50 percent in 1950 and 82 percent in 1980.

Without the great increase in the comsumption of industrial wood removals would have been much smaller than they have been during this century. Drain of stemwood smaller than its increment would have resulted in over-density, over-aging and partial deterioration of the growing stock, and a mature tree crop much larger than has happened so far.

From the point of view of forest ecology, shifting cultivation, large forest fires, and heavy utilization of timber prevented overmaturing of the tree stands and the widespread development of climatic climaxes dominated by spruce. During the stage of expanding industrialization there were still large virgin forests in the eastern and northern parts of Finland. In Southern Finland young and middle-aged tree stands, many of them in seral stages, dominated and produced most the timber for growing industries.

Tree stands in the stages of highest net primary production have dominated the age-class structure of forests in the principal timber producing regions. In addition to this, the intensive human disturbances also activated the nutrient stores in soils and increased the flow of the nutrient cycle between soil, trees and ground vegetation.

The aim of the first forest laws was to quarantee timber for shipbuilding and mining. The laws to promote silviculture and sustained-yield management were not enacted until the beginning of the 20th century when the demand for timber grew in the export oriented forest industries. The main objective of the current forest laws is to prevent the destructive exploitation of the immature tree stands, and to quarantee regeneration after final cutting.

Silviculture has been intensive since the beginning of the 1950's when the markets for all timber assortments improved. Thinning yield was about 60 percent, or even more, from the total removals until the 1970's and are 20 to 30 percent at the moment. During the past 20 years final harvesting with regeneration has totalled about 160 000 ha per annum of which about 125 000 ha have been planted or artificially seeded. Scarification and ploughing has totalled about 120 000 per annum.

Silvicultural and forest improvement achievements on the 19,6 mill. ha of forest land in timber production between 1947 and 1986 are as follows:

artificially planted and seeded stands	3.6 mill. ha
seedling stand improvements about	9.0 "
drainage (61 percent of the area of mires and other wet lands)	5.5 "
fertilization	2.8 "
increase of forest land capable of growing closed forest: from 17.4 to 20.1 mill. ha in 1952-1981	2.7 "
increase of tree stands younger than 40 years	3.2 "
increase of tree stands dominated by pine	3.8 "
construction of forest roads	76 000 km

The area of spruce stands on poor sites has considerably decreased, especially in Northern Finland. On the other hand spruce has invaded most of those areas which had grown pioneer tree stands after the period of shifting cultivation. Non-coniferous tree stands decreased during the period 1950-75 but have started to increase since then, especially on drained peatlands and abandoned fields. The bulk of the current broadleaved stock grows as a mixture in tree stands dominated by conifers.

Logging and regeneration cuttings have reached the coniferous forests near the northern forest boundary. In the coldest climate and on the barren sites artificial stand establishment often fails and is at least unprofitable in comparison with the natural seeding.

Natural regeneration of coniferous tree stands succeeds on cleared and prepared ground, even near the northern forest boundary, although the time required there for seedling stand to become established can be from 10 to 30 years. If the northern forest boundary has changed during the 20th century, it has moved northwards. There is evidence that the historical movements of the forest boundary have only been caused by changes in the macro-climate. Cold and dry periods with large forest fires have shifted the forest boundary southwards; warmer and more moist periods move it northwards.

From the point of view of ecological productivity, the heavy utilization of the forest via silvicultural harvesting and regeneration after final felling has resulted in an agestructure where all age-classes of tree stands are represented. Most of the stands are in the stage of greatest net primary production.

Tree-species composition have been constantly changing. Silvicultural measures have stopped the degrading development of soils under old climax coniferous stands or the stand development towards climax. On all regeneration areas there is at least a short time stage of pioneer vegetation even if the new stand is dominated by conifers in the later stages.

The silvicultural disturbances can be considered as a substitute for wild fires rejuvenating the tree stand and soil ecology. The current silvicultural measures may not counterbalance the degrading tendencies in the finnish conditions where the total area of forest fires was only 4 360 ha during the period 1976-86.

In Boreal Canada and the Soviet Union, most of the forests have been outside human settlements and the bulk of the current exploitable tree stands are at ages and seral stages where the net primary production is small or even negative. This explains the great mortality and small net increment of the stem volume. Possibly the site quality has also degenerated under the stands dominated by spruces and firs.

In those countries, almost all timber is harvested by final cuttings from old and over-aged virgin stands. The large overcut areas are frequently left without silvicultural measures to natural regeneration. Forest fires and other calamities destroy huge amounts of timber. Millions of hectares of the original coniferous forests have changed to seral successions dominated by broadleaved trees.

In the northern European Soviet Union and West Siberia, where the rivers flow into the Arctic Ocean and where the spring melting of snow and ice starts at the fountainheads, the flat terrain is inclined to floods and paludification. Large clear-cuttings without immediate regeneration may lead to reduced evaporation to an extent that former dry lands change into mires.

As stated earlier, the Nordic countries have reached a postindustrial stage of economic development (2f, Fig. 5). Future timber removals will be, at least for the time being, about 20 percent smaller than the net increment of growing stock volume. The share of thinnings will be 20 to 30 percent of the total removals which is too little to maintain the good silvicultural conditions of the growing stock. The density and age of the growing stock will increase and many of the spruce and pine stands will develop towards plagioclimaxes.

Side by side with the technological, economic and social development the function of forests has changed from a commodity function to a protective, social and cultural function (3a-d, Fig. 5). As a consequence, effective and profitable timber production measures are often considered to be harmful and undesirable. Further, the great share of private non-industrial forests composed of numerous small holdings seriously restrict effective timber production.

Both the increasing density and age of the growing stock and the share of the overmature climax stands will increase the mortality and losses of the timber crop and degrade the forest as a productive element and a good environment. Long term consequences are most serious if this development also leads to a degrading nutrient cycle and a deterioration of the site qualities.

The latest human disturbance and menace to the Boreal forest are the airborne pollutants and the increase of the carbon dioxide in the atmosphere. There is some evidence that the precipitation of nitrogen and the increase of carbon dioxide have temporarily increased the growth of the trees. Damages caused by direct fume effects and the precipitation of sulphur ant other pollutants in the neighbourhood of industrial centres are obvious. The accumulation of pollutants in large forest areas is considered great enough to cause changes in the ecosystems.

Several industrial compounds and high-level jet exhaust may damage the earth's protective ozone layer. The reduced ozone layer causes an increase of harmful ultraviolet radiation. The phenomenon may be most severe in the Boreal latitudes.

The continuing increase of atmospheric carbon dioxide is considered to result in an increase in the mean air temperature which in turn may change the precipitation and wind conditions. Although the process is slow and its consequences may, at least at the moment, be hypothetical, the subject matter is of utmost importance for the future of the Boreal forests. Even seemingly small increases in the mean temperature increase the competitiveness of broadleaved trees with regard to the conifers. This results in areal changes in the tree-species composition and pushes the Boreal belt northwards.

4. FINDINGS AND DISCUSSION

The Boreal countries posses rich forest resources. The area of exploitable closed forest varies from 1.6 to 9.0 ha per capita and removals around 1980 from 1.4 to 8.9 m^3 per capita while the world averages are only 0.44 and 0.66 respectively.

In all Boreal countries and Alaska timber in an important raw material. Processed by forest industries into commodities it is a valuable export asset. These regions account for 21 percent of the world removals, 45 percent of the coniferous removals and 31 percent of the removals of industrial timber.

Canada, the Nordic countries and the Soviet Union account for 35 percent of the world production of the basic forest industries, 21 percent of paper and paper board and 53 percent of both mechanical pulp and newsprint. Their share of the export value of the forest products is 47 percent, 55 percent of the value of sawnwood exports, 66 percent of woodpulp and 53 percent of paper and paper board.

In order to maintain their share of world production and trade, Boreal countries have to intensify their forestry and move logging deeper and deeper into the remaining wilderness.

Net annual increment of stem wood per hectare is 2 to 3 times and removals about 3 times greater in Nordic countries than in other Boreal areas. In regard to the climate they are greatest in Finland and second greatest in Sweden. There are obvious reasons for this:

During past centuries the Nordic people have lived inside the forests and utilized them heavily. The consumption of wood was so great during the time of the muscular power that the growing stock volume was very small in the 19th century and at the beginning of the 20th century. At that time virgin forests existed only outside the reach of man, horse and waterways.

The heavy utilization of timber continued for the growing forest industries later in the 20th century. This maintained conditions where the mature tree stands were cut ant new young stands were regenerated after the final cuttings. Therefore the bulk of the current tree stands are in the ages of great net primary production.

Silviculture has been at a high level during the last 50 years. Forest owners have been responsible for establishing a new tree stand after harvesting the mature stock and applying silvicultural thinnings to immature stands. Thinning yield was about 60 percent of the total removals around the middle of this century and is still 20 to 30 percent now. Mortality and the decays of stemwood in the forest has been comparatively small.

Human disturbances, earlier combined with large wild fires, have maintained the rejuvenating seral successions of the tree species and activated the free nutrients in the soils. Large scale drainage of mires in Finland has restricted the paludification and peat-forming processes and increased productive tree stands on drained and fertilized peat lands.

In Canada and in the Soviet Union almost all timber is harvested by final cuttings, mostly without proper regeneration measures, from mature and overmature tree stands away from human settlements. Mature and immature climax stands are in the stages of small, zero or negative net primary production and the site under them is susceptible to degenerative processes.

Mortality and fire damages are huge. Large areas of earlier coniferous forests have changed into shrub forests and successive sub-seral stages dominated by low-value non-coniferous trees.

Paludification and mires may increase on flat lands, especially along rivers flowing to the arctic ocean. Harvesting of timber is moving to far-away virgin forests which increases logging and transport costs and may lead to decreasing quality of timber.

In post-industrial Nordic countries repeating wild fires have been effectively eliminated. Removals are about 20 percent smaller thant the increment of growing stock. The bulk of the tree stands are becoming denser and older. If this continues long enough mortality will increase and the value of timber stock will decrease. Over-dense and over-mature tree stands are not the best environment for the multiple-use purposes.

In large areas, old spruce stands and the risk of degenerating soil fertility will increase. In neglected degeneration areas, seedling and young stands on peat lands and abandoned fields, the low-quality non-coniferous trees are also increasing in Nordic countries.

The environmental turmoils in Boreal forestry call forth many topics for further research:

Logging is moving farther and farther away from the settled areas and mill sites to the remaining virgin forests. How much will this increase the costs of production and transport? What will be the quality of timber? E.g., if the quality of coniferous sawlogs decreases, what are the consequences in the sawnwood markets?

An important item is the extent and tree-species composition of the pioneer stands established by natural reproduction on the over-cut areas and how long a time will the seral development take from non-coniferous stands to harvestable coniferous stands under different site conditions.

The process from broadleaved stands to spruce stands lasted about 100 years without silvicultural measures in Southern Finland following the cessation of shifting cultivation. The time was reduced to 50 to 70 years by silvicultural cuttings, and to 30 to 50 years using planting and other silvicultural measures.

A minor but locally important topic for investigation is the rate of tree-stand successions on drained peat lands and abandoned fields.

It would be interesting to find out whether economically possible means exist to release the inactive storage of soil nitrogen for trees and thus increase the productivity of the Boreal sites.

There is evidence that in large areas in Boreal regions where flat land with poor drainage conditions dominates, paludification and development of mineral sites into mires increases after harvesting old coniferous stands. What is the geographical distribution of this process and what are the consequences?

The benefits and value of site preparation, herbicides, drainage, etc., require further studies. For example, in Finland there are large over-cut areas in stages of regeneration near the northern forest boundary. Although there will be new tree stands, what is their species composition and how long a time is needed to grow harvestable timber in these rigorous conditions?

And finally, too little is known what are the consequences in Boreal forests of the air-borne pollutants and the changing composition of the atmosphere.

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Table 1. Forest resources of the Boreal regions and their share of the world totals.

		Alaska	Canada	Norway	Sweden	Finland	Nordic countries	USSR	Total	Per cent of world
Population	mill.	0.40	23.94	4.09	8.31	4.78	17.18	265.54	307.06	7
Land	1000 ha	146 698	916 700	30 754	41 148	30 547	102 449	2 227 500	3 393 347	26
Forest and other wooded land	"	48 218	436 400	8 701	27 842	23 225	59 768	929 600	1 473 986	36
Closed forest	"	..	264 100	7 635	24 400	19 885	51 920	791 600	1 107 620	2)38
Exploitable closed forest	"	4 512	214 780	6 600	22 230	19 445	48 275	534 500	802 067	2)41
- coniferous	"	..	137 910	5 280	21 103	17 884	44 267	405 900	588 077	59
Growing stock	mill.m^3,o.b.	1 294	22 958	575	2 264	1 568	4 407	66 996	95 655	45
- coniferous	"	1 222	18 310	459	1 934	1 290	3 683	54 669	77 884	53
Net annual increment	1000 m^3,o.b.	3 583	356 000	17 310	78 500	61 930	157 740	750 300	1 267 623	31
- coniferous	"	1 863	267 000	13 710	65 155	48 119	126 984	601 500	997 347	45
1)Removals, per annum	1000 m^3,u.b.	3 132	152 048	9 103	50 404	42 460	101 967	357 220	614 367	21
- coniferous	"	2 999	139 459	8 339	43 251	34 464	86 054	297 680	526 192	45
- industrial timber	"	2 900	147 182	8 461	46 278	38 376	93 115	277 420	520 617	37

1) Annual averages of 1978-82

2) Approximately

Table 2. Production of forest industries in Canada, Nordic countries and the Soviet Union in equivalent tons per annum, 1978-82 averages.

	Canada	Norway	Sweden	Finland	Nordic	USSR	Total	Per cent of world
Basic industry								
Sawn wood	18 174	1 001	4 742	3 714	9 457	42 948	70 579	38
Wood-based panels	2 254	267	846	745	1 858	4 926	9 039	19
Mechanical pulp	7 386	886	1 870	2 276	5 032	1 773	14 191	53
Chemical and other pulp	11 614	628	6 645	4 612	11 885	7 274	30 773	32
Total	39 428	2 782	14 103	11 347	28 232	56 921	124 581	35
Paper and paper board								
Newsprint	8 641	600	1 441	1 482	3 523	1 384	13 548	53
Writing and printing	1 453	301	978	2 015	3 294	1 166	5 913	15
Other	3 187	437	3 624	2 268	6 329	6 376	15 892	16
Total	13 281	1 338	6 043	5 765	13 146	8 926	35 353	21

Table 3. Percentage share of the Boreal countries from the world totals.

	Canada	Norway	Sweden	Finland	Nordic	USSR	Total
Production of timber	5.2	0.3	1.7	1.5	3.5	12.1	20.8
Production of sawn wood	9.7	0.5	-2.5	2.0	5.0	22.9	37.6
-"- wood based panels	4.8	0.5	1.8	1.6	3.9	10.4	19.1
-"- mechanical pulp	27.5	3.3	6.9	8.5	18.7	6.6	52.8
-"- chemical and other pulp	12.1	0.6	6.9	4.8	12.3	7.6	32.0
Production of total basic industry	11.0	0.8	3.9	3.2	7.9	15.9	34.8
Production of newspring	33.7	2.3	5.6	5.8	13.7	5.4	52.8
-"- writing and printing paper	3.6	0.7	2.4	5.0	8.1	2.9	14.6
-"- other paper products	3.1	0.4	3.6	2.3	6.3	6.3	15.7
Production of total paper and paper board	7.9	0.8	3.6	3.5	7.9	5.3	21.1
Value of exports							
roundwood	2.0	0.4	0.7	1.5	2.6	10.6	15.2
sawn wood	26.3	0.5	10.5	8.4	19.4	9.1	54.8
wood based panels	5.6	0.4	3.3	7.7	11.4	3.9	20.9
wood pulp	34.6	2.5	15.8	8.9	27.2	3.8	65.6
paper and paper board	20.8	2.8	13.3	13.6	29.7	2.0	52.5
total	20.0	1.7	10.3	9.3	21.3	5.3	46.6
Value of imports							
roundwood	0.9	0.6	1.9	1.2	3.7	0.3	4.9
sawn wood	1.8	0.9	0.5	0.1	3.3	0.6	3.9
wood based panels	1.9	1.4	1.9	0.2	3.5	0.8	6.2
wood pulp	0.8	1.1	0.3	0.2	1.6	1.4	3.8
paper and paper board	1.2	0.6	0.9	0.3	1.8	2.8	5.8
total	1.3	0.8	1.0	0.4	2.2	1.5	5.0
Population	0.5	0.1	0.2	0.1	0.4	6.0	6.9

Table 4. Forest production per hectare of expl. cl. forest and per capita in Boreal countries.

		C	N	S	F	NC	USSR	W	C	N	S	F	NC	USSR	W
		per ha of expl. cl. forest							per capita						
Expl. closed forest	ha								9.0	1.6	2.7	4.1	2.8	2.0	0.44
Removals	m^3,u.b.	0.71	1.38	2.27	2.18	1.96	0.67	1.50	6.4	2.2	6.1	8.9	5.9	1.4	0.66
Sawnwood	kg	85	152	213	191	182	80	96	759	245	571	777	550	162	43
Wood-based panels	"	10	40	38	38	36	9	24	94	65	102	156	108	19	11
Mechanical pulp	"	34	134	84	117	97	3	14	309	217	225	476	293	7	6
Chemical and other pulp	"	54	95	299	237	229	14	49	485	154	800	965	692	27	22
Total basic industry	"	184	422	634	583	544	106	184	1647	680	1697	2374	1643	214	81
Newsprint	"	40	91	65	76	68	3	13	361	147	173	310	205	5	6
Writing and printing	"	7	46	44	104	63	2	21	61	74	118	422	192	4	9
Other	"	15	66	163	117	122	12	52	133	107	436	474	368	24	23
Total paper and paper board	kg	62	203	272	296	253	17	86	555	327	727	1206	765	34	38

Table 5. Value of forest products exports and imports, annual averages of 1978-82.

	Exports			Imports		
	mill. $ U.S.	per cent	$ U.S. per cap.	mill. $ U.S.	per cent	$ U.S. per cap.
World	48 144	100.0	11	54 040	100.0	12
Canada	9 650	20.0	403	701	1.3	29
Norway	802	1.7	196	438	0.8	107
Sweden	4 949	10.3	596	527	1.0	63
Finland	4 502	9.3	942	221	0.4	46
Nordic countries	10 253	21.3	597	1 186	2.2	69
USSR	2 548	5.3	10	789	1.5	3
Total Boreal	22 451	46.6	73	2 676	5.0	9

FIG. 1. ANNUAL REMOVALS, M^3, U.B. PER HA OF EXPLOITABLE CLOSED FOREST.

AVERAGES OF 1978-82; ANNUAL OF 1977 IN REGIONS OF THE USSR

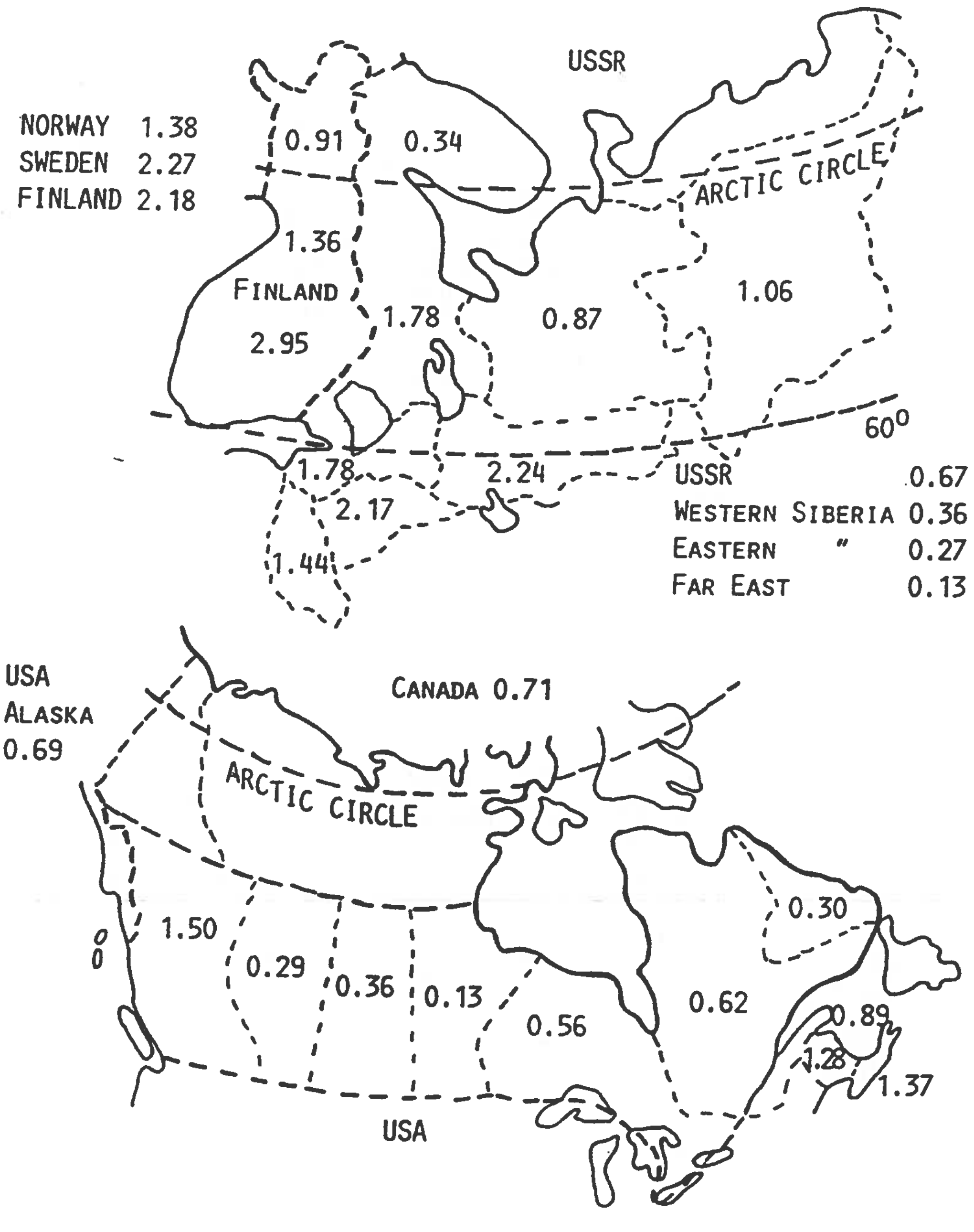
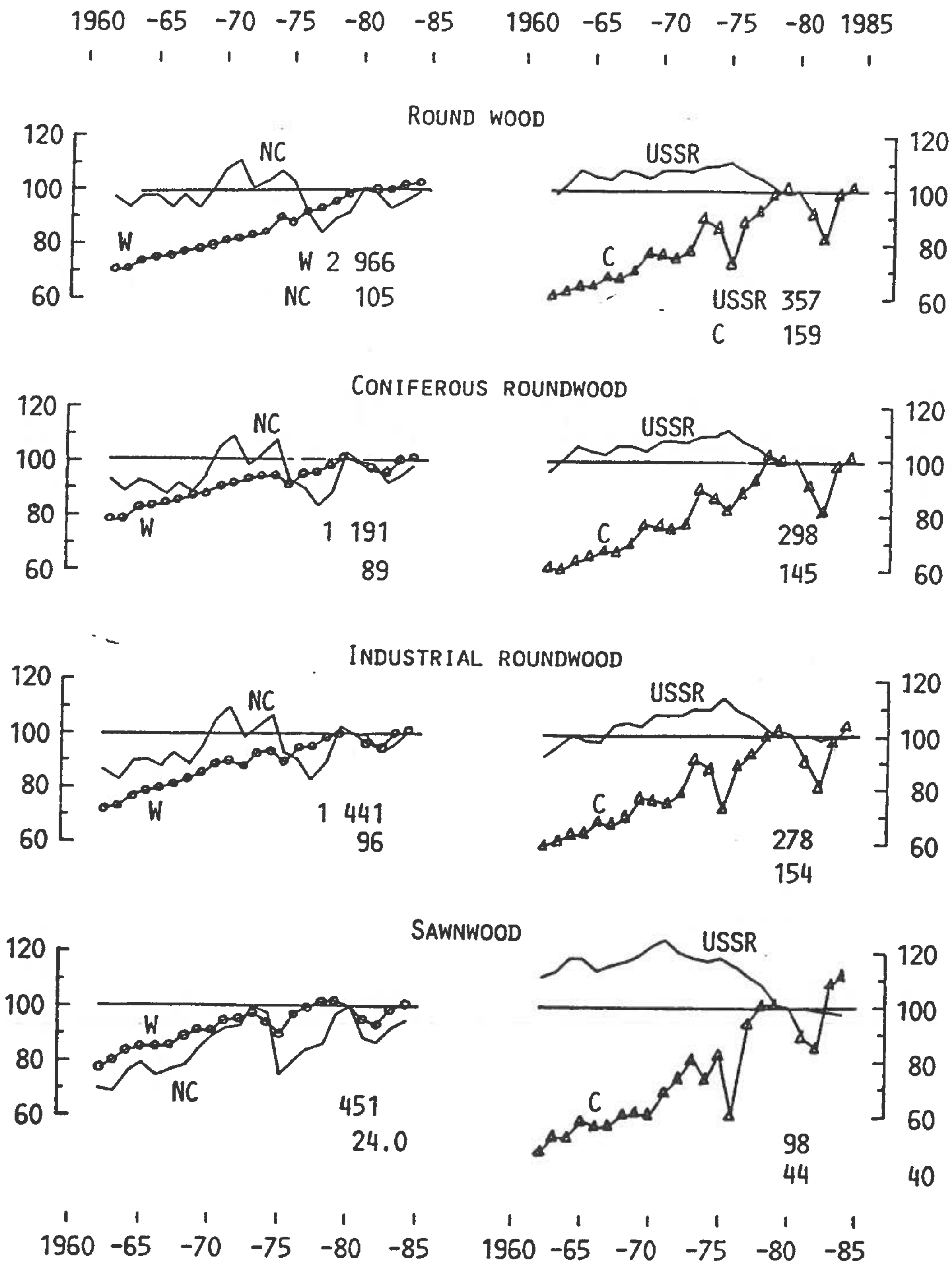


FIG. 2A. PRODUCTION OF FORESTRY AND FOREST INDUSTRIES 1962-84.



W = WORLD NC = NORDIC COUNTRIES USSR = THE SOVIET UNION C = CANADA

PRODUCTION IN 1980 = 100; ROUNDWOOD, SAWNWOOD AND WOOD-BASED PANELS IN MILL. OF M^3; PULP, PAPER AND PAPER BOARD IN MILL. OF TONS

FIG. 2B. PRODUCTION OF FORESTRY AND FOREST INDUSTRIES 1962-84.

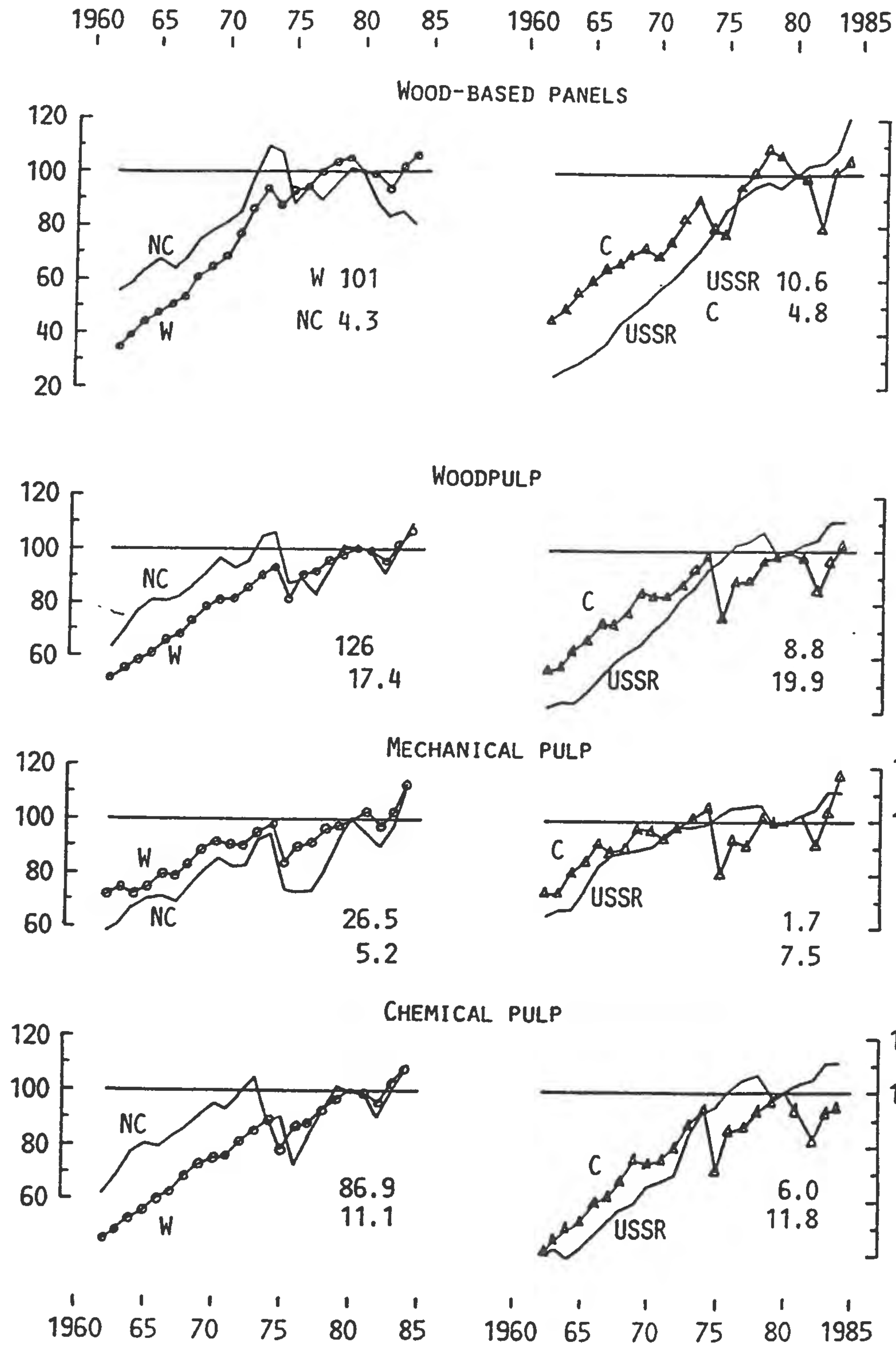


FIG. 2c. PRODUCTION OF FORESTRY AND FOREST INDUSTRIES 1962-84.

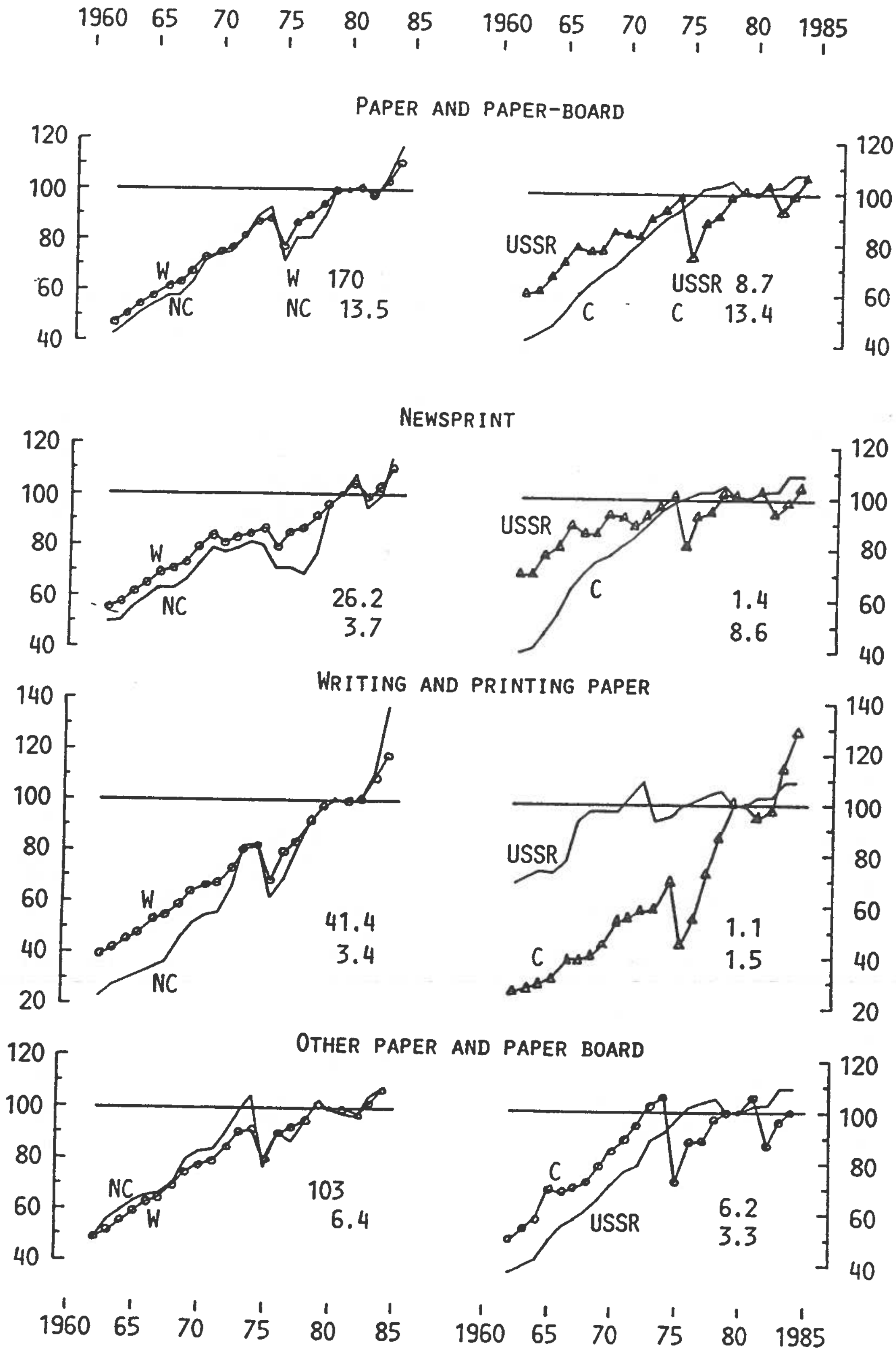
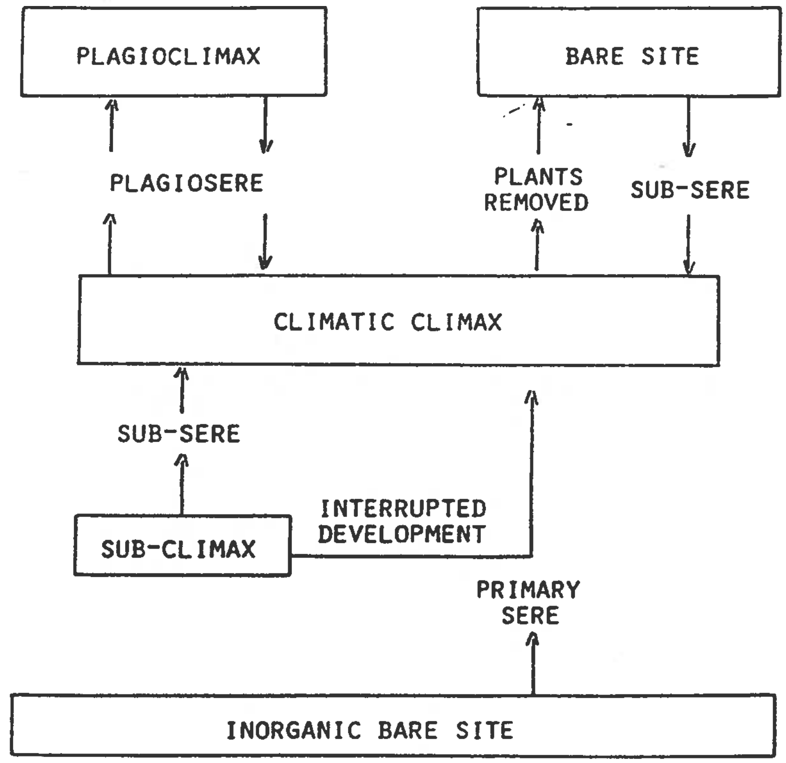


FIG. 3. SUCCESSIONS OF PLANT COMMUNITIES.



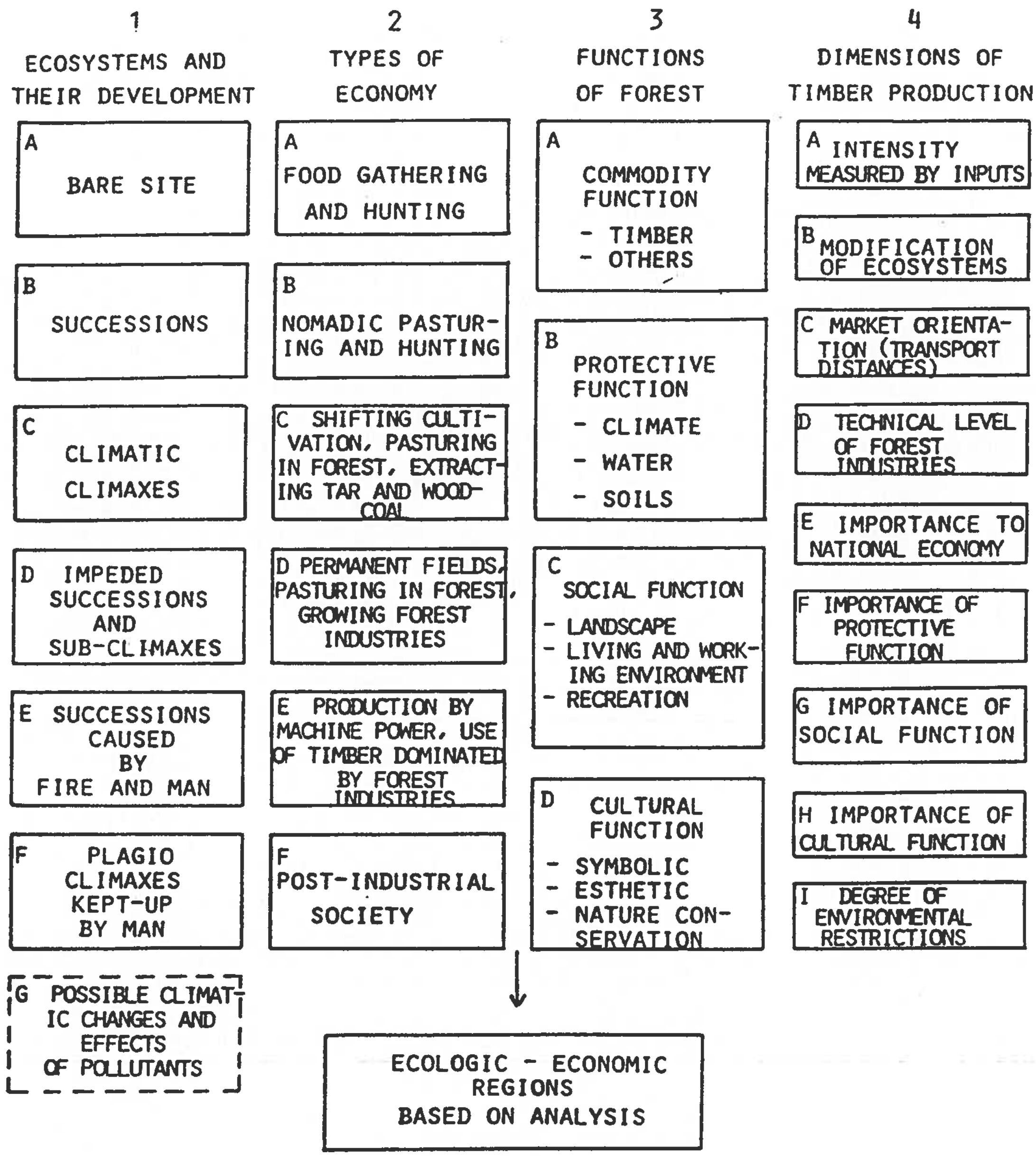
PHASES IN THE PROCESS OF SUCCESSION:

1. NUDATION, BARE SITE AS A RESULT
2. MIGRATION OF PIONEER SPECIES TO THE SITE
3. ADJUSTMENT OF SPECIES TO THE ENVIRONMENT
4. COMPETITION AND PATRONIZING BETWEEN SPECIES AND INDIVIDUALS
5. REACTION OF PLANTS AND ANIMALS TO THE SITE
6. STABILIZED CLIMAX IN EQUILIBRIUM WITH THE ENVIRONMENT

FIG. 4. TREE-STAND SUCCESSIONS IN BOREAL FINLAND

PARANT SOIL MATERIAL	GLACIAL ALLUVIAL SAND AND GRAVEL — MORAIN — GLACIAL ALLUVIAL LOAM AND CLAY INCREASING SHARE OF CLAY PARTICLES AND FERTILITY → GOOD CONDITIONS OF DRAINAGE INSUFFICIENT NUTRIENTS RESTRICT GPP MORE THAN SOLAR RADIATION, TEMPERATURE AND SHORTAGE OF WATER INCREASING SUSCEPTIBILITY TO WILD FIRE ←
COLONIZATION BY TREES OF BARE SITE	PINE — PINE, BIRCH, ASPEN — BIRCH - ASPEN - ALDER, PINE
ADAPTATION OF SPECIES TO THE SITE; COMPETITION AND PATRONIZING BETWEEN SPECIES	PINE — PINE RECEDING BIRCH, ASPEN, ALDER RECEDING PINE INCREASING SHARE OF SPRUCE →
CLIMATIC CLIMAX PLANT COMMUNITIES WITH REPEATING WILD FIRES	PINE — PINE, SPRUCE UNDERGROWTH — SPRUCE — SPRUCE, PINE MIXTURE
WITHOUT WILD FIRE	GROWTH OF RAW HUMUS AND DENERATING NUTRIENT CYCLE INCREASING PALUDIFICATION →
CLIMATIC CLIMAXES	PINE OR SPRUCE ? — SPRUCE, MIXTURE OF PINE — SPRUCE, MIXTURE OF BIRCH, ASPEN — SPRUCE
PEATLAND CLIMAXES	IMPEDED DRAINAGE PALUDIFICATION — MIRE PLANT-COMMUNITIES

FIG. 5. SCHEME OF ANALYSIS OF THE NATURE, ROLE AND DEVELOPMENT OF BOREAL CONIFEROUS FORESTS.



NINE THOUSAND YEARS OF FORESTS IN FINLAND

Synopsis of a slide show

S-E. Appelroth

SUMMARY: When the continental ice had melted first arrived the birch, alder and Scots pine as pioneer species followed by Norway spruce as climax species. Several huge forest fires (sometimes storms) each millium renewed the forest with pioneer species. The forests gave shelter, fuel and game for food. For thousands of years forests were burnt into ash, used as fertilizers for cereal crops. For centuries best quality trees were harvested for tar and lumber production. Over a century first the roundwood export and then domestic consumption of industrial wood had drained the growing stock and yield. However, a sufficent demand of all tree species and reasonable stumpage prices during three decades gave prerequisites for management of even-aged and stocked stands resulting in a present total growing stock and yield higher than ever measured before. Together with an even age class distribution of the forests by area an escalating and sustained yield in the future have been obtained.

KEYWORDS: Forest history, tree species, shifting agriculture, tar production, wood production, forest management.

INTRODUCTION

The aim of this slide show is to provide a background and a context for other presentations at the symposium. A synthesis of scattered fractions of available facts, events and also maps and pictures related to the Finnish forests during the last nine thousand years has now been produced in slide form to explain why and how the present state of the Finnish forests has been reached. Some of those slides are as samples included as figures in this paper.

Acknowledgement. The author expresses his thanks to his father Dr. Eric Appelroth for contributions on this subject over forty years and to Dr. Martti Linkola at the National Board of Antiquities for useful comments on the manuscript.

Dr. Sven-Eric Appelroth is a scientist in work studies on silvicultural operations at the Finnish Forest Research Institute in Helsinki, Finland.

THE CONTINENTAL ICE

20 000 BP (before present) northern Europe was covered by continental ice up to two kilometer thick (fig. 1). As the climate became milder and the ice cap shrank the rate of ice melting in summer was faster than the accumulation rate of new ice in winter. In the period 12 000 - 8 800 BP the ice resumed to melt away from Finland beginning from south east (fig. 2).

The heavy ice cap slid slowly down from the high Norwegian mountains; in South Finland towards the southeast and north of the Arctic Circle towards the northeast. As during previous Glaciennes the ice surfaced mountain tops, and crushed eroded cliffs into morain. In summer the flooding water washed the finer clay particles far into the sea before they settled on the bottom, while larger particles mixed in the ice dropped down close to the ice edge. On the bottom of deep rivers cut in the ice the rinsed coarse mineral soil was left, creating gravel ridges in the direction of the ice movement. When the rate of melting equalled the

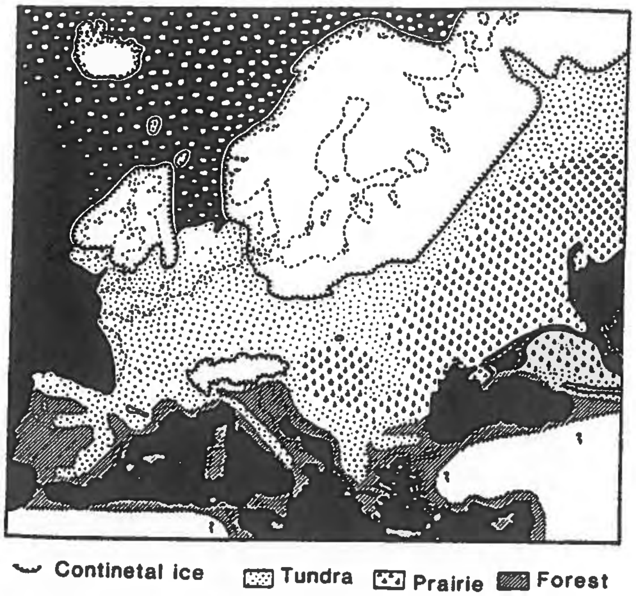


Figure 1.--Vegetation zones 20 000 BP (Stenberger 1964).

rate of ice movement huge amounts of coarse mineral soil were dropped down at the ice edge creating gravel ridges i.e. the Salpausselkä along the ice edge. Large stones and bolders in the ice were dropped down. The heavy load of the ice pressed down the bedrock. Still today land lift occurs and the ground is rising after its release from the heavy ice. At the narrow strait of Gulf of Bothnia the ground level today is 300 m higher than during the Ice Age, and the land lift there has a current rate of 9 mm/a.

CLIMATE AND TREE SPECIES

The climate has varied considerably over the last 10 000 years, affecting the forests and their composition by tree species (fig. 3). The Baltic Ice Lake period (10 500 - 10 200 BP) was humid and cold with fresh water in the Baltic Ice Lake. There was land above sea level only northwest of Lake Ladoga.

Figure 2.--Extent of the continental ice since 20 000 BP.

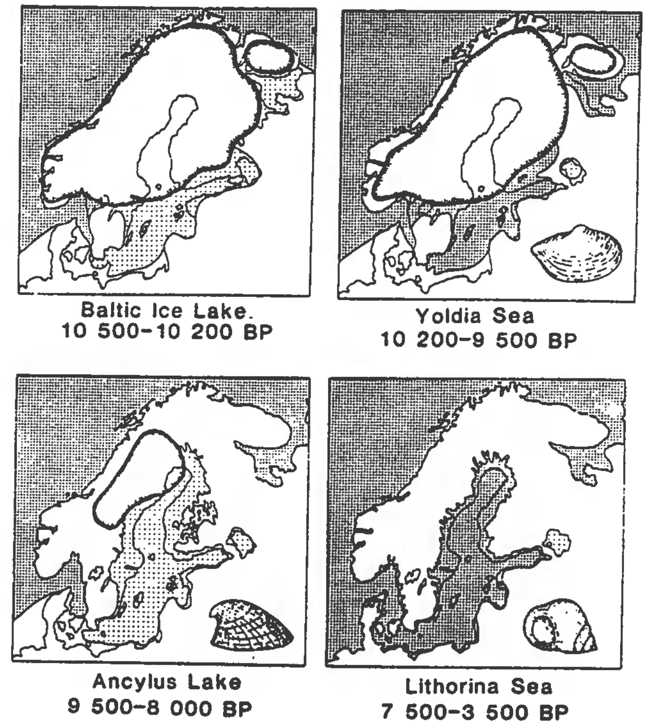


Figure 3.--Areas below water level during four periods.

The Yoldia Sea period (10 200 - 9 500 B.) was dry and cool. When the barren land was occupied by alges, mosses and herbs, the birch (Betula sp.) came as the pioneer tree species to the present area of Finland from southeast some 9 000 years ago. The birch provided man with wood for shelter and fuel. Wooden sticks were used for making primitive tents covered possibly by furs.

During the short Ancylus Lake period (9 500 - 8 000 BP) the climate was dry and warm and there was fresh water in the Baltic Sea. The grey alder (Alnus incana) and Scots pine (Pinus sylvestris) came from the south east about 8 000 years ago, also as pioneer tree species. The first people in Finland immigrated. Polished stone tools dominated in the Suomusjärvi culture 8 500 - 6 200 BP. Large areas of West Finland were still below the water level.

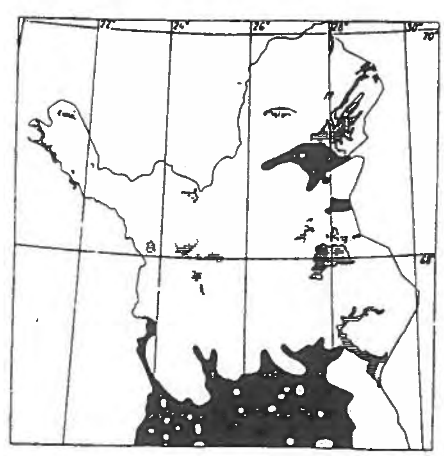


Figure 4.--Area below the Lithorina Sea level with salt water (black south of 68°N) in Lapland (V. Tanner).

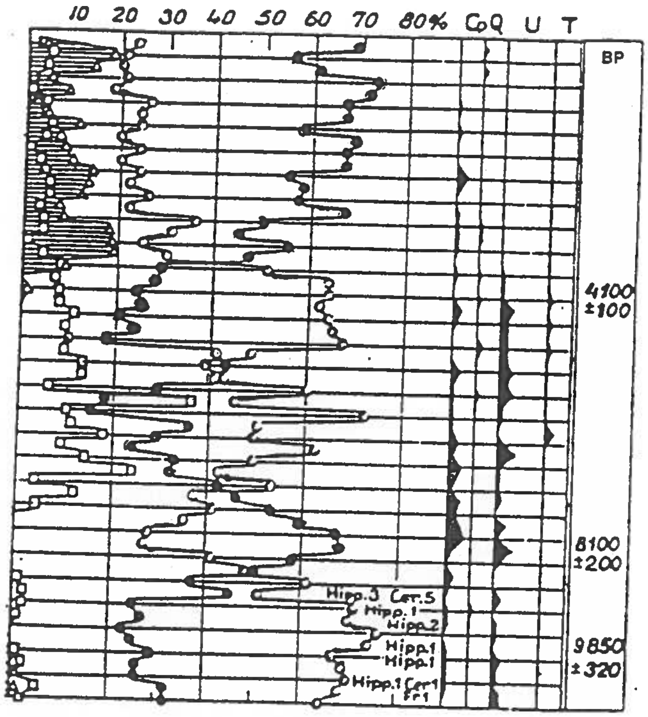


Figure 5.--Pollen percentages of Alnus □, Betula ○, Picea △, Pinus ●, and occurrence of Corylus (Co), Quercus (Q), Tilia (T) in SW Finland through 10 000 years (Martti Salmi).

The long Lithorina Sea period (7 500 - 3 500 BP) was humid and warm. The water was salty once again. Large areas were below the salty sea water even in Lapland (fig. 4). Trees grew big and now provided man with large logs which could be shaped with fire and sharp stones to form canoes along lake and river shores to new fishing and hunting areas. Along the coast a wealthy Bronze Age occurred. A new population with comb ceramics and hunting dogs spread rapidly. Alder (Alnus), hazel (Corylus avellana), linden (Tilia cordata), elm (Ulmus laevis and U. scabra) and oak (Quercus robur) spread over southern Finland (fig. 5).

Before the end of the Lithorina period quite primitive agriculture and cattle raising were introduced. Yet we are still talking about the Stone Age. Aspen growing on fertile vallies was preferred for canoes, since it was softer wood and easier to carve with primitive tools.

The Norway spruce (Picea excelsa) arrived to south east Finland slowly as a climax tree species from the east during the mild Lithorina period about 5 000 years ago under a shelter of broadleaves or of Scots pine. It moved westward and reached the west coast raised up from the sea about 3 000 BP. and arrived in the Åland islands about 2 000 BP. The Norway spruce arrived along the vallies of Lapland late after the Lithorina period, having grown there for only 20 - 30 climax rotations. Thus, the Norway spruce is obviously not yet genetically adapted to the present climate of northern Finland.

FINBUL WINTER

After this Lithorina Sea period the climate turned humid and considerable colder, the so called Finbul Winter. Long fluctuation periods in temperature occurred. Annual climate fluctuations between years still cause up to ± 20 % differences in the annual growth of our forests.

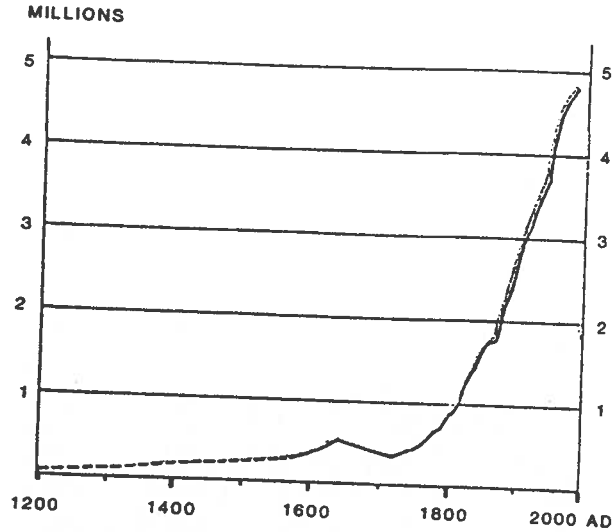


Figure 6.--Population of Finland since 1200 AD (Statistical Yearbook 1983, Talve 1970).

Locally the true impact of shifting agriculture was felt. However, climax stands of Norway spruce still dominated untill the population increased and pioneer stands of Scots pine became dominant 1 000 years agodue to frequent burns. Yet, it could have been uncontrolled fire and lightning rather than prescribed burn for growing cereals and grazing which destroyed climax stands. Grazing increased the population of Juniperus communis. Where shifting agriculture returned frequently to the same site grey alder (Alnus incana) became increasingly common as pioneer species on the fertile sites.

EARLY HISTORICAL TIME

The Finnish population remained very small until 250 years ago, when it began to escalate (fig. 6 and 7). Yet it had already had a strong impact on

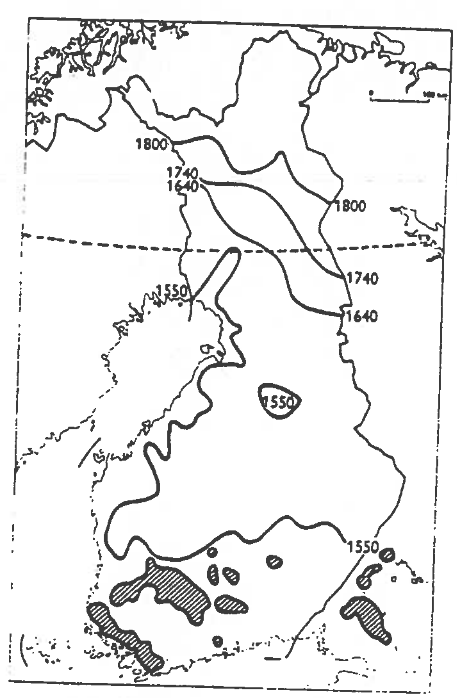


Figure 7.--Northern limits of permanent settlement since the prehistoric time (grey areas).

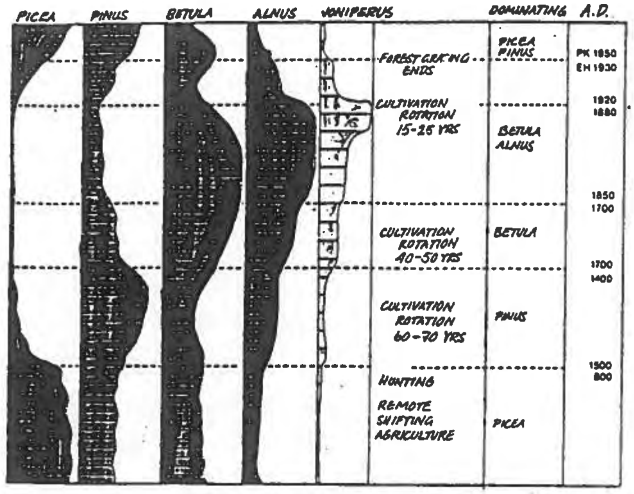


Figure 8.--Abundance of pollen by tree species during historic time in northern Carelia (PK) and SW Finland (EH) (Huttunen).

the forests along the coastline and on the shores of rivers and lakes where the climate had at least 1 200 dd of effective cumulated temperature and shifting agriculture with slash-and-burn cultivation gave a cereal crop. The forest biomass was used mainly as ash fertilizer and fuel for heating. Fishing and hunting remained quite important in the Middle Ages (fig. 8).

16TH AND 17TH CENTURY

Hand sawn lumber, bricks requiring wood fuel and shipbuilding for export along the sea shores were recognized in the 1500s. The first waterpowered sawmill was built in 1533. Substantial tar exports from Ostrobothnia were recorded in 1570. It was

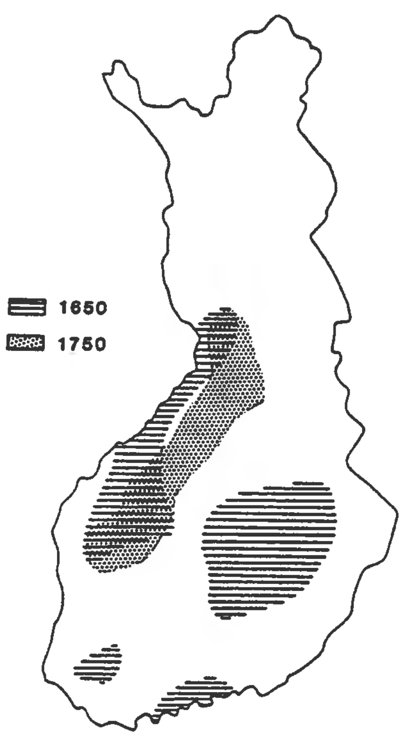


Figure 9.--Areas of intensive tar production around 1650 and 1750.

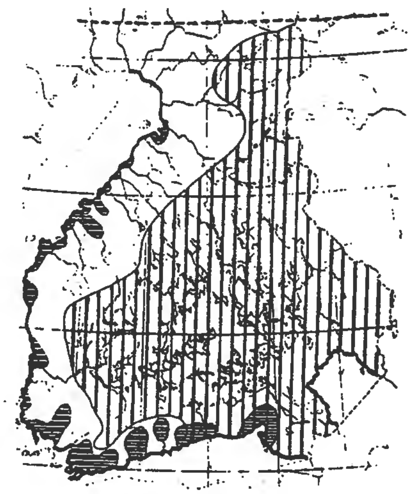


Figure 10.--Areas of intensive shifting agriculture (vertical), and lumber production and shipbuilding (horizontal) around 1750.

practiced in whole Lake Finland. These increased (fig. 6) and in 1650 more than half of the export revenues came from tar. In 1600s charcoal for iron and calcium carbonate of birch ash for glas factories were produced. The first papermill was established. Even if textile fabrics were at that time used for paper making this laid the foundation for our three-centuries-old paper making tradition.

18TH CENTURY

In the 1700s water-powered frame saws were used. However, intensive shifting agriculture and tar production (fig. 9 and 10) in inland areas and heavy consumption of fuelwood on the more densely populated coastland reduced the volume of growing stock to such an extent that the authorities became concerned of that Finland was running out of wood. The first doctorial thesis on forestry (Peter Kalm 1753) was on the necessity to better manage Finnish forests. The available wood supply in Finnish forests was quite small in populated areas.

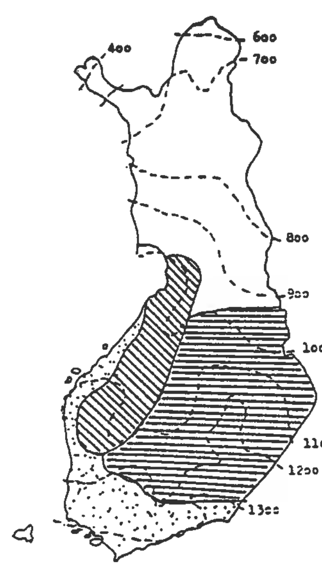


Figure 11.--Areas of intensive tar production [hatched], shifting agriculture [horizontal lines], and harvesting as well for homesteads as hign grading of sawlogs [dotted], in 1750 - 1850.

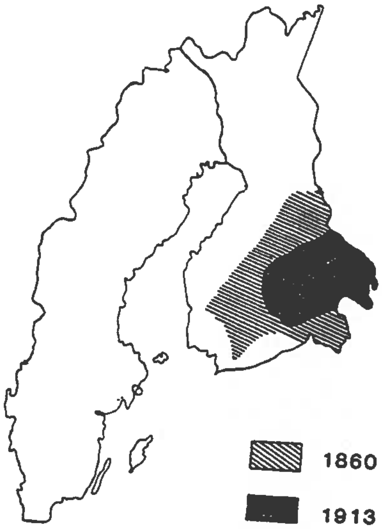


Figure 12.--Area of intensive shifting agriculture in 1860 and 1913 (Olli Heikinheimo 1915).

19TH CENTURY

With the escalating population the impact on the forests also increased as a result not only of shifting agriculture but also of tar exports etc. (fig. 11 and 12). The Oulu harbour became the second largest tar export harbour in the world after Archangelsk. In 1857 the first mechanical pulp mill was established and in 1859 steam powered saw mill went into operation. Forestry education was resumed in the 1861 and in 1880s were sulfate and sulfite pulp mills established. There was a boom in shipbuilding for which best quality of wood was harvested. A good century ago there was a shortage of wood in all densely populated areas (fig. 13).

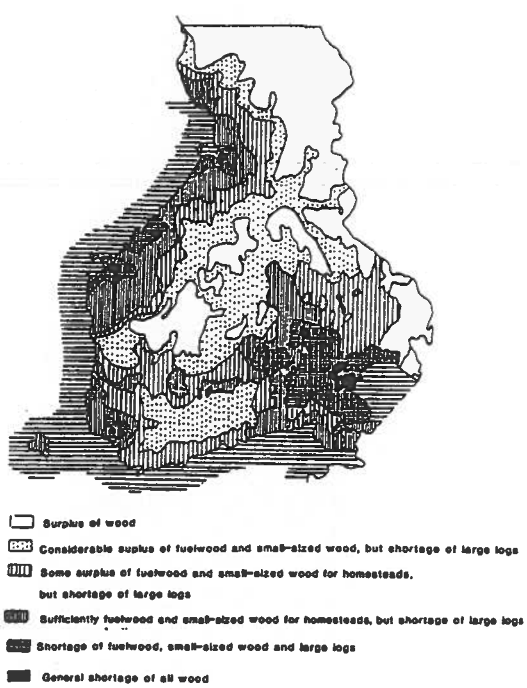


Figure 13.--Areas with various degrees of shortage of wood in 1850 (C.W. Gylden).

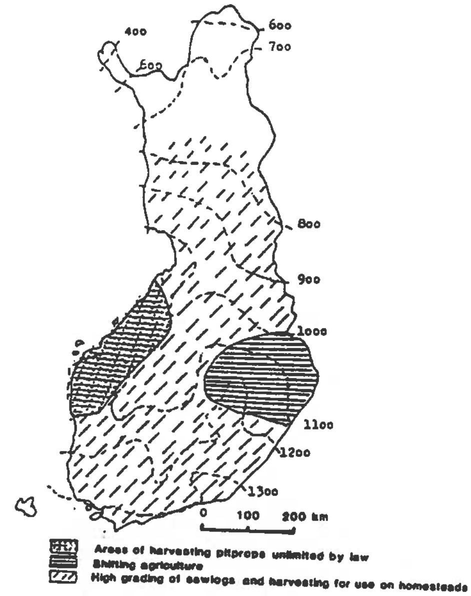


Figure 14.--Areas of main use of forest around 1900.

20TH CENTURY TO THE END OF WORLD WAR I

At the begin of the 20th century export of pitprops on the west coast (fig. 14) increased considerably the harvest of small sized wood. Forestry education was transferred to the University of Helsinki in 1908. The first plywood mill was established in 1912 and the Finnish Forest Research Institute was founded in 1917. Having been an autonomous Grand Duchy of the Russian Empire for a century Finland went through a devastating war of independence during the World War I in 1918, and the peace treaty between the Republic of Finland and USSR (at that time Soviet Russia) was signed in Tartu, the Republic of Estonia on the 15 October 1922.

THE PERIOD BETWEEN WORLD WARS

The forests had to be extensively exploited to raise money for rebuilding the devastated country and to build a whole new administration. The entire forest industry was expanded and rebuilt to meet the new quality requirements of western markets. Saw mill industry production reached a peak not surpassed during the next forty years. The forests were repeatedly high graded for saw logs, which was destructive to the yield of forest stands. A demand for pitprops and pulpwood for export had for a long time prevailed along the coasts and rivers. Now coniferous pulpwood spread throughout southern Finland and the demand of birch fuelwood increased with the increasing population. Drainage of peatlands for wood production became common especially in industrially-owned forests. This also provided employment during the worldwide recession. At the begin of the 1930s three million Scots pine stems were pruned annually to increase saw log quality in the future. When it was time to receive the return on the major investments in the forest industry made in the 1920s, the industry was hit by the depression of the early 1930s.

We had now learned a lot about our forests. Production and yield tables for virgin stands of our three main tree species were produced (Ilvessalo 1920). In 1921 - 1924 the first national forest inventories were carried out. In 1928 shifting agriculture became prohibited by law and effective forestry laws were introduced to prevent further devastating of forests.

THE 1940S

The Winter War began on 30 November 1939. Finland with a population of 3,5 million was attacked by the Soviet Union with a population of about 200 million. During World War II our forests had to provide fuel of wood for heating, railway engines and automobiles, since Finland has no fossile fuel. Under the armistice with the USSR in 1944 Finland lost some 40 000 sq km land. Some 420 000 refugees, who all arrived in two weeks, had to be given food and shelter and then resettled. About 2,6 million hectares of forest land was expropriated for new homesteads from the state forests, company forests and large private forest holdings. This and the rebuilding of the country devastated by war as well as the production of products for war reparations to the USSR caused a severe shortage of labour and capital. About 87 000 men were lost in the war. In order to harvest sufficient volumes of wood for industry and fuelwood for the whole nation emergency clearcuttings were required by the authorities, which, however, took responsibility for the artificial regeneration of these new cutovers. In 1948 a public appeal to stop selective cuttings by devastating high grading and to favour management of fully stocked, even-aged stands and systematic commercial thinnings of stands for production of best growing and best quality stems of the best suitable species for each site, was published by top silviculturists and forest managers with the chairmanship of the director of the Finnish Forest Research Institute.

THE KOREAN WAR BOOM

At the beginning of the 1950s Finland had paid off its war reparations to Soviet Union and could finally concentrate on developing its own economy. During the past five centuries there had been in Finland already one century of devastating wars. The Korean War in early 1950s turned money in fast circulation all over the world because of a risk of a third World War. The global demand for newsprint and other forest products resulted in a strong increase of the stumpage prices in Finland. This also changed the forestry in Lapland completely. Previously, there had been stumpage for cordwood only along the major river and lake shores from which wood could be inexpensively floated down the rivers to the mills on the coast. In other parts only destructive high grading of sawlogs was possible. Now, there was suddenly a stumpage also for cordwood throughout almost the whole of Lapland. Large scale renewal of overmature by selective cuttings high graded stands with rather low stocking was carried out mainly by clear cutting, prescribed burning and direct seeding of Scots pine was was introduced.

Throughout the country the landscape slowly began to change. The shaggy, high graded climax stands of Norway spruce with very low stocking slowly vanished. The custom to let cattle graze in forest rapidly reduced. This change improved natural regeneration of conifers. The annual areas of artificial regeneration escalated and young fully stocked patches of even-aged stands of Scots pine became a common new feature in the landscape.

In the 1950s production and yield tables for different site indexes for our main tree species were published. The productivity of forest operations increased slowly as hand saws were replaced by chain saws and tractors were introduced for hauling wood. Tree breeding programmes resumed.

THE 1960S

The promotion of forest management among private woodlot owners, who possess the bulk of the forest land in Finland, was intensified and had a positive result. Previously a given volume of one assortment of wood at a time used first to be sold, after which the trees were marked in the forest. When only coniferous saw logs, plywood birch or pitprops were harvested from a forest stand this naturally had a destructive impact on the growing stock and hence on the production of that stand. In the 1960s it became common to first mark the trees to be harvested in order to increase the value of the production of the stand, and then sell all the trees to be harvested in one operation. In the event that the buyer did not itself process all wood assortments, it traded the not needed assortments with another company. The result of this was that the growing stock of each stand slowly grew closer to its optimum at each age in respect of wood production value.

Cordwood birch had previously been used mainly as fuelwood. Now it finally had a demand as pulpwood. Economic prerequisites for rational silviculture and forest management finally existed. Motivation for good forest management had been augmented by state loans and to a limited extent even grants to non-industrial private woodlot owners. Guidlinens for minimum thinning limits regarding commercial thinnings were introduced. They were based on the basal area against the dominant height of the stand by tree species and site index. The 1960s saw an escalation in the annual area of artificial regeneration with a peak of prescribed burning and a change from direct seeding to planting. Exports of roundwood had decreased and imports increased (fig. 15).

THE 1970S

Nationwide input-output calculations were made which showed how much wood production could be increased by different extents of basic forest improvement activities. Now most owners of private woodlots, more than 300 000 in number, knew about forest management or had available adequate assistance. The volume and value of the forest industry production continued to increase.

Since the rotation period of a stand varies between 50 years in birch plantations on fertile sites in the south up to some 130 years for Scots pine north of the Arctic Circle, we deal in Finland with an average rotation period of about 100 years. This means that we should renew one percent of our total productive forest area annually and promptly in order to maintain a sustained yield and equal annual harvestable

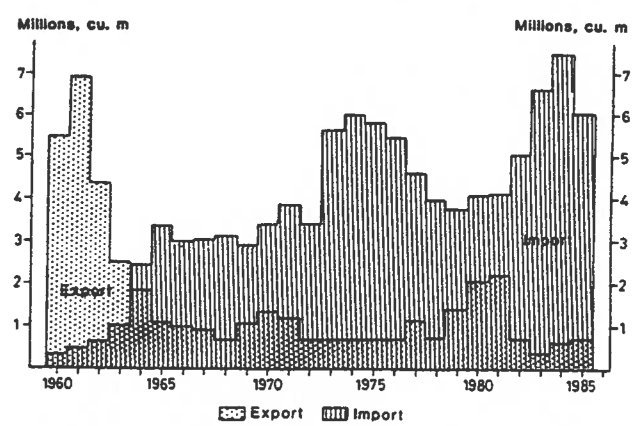


Figure 15.--Annual volumes of export and import of wood (Yearbooks of Forest Statistics).

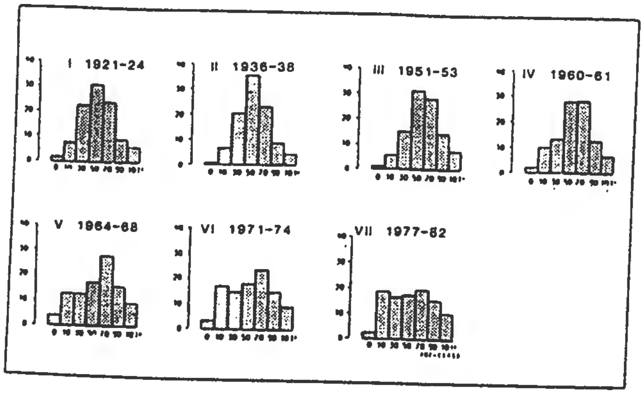


Figure 16.--The age class distribution of forest stands by percent of the productive forest area in seven forest inventories (Yearbooks of Forest Statistics).

volumes of wood over long periods of time in the future. Finland had reached this point in the 1970s.

The escalation in energy prices revived interest in wood as an energy source. Shortage of cash among woodlot owners reduced interest in forest fertilization. The age class distribution of our forests improved (fig. 16) ensuring a constant annual wood supply and a sustained slowly increasing yield. The minimum thinning limits for commercial thinnings were generally applied slowly resulting in a more optimal stocking at each age of the stand. Increased energy prices resulted also in slow marketing of forest industry products which severely reduced forest industry exports and consequently also the annual harvested volume of wood (fig. 17).

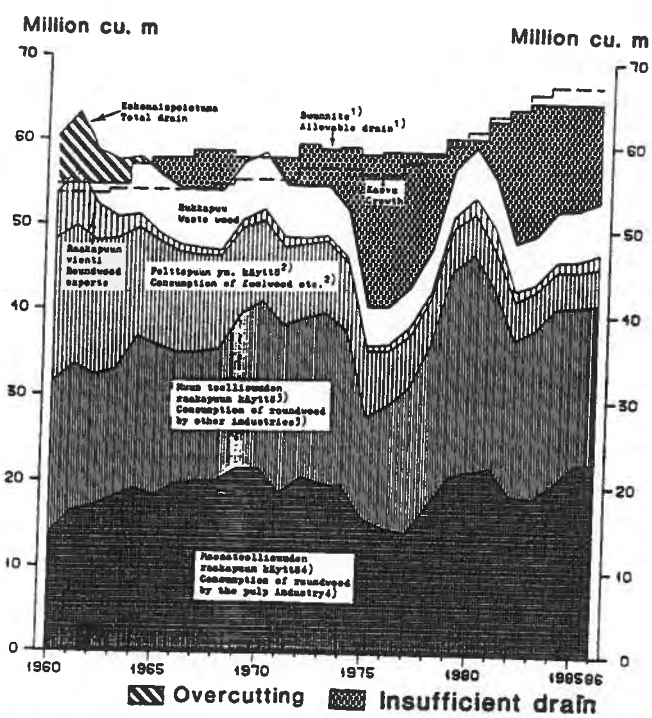


Figure 17.--Annual drain, growth and allowable cut in 1960-1986 (Yearbook of Forest Statistics 1987).

THE 1980S

Disturbances in the domestic roundwood market reduced the annual volume of wood harvested much below the annual allowable cut (fig. 17). From beening the biggest exporter in the 1950s Finland became the biggest importer of roundwood in Europe (fig. 15). Forest 2000, a comprehensive analysis of the forest sector (forestry as the forest industry) was made. It revealed potentials for a continuous increase in the production of the forests and the forest industry. The multiple use of the forests was included in this analysis. A special analysis of the northernmost forest was ongoing and called Lapland's Forests 2000. Symptoms of immission damage to forests had been recorded.

MAIN IMPACTS OF MANKIND

The large forest fires which might have covered millions of hectars in the past before interference by mankind have today ceased due to increased population and to access roads for fire fighting. The huge monocultures of pioneer tree species (pine or birch) and then climax species (spruce) created centuries ago after tremendous forest fires by nature have almost disappeared. At the begin the forests were mainly used for hunting, shelter and fuel. Shifting agriculture during thousands of years, tar production for centuries, export of roundwood, lumber and other forest industry products had drained the growing stock in 1940s. Three decades of demand of all tree species and resonable stumpage prices have created prerequisites for forest management aiming at escalating sustained yield. The size of individual stands had reduced to a quite small one, especially in this century due to increased number of forest owners and decreased mean size of forest holdings. The annual area of forest regeneration has been stabilized at an optimal constant of about one percent of the total productive forest area. The annual wood yield has increased. The total volume of the growing stock of the Finnish forests is now larger than ever and we have more large sized trees than ever measured.

In the last half century Finland moved from the exploiting mining of its forests by selective cuttings into successful forest management so that we can annually harvest more than two m^3/ha industrial wood as an average on 20 million hectares. Finland also raises almost US $ 1.6 billion each year in net stumpage revenues. The total harvested volume of wood over 25 - 30 years equals the total growing stock over the whole country. One out of every five jobs in Finland serves the forestry sector directly or indirectly. Having previously been mainly hunting areas and then sites for shifting agriculture or tar production now wood production has become the main use of our forest land and about half of our net export revenues are today obtained from forest industry exports. Forestry has become a rational and profitable large scale business in Finland.

EFFECTS OF SITE PREPARATION ON THE DEVELOPMENT OF PLANTED SEEDLINGS IN NORTHERN SWEDEN

Göran Örlander

ABSTRACT: The choice of site preparation method is important for the performance of planted seedlings. In an analysis of a scarification experiment in Lycksele, mounding and tilt-plowing was found to be favourable for survival and growth of the seedling. It was also found that difficult spots (mostly moist) were more effectively regenerated using mounding or tilt-plowing due to the positive effects on soil temperature, aeration, drainage and nutrient supply. Some of the negative effects of mounding discussed in this paper are as follows: The risk of low soil moisture during dry periods and low soil temperatures in the winter as well as the increased risk of frost heaving and spring frost.

INTRODUCTION

Site preparation as a means of improving the performance of planted seedlings has been known by foresters for hundreds of years. As an example, Gayer describes mounding methods in a German textbook of 1880.

The biological reasons for site preparation are many and those considered to be most important are discussed here. Special emphasis will be put on mounding.

Systematic research concerning mounding was started in the early seventies by professor Söderström in Sweden (e.g. Söderström et al., 1978). Field experiments were established in both southern and northern Sweden. Two of the experiments in northern Sweden were inventoried in 1985 and the results from these experiments will be presented in this paper.

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THE IDEAL MICROSITE FOR THE PLANTED SEEDLING

It is well known that seedlings suffer from a transplanting shock after planting, which often results in mortality and poor growth of the seedlings. Such seedlings often suffer from water stress after planting (e.g. Örlander 1984, 1986). As the water-absorbing capacity of newly planted seedling is often poor, efforts must be made to enhance the capacity. One way of doing it is to choose the proper scarification method.

Soil temperature

Low soil temperatures negatively affect the water-absorbing capacity of the seedlings (fig. 1) mainly due to the facts that the viscosity of water increases and the permeability of root membranes decreases at low soil temperatures. A rise in soil temperature up to an optimum of 20-30°C increases root growth and accordingly speeds up the recovery from water stress.

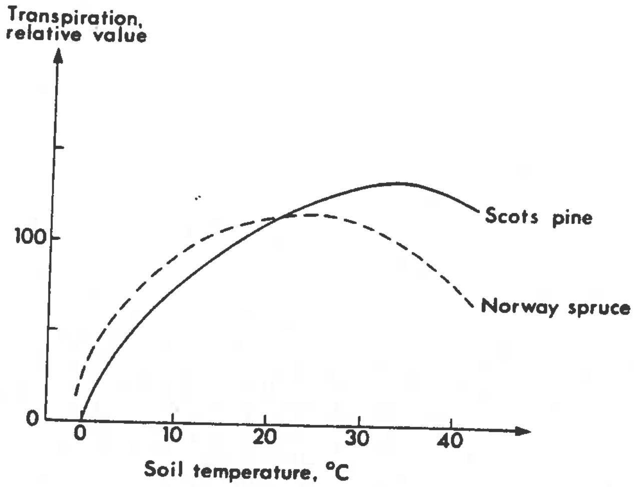

Figure 1.--Effects of soil temperature on the transpiration of 1-year-old Scots pine and Norway spruce seedlings.

The soil temperature is usually low below the unbroken humus layer (fig. 2). The good insulation capacity of the humus layer decreases both absorption and emittance of heat from the soil and the soil temperature will be low even during the summer with low amplitude in daily maximum and minimum temperature (fig. 2). Patch scarification raises the soil temperature during periods of high insolation. The temperature amplitude between day and night increases compared to that below the unbroken humus layer. The highest soil temperatures and temperature amplitudes are found after mounding, especially if the mound is placed on an inverted humus layer (fig. 2). The temperature sum (daily mean temperature - 5 degrees) is higher in mounds than in scarified patches or below the unbroken humus layer (fig. 3) in spring and summer. In the autumn the situation is the opposite and the mounds freeze relatively early. We have measured rather low minimum temperatures in mounds, especially those placed in inverted

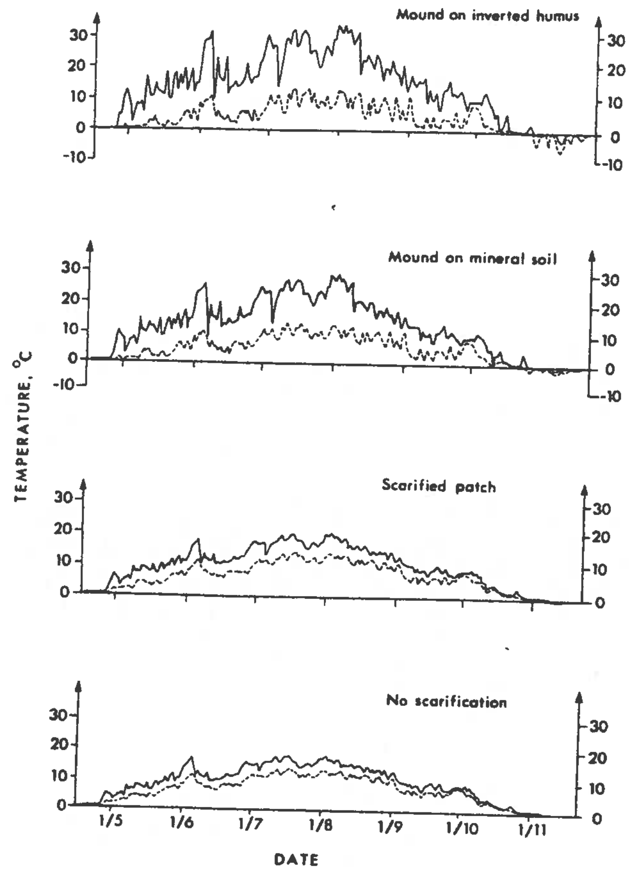

Figure 2.--Effects of some methods of soil treatment on daily maximum and minimum temperatures 10 cm below soil surface. Field Research Station, Vindeln (64°15'N, 19°45'E, alt. 225 m) 1982.

humus (cf. fig. 2). Although negative effects of low soil temperatures are reported from nurseries (Lindström 1987), no harmful effects of low soil temperatures in mounds have been reported, so far.

In the spring the mounds thaw earlier than the soil in scarified patches or below the humus layer. Occasionally, depending on the weather conditions the mounds will be repeatedly thawn and frozen, which increases the risk of frost heaving.

Reduce to 80% of original

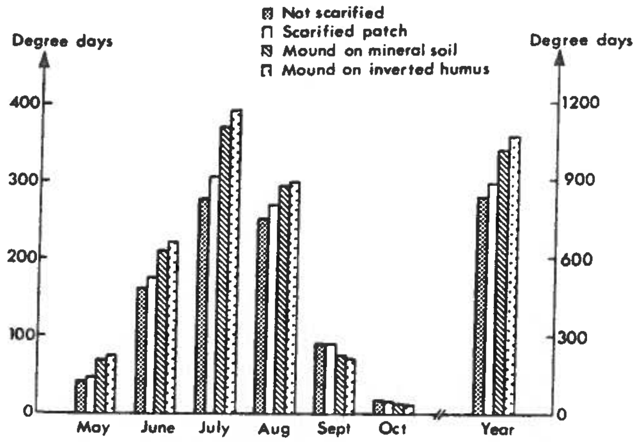

Figure 3.--Temperature sum (>5°C), 10 cm below soil surface in soil treated in different ways. Vindeln 1982.

Soil moisture and aeration

Soil moisture is of course an important factor affecting transpiration. Normally, at a clear-felled area there is an abundance of soil water since the transpiring stand has been removed.

Planted seedlings seem to be more sensitive to low soil water potentials than established ones (Örlander 1986). However, detrimental soil water potentials are seldom found if the soil is patch scarified (e.g. Söderström 1976). In mounds, especially in mounds placed on the humus layer, low soil water potentials have been found during dry periods (Örlander 1984, 1986; Mälkönen 1987). Below the humus layer the soil water potential seems to be constantly high (Örlander 1984).

Poor soil aeration, which is a common occurence on clearfelled areas, is a big problem for the water uptake. Local drainage of the planting spots is provided by choosing high elevated planting spots.

Aeration is also improved by loosening up the soil, which increases root growth both as a result of better oxygen supply and less mechanical resistance for the root growth.

Nutrients

Adding of nutrients at the time of planting may drestically decrease the root growth and the water uptake of the seedlings (cf. Örlander 1987).

Results reported from fertilization experiments do not speak in favour of using this method. If, however, nutrients could be added to the planted seedlings in low concentration continuously it is possible that fertilization might be more positive. In some previous field experiments (Örlander 1987), where nutrients were added to planted seedlings with drip irrigation, the period of stagnation in growth after planting was avoided even for spruce.

The mineralization of nutrients can be controlled by the choice of scarification method. The fastest mineralization is achieved if mineral soil and humus are mixed whereas the mineralization in an inverted humus layer is somewhat lower (eg. Mälkönen 1987). On an optimal planting spot the mineralization of nutrients should be so fast as to cover the needs of the seedling. However, too fast mineralization (total mixing of humus/mineral soil or heavy plowing) could endanger the long-term productivity of the stand because mineralized nutrients which are not utilized by the plants may leach out (cf. Mälkönen 1987; Bäcke _et al._, 1986).

Frost and frost heaving

The risk of frost is supposed to decrease on scarified areas. However, after patch scarification the rise in temperature is relatively small compared to undisturbed soil. Lundmark (1985) reports the air temperature increase at 5 cm height to be 0.5°C in a scarified patch and 2°C in a mound (20 l) compared to undisturbed soil. Plowing increases the minimum temperatures even more than do the mounds.

Frost heaving might be more serious in mounds than in patches and unscarified spots. The temperature in a mound is relatively instable and freezing/thawing may occur several times during a short period in spring or autumn. The soil is more loose in the mound than in the scarified patch, which might also increase the risk of frost heaving. The risk of frost heaving seems to be less in mounds placed on the humus layer than in those placed on mineral soil, probably due to the lower soil water potential in the mound on humus.

SCARIFICATION EXPERIMENT IN LYCKSELE - AN EXAMPLE

Background

In 1973 and 1974 experiments were established in northern and southern Sweden in order to test planting in mineral mounds placed either on mineral soil or on humus. The first results of the experiments presented by Söderström et al., 1978. The plots were remeasured in 1979 and 1985. In 1985 the trees on the plots in southern Sweden were so high (about 5 m) that severe competition had occurred among the seedlings. Since the experimental design was 5-tree plots, no further measurement was made.

In the following, results from two of the experiments in northern Sweden, Lycksele 1 and 3, will be briefly described. These experiments will be referred to as Expts 1 and 3.

Expt 1 includes the treatments: No scarification, patch scarification, mound on mineral soil and mound on humus (the size of mound about 15 l). In Expt 3 disc trenching and plowing (terrace- and tiltplowing) were also added as treatments. Four of the treatments, disc trenching, mound on humus, terrace- and tilt-plowing were measured and will be presented here.

In both experiments the experimental design was 5-tree plots with 40 replications.

Survival and growth of the seedlings

Generally, mounding was favourable in both experiments (table 1). In Expt 1 the mean survival for no scarification of all species and types of seedlings was 65 %, 67 % for patch scarification and 85 % for the mounds. In Expt 3 the survival for disc trenching was 78 %, for mounds 89 %, for terrace-plowing 81 % and for tilt-plowing 88 %.

Table 1.--Effects of some methods of soil treatment on survival, mean height and stem volume of Scots pine and Norway spruce seedlings. Experiments 1 and 3. Values followed by the same letter do not differ significantly ($p<0.05$)

	Soil treatment	Survival %	Mean height, cm	Mean stem volume, dm^3
Expt 1				
Scots pine 2/0	Not scarified	55.7 a	225.8 a	3.05
	Patch	61.6 ab	234.8 a	2.89
	Mound on mineral soil	67.2 ab	284.1 b	5.69
	Mound on humus	73.5 b	278.6 b	5.05
Scots pine paperpot	Not scarified	67.9 a	224.3 a	2.45
	Patch	61.7 a	214.3 a	2.88
	Mound on mineral soil	85.2 b	266.8 b	4.28
	Mound on humus	88.3 b	262.5 b	3.29
Norway spruce 2/1	Not scarified	72.0 a	149.3 a	0.66
	Patch	77.3 a	144.9 a	0.66
	Mound on mineral soil	97.9 b	159.9 a	0.83
	Mound on humus	96.8 b	161.2 a	0.85
Expt 3				
Scots pine 2/0	Disc trenching	68.5 a	220.7 a	2.72
	Mound on humus	82.7 b	236.8 ab	3.17
	Plow, terrace	71.2 a	225.4 a	2.45
	" , tilt	81.9 b	259.7 b	4.60
Norway spruce 2/2	Disc trenching	87.4 a	123.1 a	0.44
	Mound on humus	96.0 b	130.5 a	0.54
	Plow, terrace	89.9 ab	157.8 b	1.13
	" , tilt	93.8 ab	174.4 b	1.28

Mounding was almost equally favourable irrespective of species and type of seedling. The growth of the seedlings was also positively affected by mounding. The effect was roughly the same for mounds placed on mineral soil and those placed on humus. In Expt 3 the best growth was found on the plowed tilt. This was especially evident for the spruce.

The relatively small differences in survival and height development measured the first years after planting increased with time (fig. 4 & 5). Especially for seedlings planted in mounds or plowed tilts, the mortality was low after the first years.

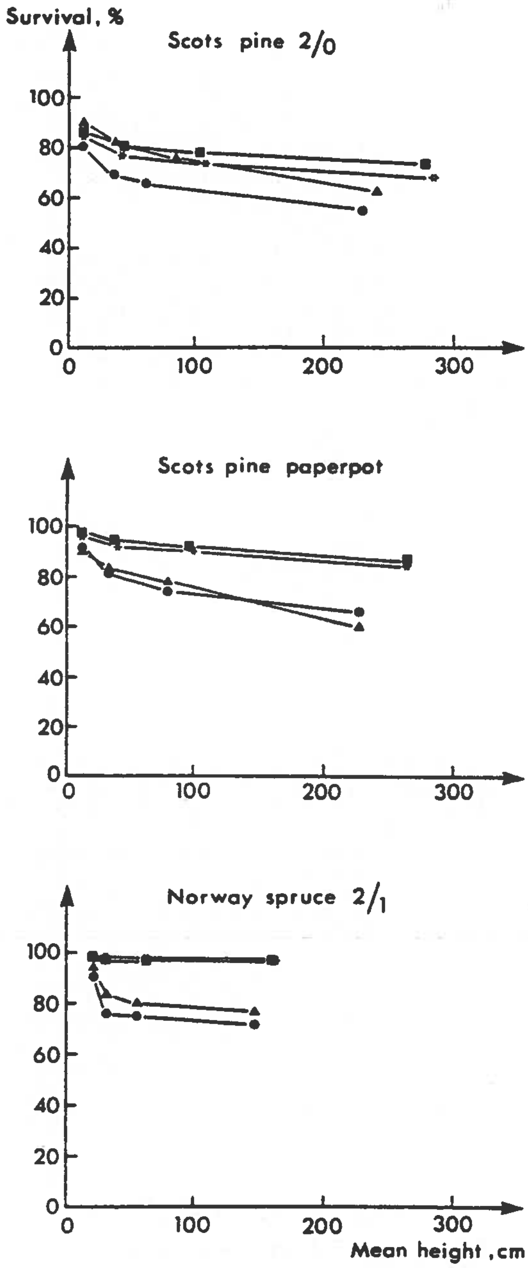

Figure 4.--Relation between mean height and survival for seedlings of Scots pine and Norway spruce. Planting year 1973. Inventoried in 1974, 1976, 1979 and 1985. Expt. 1 ● = Not scarified ▲ = Patch scarification * = Mound on mineral soil ■ = Mound on humus.

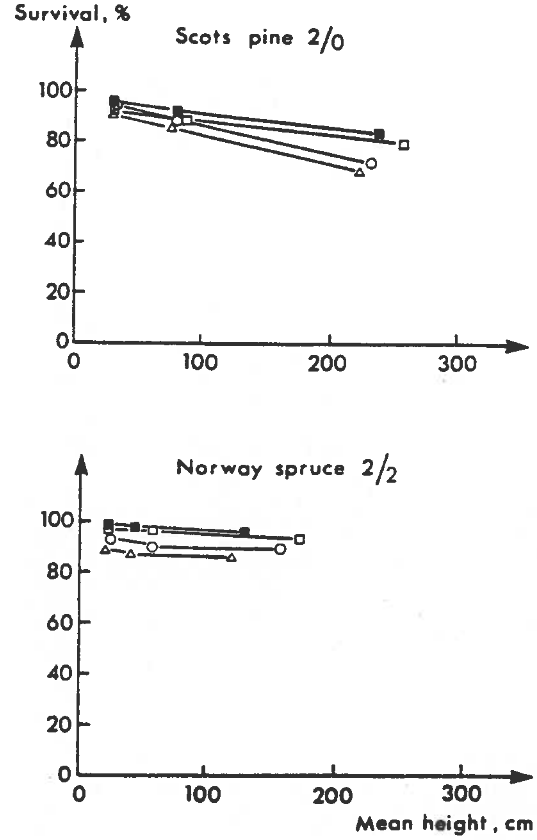

Figure 5.--Relation between mean height and survival for seedlings of Scots pine and Norwa spruce. Planting year 1974. Inventoried in 1976, 1979 and 1985. Expt. 3. Δ = Disc trenc ing ■ = Mound on humus o = Plow, terrace □ = Plow, tilt.

The experiment was mainly planted on mesic dwarf-shrub type. However, some of the plots were planted on moist spots. In table 2 growt and survival of the seedlings is shown after dividing them into two soil moisture classes. On blocks that were classified as moist both survival and growth was lower for seedlings planted in scarified patches than on mesic one: (table 2, Expt 1). This was not found for the other soil treatments. In Expt 3 the survival on moist sites was considerably lower for seed ling planted after disc trenching. For seedlin planted on plowed tilt both survival and growt was somewhat better on the blocks that were moist.

Table 2.--Effects of some methods of soil treatment on height and survival (within brackets) of Scots pine and Norway spruce seedlings. The blocks were grouped according to mesic and moist soil conditions. Expt 1 and 3.

Soil treatment	Scots pine Soil moisture		Norway spruce Soil moisture	
	Mesic	Moist	Mesic	Moist
Expt 1				
Not scarified	227.7 (60.4)	228.1 (66.4)	142.0 (66.2)	159.3 (86.5)
Patch	234.2 (64.4)	229.6 (52.8)	150.7 (82.1)	133.2 (64.7)
Mound on mineral soil	275.0 (77.9)	278.5 (70.6)	159.5 (97.0)	164.0 (100.0)
Mound on humus	271.5 (81.6)	265.5 (79.2)	160.3 (96.2)	168.3 (98.1)
Expt 3				
Disc trenching	218.9 (67.9)	232.0 (71.4)	122.5 (90.0)	125.7 (75.6)
Mound on humus	233.4 (85.2)	242.1 (71.4)	128.6 (94.8)	141.4 (100.0)
Plow, terrace	221.0 (70.1)	238.2 (74.3)	160.9 (91.3)	157.2 (85.4)
" , tilt	253.4 (81.1)	275.0 (85.7)	172.4 (93.3)	184.0 (95.3)

An analysis was made to study whether the size of gaps decreased with increasing survival. The 5-tree plots were therefore divided into 6 classes; 0, 1, 2, 3, 4 or 5 surviving seedlings/plot. Some of the results are shown in table 3.

Table 3.--Effects of some methods of soil treatment on the number of surviving seedlings per plot. 5-tree pots. Expt. 3.

Soil treatment	Survival, %	Number of plots with ≥ 2 surviving seedlings	Number of plots with ≥ 3 surviving seedlings
Disc trenching	68.5	80.0	50.0
Mound on humus	82.7	92.5	77.5
Plow, terrace	71.2	85.0	65.0
" , tilt	81.9	92.5	72.5

Soil treatments that were favourable for survival, such as mounding and plowing, also decreased the number of plots with few surviving seedlings (table 3). Thus an increased survival also resulted in a decreased frequency of large gaps.

CONCLUSIONS

Mounding as a means of soil treatment has a lot of advantages compared to disc trenching and patch scarification. Positive biological effects are increased soil temperature, sufficient local drainage of the planting spot, good aeration and decreased frost risk. If the mounds are placed on humus, or on an inverted humus layer, the nutrient supply will also be beneficial. Positive effects of mounding are reported in the present study and in several other reports (eg. Söderström et al., 1978; Mc Minn 1985; Edlund & Jönsson 1987).

However, as shown in the present report, there are also some disadvantages that are especially pronounced if the mounds are placed on a humus layer. The temperature amplitude between night and day is very high in a mound and low temperatures are to be expected in autumn before the snow falls. Low soil water potentials could be expected during dry periods, especially if the mounds are placed on the humus layer (Örlander 1984, 1986; cf. Mälkönen 1976, 1987; Sutton 1984). Frost heaving and frost damage in the spring (Söderström 1978) may also increase in mounds.

In my opinion, the problems with drought risk, insufficient nutrient supply, the risk of frost heaving and insect attacks by Hylobius abietis are not yet satisfactorily solved for areas with low humidity (cf. Bäcke et al., 1986). Some field studies are now started to further investigate the problem. The experiments include for example effects of planting depth and choice of planting spot within a mound. Results from the experiments will be presented in the near future.

In the present study the positive effects of soil treatment seem to increase with seedling age/size. On parts of the experimental area where for example patch scarification is not a good method (particularly on moist spots) both survival and growth were improved by mounding or plowing and planting in the tilt.

Mounding is today assumed to be the most suitable method of soil treatment in Sweden (cf. Bäcke et al., 1986). However, no scarification principle is universal. On cold soils with an inactive humus layer mounding might not be sufficient with regard to soil temperature increase, drainage and nutrient mineralization. On such sites plowing or mounding with excavator is recommended. In areas with low summer precipitation no ideal scarification method is available today. The problem is pronounced on dry soils.

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EFFECT OF SITE PREPARATION ON SEEDLING PERFORMANCE IN A HYLOCOMIUM MYRTILLUS-STAND

Aulis Ritari

ABSTRACT: In a comparative study conducted on a northern Hylocomium Myrtillus - site the best group of planted Scots pine, Norway spruce, Siberian larch and natural Norway spruce seedlings with respect to the previous summer's height and length of shoot was found where the soil was prepared using tilt ploughing or rotary tilling. After eight growing seasons the behaviour of larch differed from the other species in that its best seedling group with respect to survival was also located on elevated microreliefs.

Proper drainage and a rise in temperature of the substrate were found to be important for the growth of seedlings. The findings support the idea that the reason for the low survival of planted pine and spruce seedlings on elevated microreliefs lies in their poorer resistance to late winter low temperatures and frost desiccation. This situation is aggravated by the short growing season and a gradual depletion of nutrients from the substrate. The larch, which grows fast and sheds its needles, would seem to succeed better on a tilt than planted pine and spruce seedlings.

INTRODUCTION

The regeneration of spruce forests became topical in Finnish Lapland in the 1930s. It was at this time that studies were begun in the form of soil preparation and cultivation experiments (Heikinheimo 1939).

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Previously, Renvall (1919) had called attention to poor seed crops and soil conditions and the seedling damage attributed to reindeer as obstacles to regenerating pine forests at the timberline.

Results of regeneration on areas burned in wild fires indicated that prescribed burning could provide necessary improvement in soil conditions at least on drier sites (Sarvas 1937). In the 1950s and even later it was generally held that spruce stands grow on degenerated raw humus sites whose original fertility could be restored through prescribed burning (Sirén 1955). Production considerations spoke in favor of a change in species from spruce to pine (Ilvessalo 1937). The burned area to be reforested was first prepared through manual scalping, mechanical scalpers being introduced in the 1950s. In the 1960s the main means of soil preparation on moist upland sites became ploughing when extensive failures were observed in earlier pine cultures on burned and scalped sites (Etholén 1972). At present an attempt is being made to employ lighter methods whenever drainage conditions permit.

The ideas - or at least the relative weight thereof - concerning the environmental factors which limit the germination and growth of seedlings have thus varied and research findings have been available only years after the introduction of a new method. For these reasons as well as owing to technical and economical considerations involved in soil preparation and cultivation, equipment development has often been guided by concerns other than the goal of creating the optimum environment for tree seedlings.

The environment of a seedling can be roughly divided into the soil and the ambient air, whereby examination thereof takes place in terms of edaphic and climatic factors. Disadvantageous soil factors such as excessive moisture and the concomitant poor aeration as well as the coldness of the soil have been found by Leikola (1974), Mutka and Lähde (1977) and Söderström et.al.(1978) to be connected with the poor performance of seedlings in a northern climate. The significance of growth rhythm and cell-level changes for the frost resistance of trees is currently the object of active research (Kallio 1978, Koski & Sievänen 1985). The theory germane to the present study is that described by Tranquillini (1979), which deals with frost damage and desiccation of tree seedlings caused by incomplete development of shoot and frost resistance at the alpine timberline. More recently increasing attention has focused on the nutrient status of prepared soil and explanation for the development of seedlings has been sought in the chemistry of the substrate (Lundmark 1984, Ritari 1985, Mälkönen & et.al.1986, Tikkanen 1986).

The present study deals with the results of a soil preparation and cultivation experiment in Central Lapland, its goal being to estimate the dependency of seedling characteristics on environmental factors in light of current theories and hypotheses. The study is part of the reforestation investigations in the area.

MATERIAL AND METHODS

The study area is located approx. 130 km north of the Arctic Circle (67° 52' N, 26° 12'E) and is about 340 m asl. The native forest consists of sparse mixed spruce-birch forest classified as HMT (Hylocomium myrtillus-type)(Cajander 1949). Due to its northern location, elevation and successional stage the site evinces such characteristics as a short growing stock (approx.10 m) and a thick humus layer (approx.6 cm).

The glacial till soil exhibits diverse layered formations. A dense silty layer under the thin surficial moraine decreases soil permeability and makes the soil itself moist (Pernu & Ritari 1978). The soil type is humic podzol. Geological studies indicate that ultramaphic rocks are common in the area (Lestinen 1980).

The experimental area, strip-felled in the winter of 1971-72, was divided into 60x180 m blocks (4 replications) for which the mechanical soil preparation was chosen at random. The treatments in the present material are: 1) scalping, 2) shoulder ploughing, 3) tilt ploughing, 4) rotary tilling, 5) untreated, clear-cut and 6) untreated, forest - these last two constituting the control material. Each experimental block had 7 systematically placed cultivation points (8 seedlings/species/point) which formed a circular plot with a radius of approximately 5 m (Fig.1). The plots were cultivated in the summer of 1976 with bare-rooted 1+1 Scots pine (Pinus sylvestris L., local) and Siberian larch (Larix sibirica Ledeb., Raivola), and 1+2 Norway spruce (Picea abies (L.)Karst., local) seedlings. The reference to species also means the provenance and seedling type used and the physiological condition of seedlings at the time of planting.

The seedling inventory data is from the summer of 1983. At the same time control material consisting of natural spruce seedlings (the 8 highest per plot) was gathered. The characteristics under study were: height and shoot length of living seedlings and survival (for natural seedlings only height and shoot length).

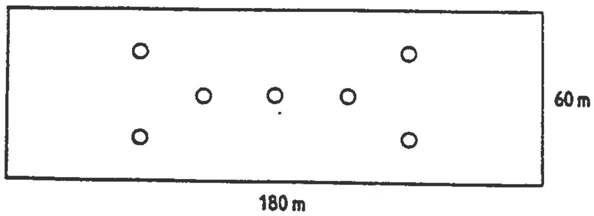

Figure 1. The location of cultivation points within the experimental blocks.

The physical soil properties are those obtained at the beginning of the period of study (soil temperature in 1983) and the chemical properties those from 1984. The observations and samples represent the uppermost 10 cm of the cultivation point. In addition to exchangeable cations and easily extractable phosphorus the reserve fractions of the same elements were studied. The details of the methods can be found in Ritari (1985).

The relationships between soil and seedling characteristics were examined by extracting the seedling material (168 plots in all) two samples, one representing the most and the other the least succesful group of seedlings in the whole population. More precisely, each group represents observations located at least one standard deviation from the mean (Fig.2).

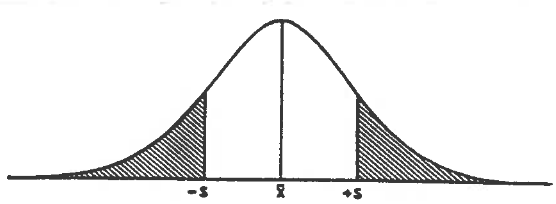

Figure 2. The studied groups (shaded) with respect to the population mean in case of a normal distribution.

This procedure yielded the largest possible contrast between the seedling populations and made it possible to keep the material undivided in the analysis.

RESULTS

Table 1 presents the mean values for the environmental variables of the largest and smallest group of seedling properties.

As far as height and shoot length are concerned the relationship of the different species with regard to the environmental properties measured was very similar. Pine and spruce behaved in the opposite fashion to larch with regard to survival, a finding also established as a negative correlation between survival and other seedling characteristics for the two first mentioned.

Distinct differences among the values of the environmental variables appeared in the chemical data gathered during the end of the measurement period. The findings indicate that the the nutrient content of the environment of seedlings showing good growth was lower than that in the environment of seedlings exhibiting poor growth.

There are at least three possible explanations for such a development which seems odd at first sight: first, the bulk densities differ between samples from different treatments - the figures in the table are expressed per a weight unit (cf.also L.I. ∿ humus content); second, the sample layer does not represent the root zone of the seedlings owing to growth of roots; third, the properties examined are simply not minimal factors determining growth. The applicability of these explanations will be evaluated in later research. On the other hand , the iron and magnesium reserves as well as the content of easily soluble aluminium were greater in the group which grew well decreasing the probability of toxic effects. The opposite situation obtained for survival of pine and spruce, i.e. high nutrient content in the environment of a seedling group exhibiting good growth, could be indicative of the role of a fertility regime in the process of frost hardening of seedlings.

Table 1. The mean values and the statistical significance of the differences (t-test) of the environmental variables for the groups of seedling properties. The explanation for the variables is in Appendix 1.

VARIABLE	GROUP	HEIGHT Pine	SHOOT LENGTH Pine	SURVIVAL Pine	HEIGHT Spruce	SHOOT LENGTH Spruce	SURVIVAL Spruce	HEIGHT Larch	SHOOT LENGTH Larch	SURVIVAL Larch	HEIGHT Spruce,nat.	SHOOT LENGTH Spruce,nat.
Ks	mean-s	5.6**	4.9*	3.9	5.6	4.9	4.5	4.4	4.9	4.3	4.0	4.5
	mean+s	3.8	3.6	4.7	4.5	4.7	5.2	3.8	4.5	4.6	4.8	4.5
Cas	mean-s	13.5***	9.2	5.2***	14.8***	13.1***	6.7	10.9***	11.7***	15.6**	19.2	17.6**
	mean+s	4.2	7.1	12.6	4.3	4.5	12.7	4.9	4.3	6.6	7.3	4.3
Mgs	mean-s	1.3***	2.2*	3.5***	0.9***	1.2***	3.5***	1.7***	1.2***	1.5***	0.9***	1.1***
	mean+s	3.2	3.0	1.4	3.9	3.9	1.7	3.7	4.2	3.3	3.5	4.1
Fes	mean-s	0.8***	1.4*	2.2***	0.6***	0.8***	2.1***	1.0***	0.9***	1.0***	0.7***	0.7***
	mean+s	2.0	2.0	1.0	2.2	2.1	1.1	2.2	2.3	2.0	1.9	2.3
Als	mean-s	2.3***	1.9**	1.4*	2.3***	1.8	1.5*	2.2**	2.5***	2.1*	1.5	1.8
	mean+s	1.2	1.4	2.0	1.4	1.4	2.4	1.4	1.4	1.6	1.8	1.5
Ps	mean-s	2.9***	2.3*	1.5***	3.0***	2.6***	1.7***	2.4**	2.6***	2.5**	2.3	2.3**
	mean+s	1.5	1.7	2.5	1.5	1.5	2.9	1.6	1.5	1.7	1.8	1.5
Pa	mean-s	66.6***	42.4*	7.8***	87.0***	75.1***	11.3**	47.5***	50.3***	54.9**	54.5	50.8***
	mean+s	2.3	15.7	64.4	4.3	5.2	59.4	4.3	1.9	15.1	18.8	2.9
Ka	mean-s	45.9***	30.2**	4.8***	51.7***	41.9***	5.5***	31.9***	40.9***	32.3***	33.2*	37.1***
	mean+s	2.7	8.1	37.5	3.2	4.2	40.9	3.4	1.7	11.0	12.7	2.9
Caa	mean-s	78.6***	43.0	11.1***	89.3***	73.9***	11.4***	60.7***	71.2***	76.9***	73.6*	78.0***
	mean+s	5.8	27.2	76.4	6.8	7.6	68.9	10.2	5.1	22.3	25.4	6.2
Mga	mean-s	82.1***	48.7	7.1***	95.4***	90.7***	4.3***	92.5***	65.1***	70.2**	78.4**	87.3***
	mean+s	2.0	16.6	56.4	7.7	10.4	64.8	2.2	0.9	16.9	5.3	1.7
Fea	mean-s	1.5	2.4	3.0*	0.9*	1.4	3.4*	2.1	1.7	1.6*	1.9	1.2*
	mean+s	2.4	2.8	1.7	2.3	2.5	1.7	2.5	2.5	2.7	2.9	3.1
Ala	mean-s	3.3***	7.3	11.2***	2.6***	3.2***	10.8**	3.8***	3.7***	3.8***	3.2**	3.5***
	mean+s	8.7	9.6	4.4	10.3	9.8	5.9	10.7	10.9	10.0	10.2	9.9
TOT-N	mean-s	8.1***	5.1*	1.2***	8.7***	7.3***	1.8***	6.7***	7.5***	6.6***	6.7*	7.2***
	mean+s	1.3	2.3	6.9	1.0	1.1	7.0	1.1	0.7	2.3	2.5	0.9
E. COND.	mean-s	3.3***	2.7**	1.3***	4.0***	3.4***	1.4***	3.1***	2.6***	2.4*	2.2	2.5***
	mean+s	1.3	1.3	2.9	1.2	1.2	2.7	1.2	1.2	1.7	2.1	1.3
cHH2O	mean-s	0.9*	0.7	0.6	1.0*	0.8	0.7	1.0**	0.9**	1.0*	1.0	1.0*
	mean+s	0.6	0.5	0.8	0.6	0.6	1.0	0.5	0.4	0.6	0.6	0.5
cHKCL	mean-s	0.9	0.8	0.6*	1.0	0.8	0.8	1.0*	0.8	1.2**	0.9	0.8
	mean+s	0.7	0.7	0.9	0.7	0.8	0.9	0.6	0.5	0.6	0.7	0.6
L.I.	mean-s	3.4***	2.2**	0.5***	3.7***	3.1***	0.7***	2.8***	3.3***	2.5***	2.7	3.3***
	mean+s	0.5	0.8	2.9	0.4	0.5	3.1	0.5	0.3	1.0	1.1	0.4
MOISTURE	mean-s	38.7***	35.6**	25.4***	36.8***	37.0***	29.7	38.3***	42.2***	39.5***	38.3**	38.8***
	mean+s	26.9	27.8	37.1	24.5	24.6	32.1	25.7	23.0	28.4	27.1	27.6
AIR	mean-s	12.3**	14.0**	28.9***	16.5**	16.6*	23.7	14.6**	7.6***	11.0***	15.0	13.4*
	mean+s	24.4	25.7	11.8	28.3	27.8	20.7	27.6	29.1	24.3	22.9	21.7
JUNE, TEMP	mean-s	8.0***	8.2***	10.1**	8.2***	7.8***	9.0	8.3***	8.0***	8.3*	8.2	8.2
	mean+s	10.2	10.7	8.1	10.8	10.4	8.8	10.8	11.0	9.7	9.3	9.6
JULY, "	mean-s	10.8***	11.3***	14.0***	11.1***	10.7***	12.5	11.1***	11.0***	11.1**	11.1	11.1*
	mean+s	14.2	14.7	11.0	15.1	14.4	11.9	15.0	15.3	13.4	12.8	13.3
AUGUST, "	mean-s	8.8**	9.3**	11.4***	9.7*	8.4**	10.1	8.4***	8.1***	9.3*	8.3	8.8
	mean+s	11.3	11.6	8.8	11.8	11.3	10.0	12.0	12.1	11.1	10.7	10.8
SEPTEMBER	mean-s	6.6	6.5**	7.1	6.9	6.3	6.5	6.6*	6.4*	6.7	6.5	6.6
	mean+s	7.1	7.5	6.5	7.3	7.1	7.0	7.4	7.4	7.0	6.8	6.7
Seedling property	mean-s	32.0***	2.3***	26.0***	19.8***	1.1***	31.7***	18.0***	1.2***	15.2***	127.9***	18.7***
	mean+s	81.9	12.4	100.0	69.5	10.3	100.0	107.3	24.0	91.1	535.6	91.4

Soil moisture was lower and air space greater for seedling groups exhibiting good growth. Survival of pine and spruce showed deviation, however, from this general rule. A similar situation prevailed for the monthly mean temperature of the soil: in seedling groups exhibiting good growth it was clearly higher than in those showing poor growth. Pine and spruce again behaved in the opposite fashion with regard to survival.In case of pine and spruce the vigorous growth made possible by well-aerated and warm soil can prove detrimental in that it may retard frost hardening, which,in turn, means a low survival rate.

The best seedling group with respect to height and shoot length for different species was most often located where tilt ploughing had been done and the worst in untreated forest (Fig.3). The environmental variables presented thus represent in the main these two treatment types. For spruce and pine, survival was best in untreated forest. Larch, on the other hand, would seem to benefit from a strong soil treatment in this regard.

DISCUSSION

The material offered an opportunity to test the applicability of some hypotheses and theories related to seedling performance under conditions prevailing in a northern HMT forest. As it deals with various forms of mechanical soil preparation and both cultivated and natural seedlings, the study material is quite extensive; nevertheless the multiplicity of growth factors and the nature of living material impose their own limitations on the interpretations (cf. Mueller-Dombois & Ellenberg 1974). It is not always even possible to measure the growth factors directly, whereby the collection of ecological observations must be based on known or assumed causal mechanisms (Kuusipalo 1985). The examination of the seedling groups exhibiting the best and poorest performance aimed at bringing out a contrast which is often obscured in comparisons of population means. Use of soil preparation broadened the range of the environmental variables, which was thought to be reflected when the dependence is strong, in the values of criterion variables.

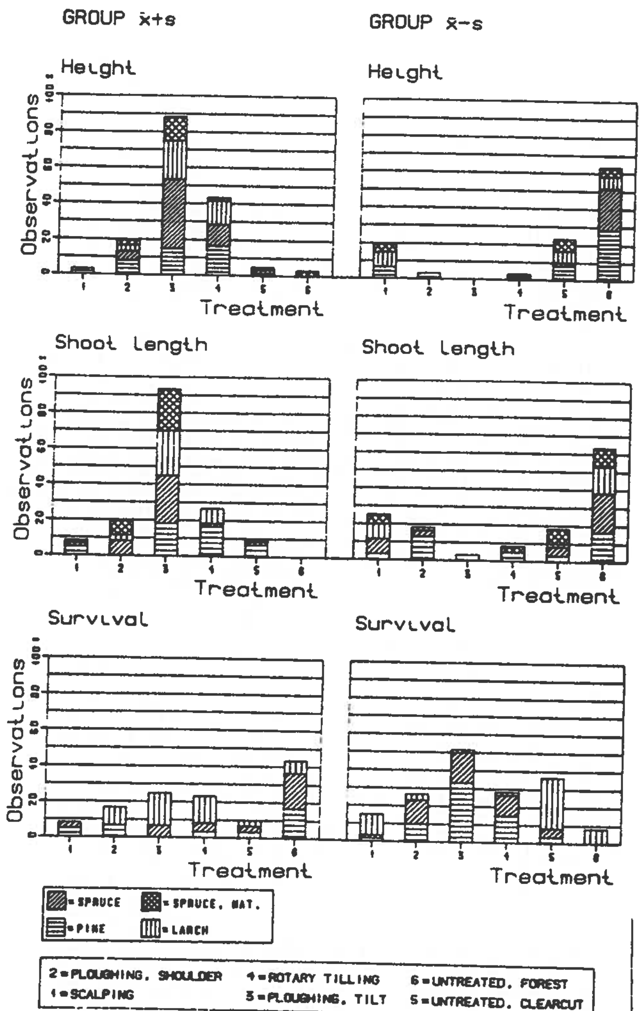

Figure 3. Distribution of observations by different treatments for seedling groups studied.

A knowledge of the environmental factors affecting seedling growth is a goal which will, when realized, provide a basis for understanding their interdependence and for regulating them appropriately. To date, the analysis of various means of soil preparation has generally confined itself to a mere statement of their effects without a closer understanding or study of growth factors. In addition, not enough attention has been paid to the choice of the criterion variables. The development of soil preparation methods has, moreover, often been dependent upon certain predilections or upon technical considerations. On the other hand, studying the effects of soil preparation on the level of growth factors is difficult because several factors are changed in the process simultaneously; interpretation of the results becomes more demanding than in the case of fertilization experiments, for example, in which the effect of an individual nutrient element is examined.

Clear evidence for the positive effect of elevated microreliefs on the height and length of the seedlings was noted for all species studied. In operating in the harsh growth conditions which prevail near the timberline it is important to be familiar with the potential and limitations of the soil. If the level of growth is mainly dependent on climatic conditions during the winter, perennial trees may not benefit much from soil preparation the positive effect of which is restricted to the growing season.

The lower survival on elevated microreliefs of pine in particular but also of planted spruce seedlings as compared with other reliefs seems to be consonant with the description and explanation of winter damages by Tranquillini (1979). Observations in the area of needle losses, mechanical damage and of Scleroderris -canker on pine seedlings support the theory (Ritari, A., unpublished data; cf. Eiche 1966). It is also known that the microclimate of the elevated microreliefs exhibits extreme fluctuation causing serious stress to root systems sensitive to high and low temperatures (Vaartaja 1954, Sutinen 1986). Late winter is a critical time if the winter dormancy ends too early (Havas 1978). Although various types of damage were in evidence on all species, larch, which adopts more xeromorphic form for winter, seems to survive better on elevated microreliefs than pine and spruce.

It proved problematical to determine the significance of the soil fertility regime and of the humus inasmuch as the extracted high content of nutrients was not found to have any direct effect on the height and growth of the seedlings. On the other hand, the survival of pine and spruce was highest on experimental plots of untreated forest comparatively rich in nutrients, i.e. those plots covered with undisturbed humus. As stated earlier, this result might be due to the fact that for the largest seedlings the samples analyzed no longer represented the principal layer, where the nutrients are extracted by the root tips.For the largest larches this is most evident. However, on ploughed tilt the bulk density of the inverted humus layer is lower than that of the soil layer above, which would lower the nutrient content when calculated per volume. It is likely that the reduced nutrient contents in the surface of the elevated microreliefs, a result of leaching, contribute to the poor frost resistance of the seedlings (cf. Ritari 1985) although it is known that the amount of nutrients available to plants in undisturbed raw humus is also low (Tamm 1953). According to Pellet and Carter (1981) the improvement of cold hardiness in plants by nutritional factors is not restricted to potassium and phosphorus but a nutrient regime which promotes optimum growth also means good frost resistance.

A better survival of pine and spruce seedlings in untreated forest as compared with ploughed tilt must be seen as an outcome of the protection by larger trees and by the snowcover (cf.Koskela 1970). A high survival rate at an age of 8 years still provides no guarantee that reforestation will succeed if the seedligs became stunted , as was the case with the seedlings planted in untreated forest. As untreated forest and untreated clearcut did not differ from one another much in respect of extracted soil nutrients (Ritari 1985), poor seedling growth in the forest must be explained by factors including inadequate light for photosynthesis and root competition.

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Appendix 1.

VARIABLE		UNITS
Ks	HCl extr.	$(*10^{-2})$, %
Cas	"	$(*10^{-2})$, %
Mgs	"	$(*10^{-1})$, %
Fes	"	%
Als	"	%
Ps	"	$(*10^{-2})$, %
Pa	NH4OAc extr.	$(*10^{-4})$, %
Ka	"	$(*10^{-3})$, %
Caa	"	$(*10^{-3})$, %
Mga		$(*10^{-3})$, %
Fea	"	$(*10^{-2})$, %
Ala	"	$(*10^{-2})$, %
TOT-N		$(*10^{-1})$, %
E. COND.		μScm^{-1} (*10)
cHH2O		$(*10^{2})$
cHKCl		$(*10^{2})$
L.I.		(*10), %
MOISTURE	soil	%
AIR	"	%
JUNE	soil temp.	°C
JULY	" "	°C
AUGUST	" "	°C
SEPTEMBER	" "	°C
Seedling height		cm
"	shoot length	cm
"	survival	%

SITE PREPARATION AND LEACHING OF NUTRIENTS

Eero Kubin

ABSTRACT: Several experimental fields were founded in northern Finland from the 1960's onwards in order to research into the ecological problems attached to artificial forest regeneration. On one of these was also examined the leaching of nutrients. Determinations were done from runoff water in the spring between 1974 and 1986. The results show that clear cutting and soil preparation increase the leaching of nutrients in surface waters. The amount of leaching, however, depends on the element. Of all the elements that were examined (NO_3-N, NH_4-N, P, K, Ca, Mg, Na and Fe) the leaching of nitrate was the greatest during about two years after site preparation. As a whole the increase in leaching lasted about 5 years.

INTRODUCTION

The ecological problems attached to artificial forest regeneration were started to be examined intensively in Finland at the end of the 1960's. The reason for this was above all the failures in forest regeneration in northern Finland. The research was started expressly in Lapland when the Department of Silviculture of the Forest Research Institute started there a wide series of field experiments in order to measure site factors in connection with different methods of site preparation and also partly with different methods of regeneration.

As a part of this series of experiment was founded the experimental field of Kivesvaara to the south of Lapland, where there was started a measuring of several different ecological site factors in 1973 with the leadership of the head of Muhos Forest Research Station, Jukka Valtanen. The work concerning the nutrient value of the soil and runoff water was started in collaboration with the Botanical Department of Oulu University, where the research group of Dr. Heikki Haapala with experience in hydrochemical research took part in the research. The analyses were at first done in the laboratory of the Botanical Department and from 1979 onwards in Muhos when the laboratories in the research station had been completed.

The experimental area of Kivesvaara is the first place in Finland where the effect of site preparation on the quality of runoff water is examined. In Nurmes-research, started in 1978, there is corresponding research into site preparation, too, but

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these treatments were not done there until in 1986 (Nurmes-research 1979). On the other hand, preliminary results have already been presented about the effect of clear cutting in Nurmes-research (Ahtiainen and Kenttämies 1985). There are also results from increased leaching of nitrogen after clear cutting in Swedish researches (Tamm et. al. 1974, Wiklander 1974, 1983) and in Sweden there are also large researches going on in coniferous forest watersheds (Rosén 1982).

As the main weight of the work on the experimental field of Kivesvaara lies on measuring ecological site factors it was from the very beginning not planned for examining the leaching in individual watersheds. The leaching of nutrients has been measured in the surface water that runs from separate prepared areas. At the same time has also been followed the total effect of the clear cutting and soil treatment of separate areas by examining also the nutrient contents of the water that runs away from the whole experimental area. The results presented now from this study represent the most prolonged series of measurements of this kind in Finland.

MATERIAL AND METHODS

The geographical location of the experimental field is 64°N 27°E (fig. 1). The topographical height varies between 198 - 215 m above the sea level. The site is of fresh mineral soil forest site (Vaccinium-Myrtillus type) and the soil is fine sandy till. The stand consists mainly of spruce with a little pine and birch. After clear cutting the artificial regeneration was done for Scots pine.

The field was clearcut in the winter of 1974 and the soil was prepared in the autumn of the same year. Between the experimental plots there were dug ditches so that the surface waters from every strip gather at the lower end into one point. The ditches were dug already before clear cutting. The methods of soil preparation were (1) unprepared or planting on a hand made scalp, (2) machine made scalp, (3) ploughing with a shoulder plough and (4) full tilling with a shoulder plough.

The follow-up of leaching was started in the spring of 1974. It was noticed during the first years that runoff water does not gather into all ditches. When snow melts there is water in all of them but this period is short and the water that melts from snow and stays partly still does not represent surface runoff. Because of this the basic idea about a runoff that could be obtained from different experimental

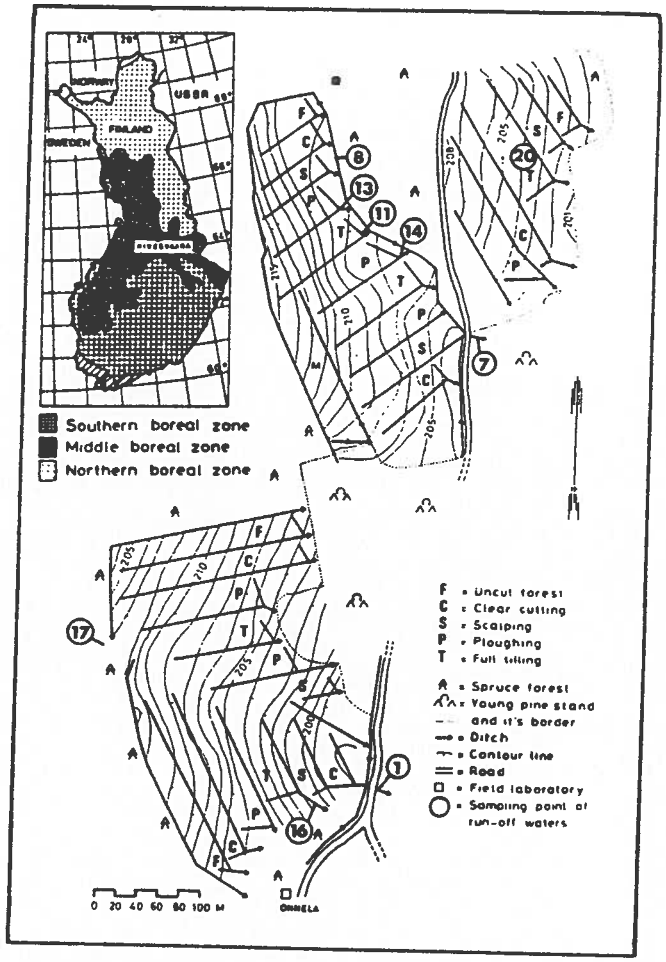

Figure 1.--The experimental field of Kivesvaara and the sample points of the research of the leaching of nutrients.

plots did not succeed but the runoff had to be measured only from certain points. Even from these the water runs out in May, so the leaching of nutrients was measured mainly during the spring runoff. There are from some years determinations from early autumn, too, but in this connection only results from the spring runoff are presented. Only some cation values are presented from the midsummer of 1974, because there were no observations in the spring.

Water samples were taken from running water into plastic bottles and the chemical analyse was started either on the same or immediately on the following day. Nutrients were determined with the methods commonly in use in hydrochemistry. Spectrophotometrically were measured NO_3-N, NH_4-N and PO_4-P, the latter as total phosphorus after reduction in an autoclave. By using a flameatomabsorbtic spectrophotometre were measured K, Ca, Mg, Fe, Mn, Na and Fe. In addition to that the pH-value and conductivity were also studied.

The formation of runoff water has varied yearly, because of which the number of sample takings also varies yearly from one or two to more than ten. As the conditions in the spring also vary both as for rains and for the way the snow melts this, too, causes deviation in the results. So the annual mean values, which are presented in the following, also describe for a great part the conditions in different years. Because of the above reasons temporal trends of development do not necessarily come forth about all the elements which were examined.

RESULTS

Total effect of clear cutting and of different site preparations

The clearcut was done in the winter of 1973 - 74 and the soil of certain strips was prepared a little before snowfall in the autumn of 1974. The total effect of these treatments on the quality of the runoff is examined in sample points 1 and in upper comparison point 17 (fig. 1). The water in sample point 17 partly flows to the sample point 1. Into sample point 1 come also waters from the sides that are outside the experimental area.

By comparing the water above the experimental area (sample point 17) and the water that runs away from the whole area with each other we find partly out the effects of clear cutting and the soil preparation of different separate areas. The bigger the part of the water that runs through, the smaller the effect of the treatments.

The results show (fig. 2) that the contents of the elements in point 1 grow compared with both the values before preparation and with the above comparison point. The increase in contents is neither sharp, nor of long duration. Magnesium, iron and natrium have similar trends with those of nitrate, phosphorus and potassium shown in figure 2. On the other hand, the content of ammonium nitrogen and manganese varied yearly more randomly. The pH-value of water showed light increase in point 1 during the first years, but otherwise there was no long-term trend in that, either. According to the annual mean values the pH-value varied between 4.25 - 4.91 and correspondingly in comparison point 17 between 4.36 - 4.74.

Sample points 7 and 8 represent a corresponding composition to sample points

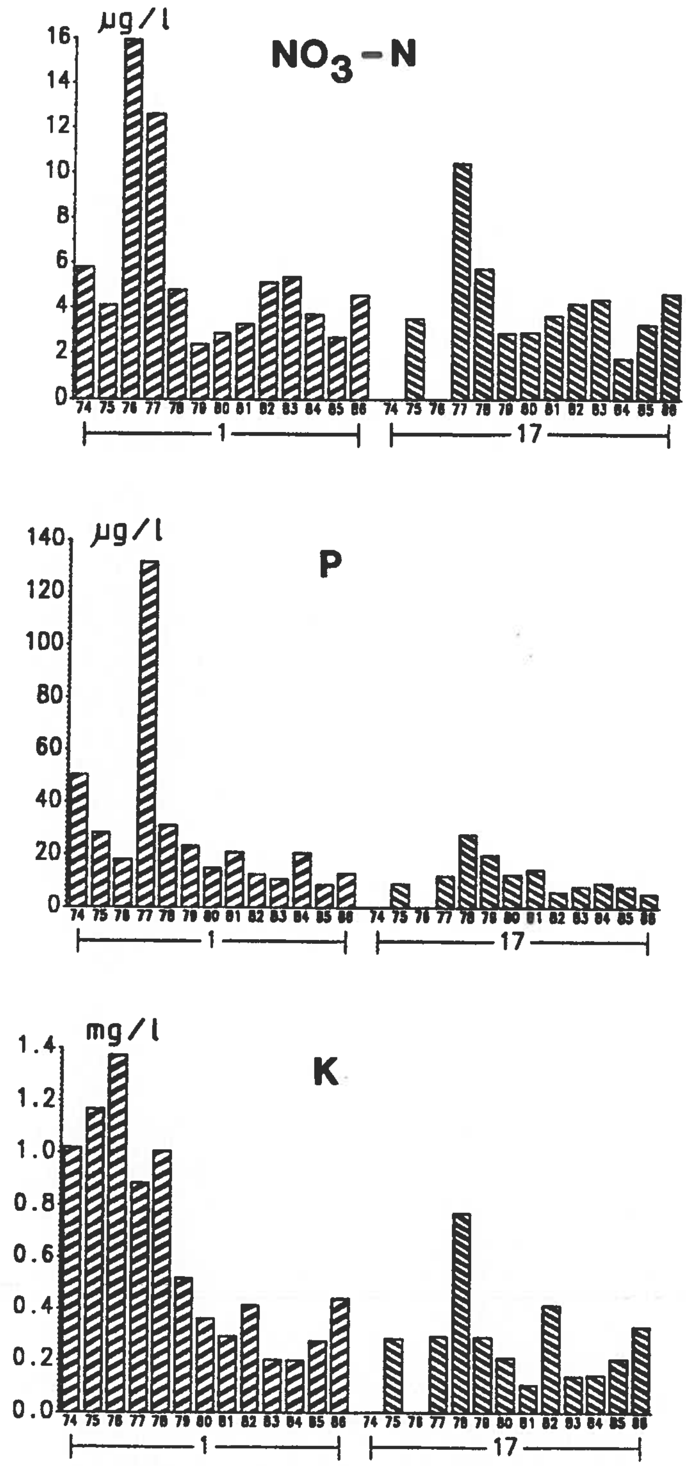

Figure 2.--Nutrient contents of the runoff water in sample point 1 and in upper comparison point 17. Determinations were done in the springs of 1974 - 1986. Clear cutting was done in the winter of 1973 - 74, site preparation in the autumn of 1974. The locations of the sample points are presented in fig. 1.

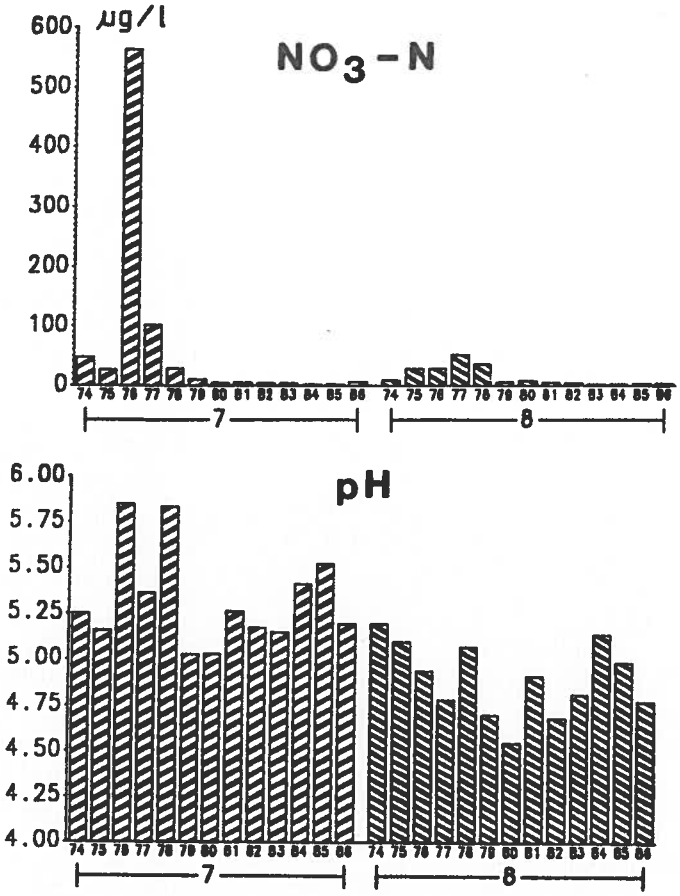

Figure 3.--Nitrate contents and the pH values of the runoff water in sample point 7 and in upper comparison point 8. Site preparation was done in 1974. The locations of the sample points are in fig. 1.

1 and 17. In point 8, however, comes forth only the effect of clear cutting because the soil above it is not prepared, nor do any waters from outside the experimental area run into it. All the water that comes into sample point 7 has thus formed in the upper area inside the experimental field.

The general picture of the changes in nutrient contents in sample point 7 is similar to that in point 1, but the increase in content values is greater. Especially nitrate content (fig. 3) increases sharply in the second summer after preparation. The maximum value was 1280 µg/l. The sharp increase was, however, followed by a considerably quick decrease. As a whole the increase in the content of the elements due to cutting and soil preparation lasted about five years. The increase in the leaching of other elements was relatively small compared to that of nitrate nitrogen. Eq. potassium values were nearly equal in point 8, above all soil treatments, with the values of point 7.

Compared to sample points 1 and 17, the pH-value of the runoff water is higher, about pH 5. In sample point 7 there was temporal development towards an increasing and decreasing direction, but the values measured in point 8 showed for many years after clear cutting decrease and then turned to an increasing direction. However, there are a few yearly observations and this, as well as the small amount of water in point 8, may have an effect on the results of pH and also on the elements.

The runoff that gathers into point 8 comes from the upper parts of the experimental field from a relatively small area. The amount of runoff is small and it lasts a short time compared to the lowest point 7. The number of observations is considerably smaller than in the lower points because of lack of water. From that point of view the effect of only clear cutting cannot be detected very reliably although the trend of the contents can be said to show at some extent exactly the effect of clear cutting. In spite of these insufficiencies we can consider the comparison of waters that gather into sample points 7 and 8 to show clearly that the leaching of nutrients increases because of clear cutting and soil preparation, expecially for the part of nitrate nitrogen.

Effect of site preparation

The runoff into sample points 13 and 14 comes only from the ploughed plots (See fig. 1). There are no measurements from the time before the soil preparation from these points but the effect of ploughing is clear and the trend is similar with its duration when one takes the former observations into consideration (fig. 4).

From sample points 11, 18 and 20 comes runoff that runs from the fully tilled experimental plots. In points 11 and 18 the runoff flows in the ditches, but point 20 differs from these so that the surface runoff is apparently born in a fully tilled area inside the experimental plot but its runoff is relatively small.

When comparing the trends of the nutrient contents of these three points they were between each other similar with their general features, with the exception of ammonium nitrogen. Its content was in point 20 in 1977, when the measurements were only started there, the biggest of all three. The lowest mean content of ammonium was in point 11. In point 18 the mean value of the spring was almost ten times bigger compared with the value before ploughing.

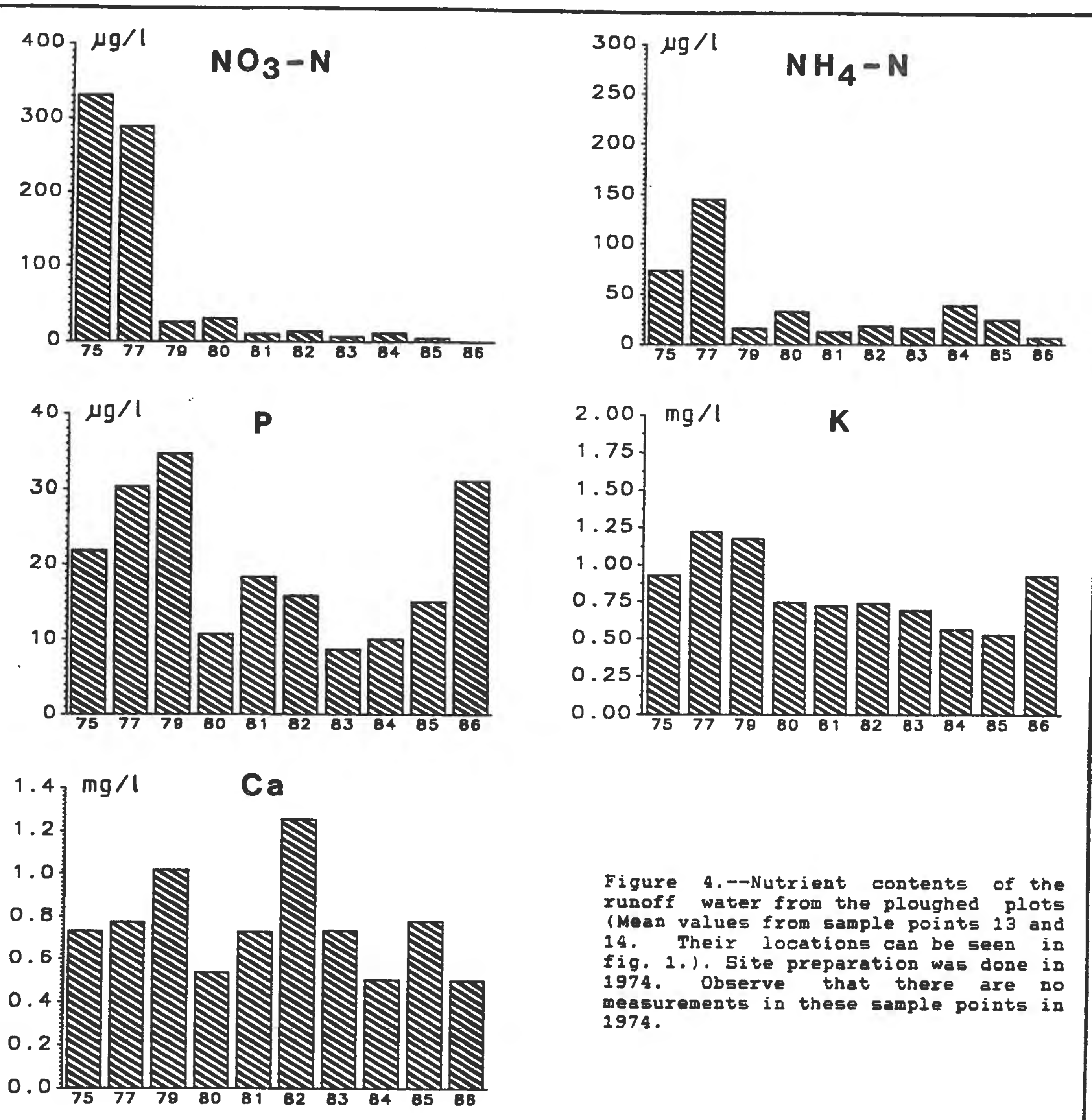

Figure 4.--Nutrient contents of the runoff water from the ploughed plots (Mean values from sample points 13 and 14. Their locations can be seen in fig. 1.). Site preparation was done in 1974. Observe that there are no measurements in these sample points in 1974.

In figure 5 there are the combined results of the above mentioned three points for the part of some nutrients. The effect of full tilling is fairly similar with that of ploughing and so the results reinforce each other. The content of potassium is interesting, its descending trend continued for almost 10 years after the peak values after soil preparation.

DISCUSSION

Surface runoff is formed either directly from rain or when snow melts into water. The melting of snow has a decisive significance for the formation of surface runoff in the experimental area in the spring. Surface runoff is also born so that rain falling may infiltrate and

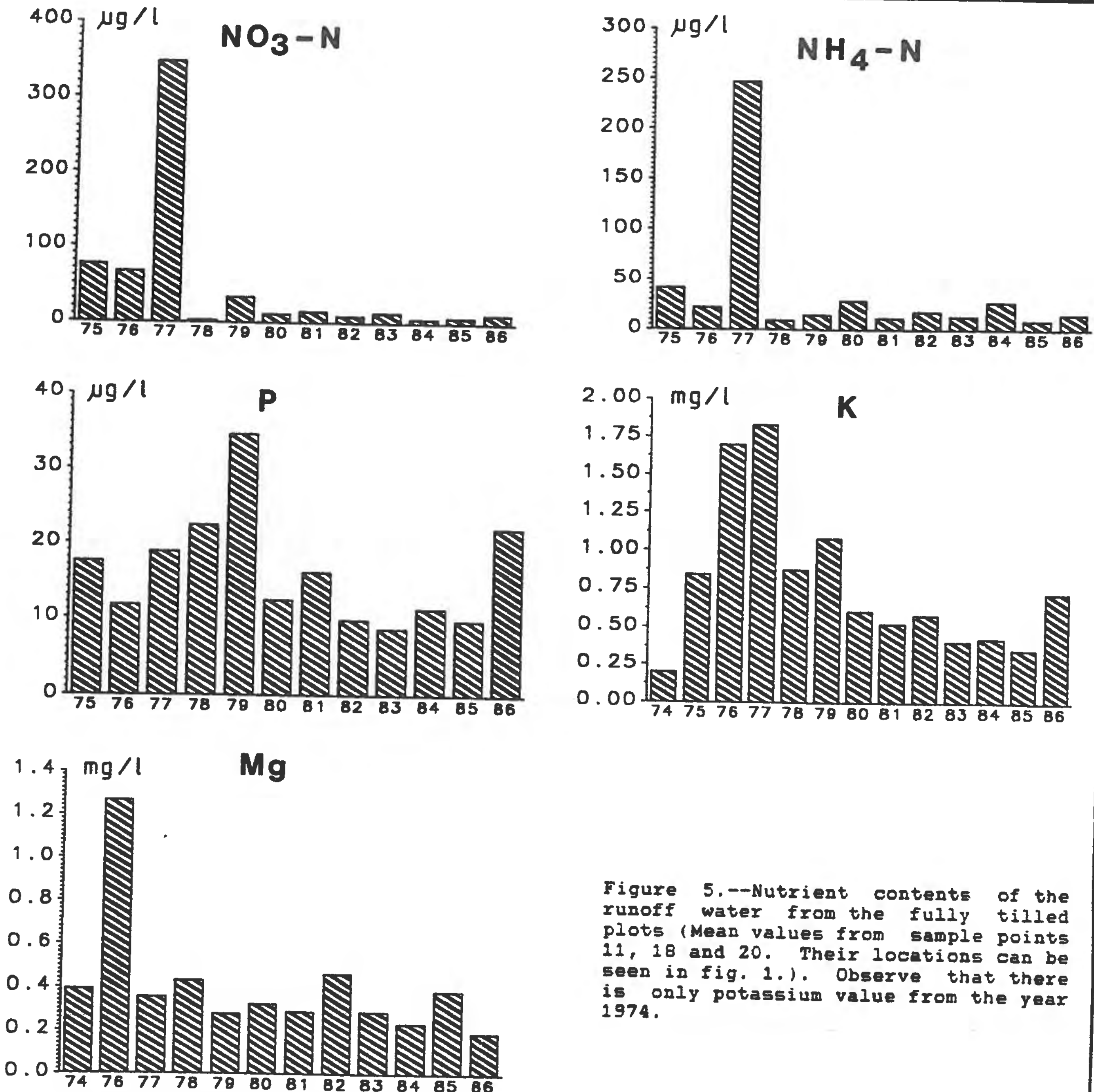

Figure 5.--Nutrient contents of the runoff water from the fully tilled plots (Mean values from sample points 11, 18 and 20. Their locations can be seen in fig. 1.). Observe that there is only potassium value from the year 1974.

travel along subsurface pathways and slowly seep from the soil into runoff water.

Evaporation and the transpiration of the plant cover have a significance to the formation of the runoff, as well as the texture and the structure of the soil. In fine soil, where the portion of clay is as a rule great, water does not filter quickly into ground water but fills the pores in the soil and soil moisture remains great. On this kind of places is also developed a thick layer of raw humus, which can store great quantities of water and also nutrients. The soil type of the experimental area is fine sandy till, which lets water through relatively slowly. Soil frost, too, which is formed in the clearcut and in the prepared areas of the experimental field (Kubin and Poikolainen 1982) has an effect on how water filters into the soil.

The chemical composition of runoff water depends greatly on the way in which the runoff water is born. There are more of several nutrients in throughfall than in free precipitation (Päivänen 1974) and when the snow melts the nutrients that have been accumulated into it fall into soil or directly into surface runoff.

The chemical weathering and the mineral composition of the soil have a decisive significance for the water that comes from inside the ground into surface runoff. In the research area 73 % of the bedrock was composed of granitic rocks, 6 % of quartzites and 21 % of basic rocks and schists (Kubin 1977). The great portion of the basic type of stones indicates relatively high productivity.

Besides the weathering of minerals, the nutrients that are released when organic matter decomposes, have a central significance in the runoff. The nutrients that get into soil water drift with water dissolved in it, and are bound to soil particles or plants take them up with their roots for constructing new organic matter. Positively reserved cations are usually bound to soil particles and many negatively reserved anions can form chemical combinations. This means that they are not leached easily, although e.g. clear increase in the content of some elements could be observed in this research.

There is plenty of nitrogen in organic matter and special consideration must be paid on it. When organic matter decomposes the compounds of nitrogen are released and positive ammonium nitrogen is formed. Ammonium nitrogen may get bound to the negative parts of soil particles and thus it has not been considered very liable for leaching (Tamm et. al. 1974). The results of this research show perhaps a little suprisingly that during the years after site preparation the contents of ammonium nitrogen in the runoff water also increase.

Released ammonium nitrogen may oxidize through nitrification to nitrite and nitrate. The only way in which nitrate nitrogen is bound in the biological cycle is by the uptake of vegetation. Nitrate nitrogen is also easily soluble and it is leached in a very short time. E.g. the preliminary phases of snow melting cause decrease in nitrate content in meltwater (Kubin and Lippo 1987).

In the situation which prevails after clear cutting vegetation binds very little nitrogen because of which its content in surface and in ground waters has been observed to increase (Tamm et. al. 1974, Wiklander 1974, Wiklander 1983). If the site quality is high, the leaching is greater than if the site quality is low. The results of this research, too, about the effect of clear cutting and site preparation on the leaching of nitrate are similar to those observed in Sweden about clear cutting. We, too, have measured high nitrate concentration in the raw humus under the tilts some years after ploughing and so a great amount of leaching is possible. In Nurmes-research that is going on in Finland has also been observed that clear cutting increases the leaching of nutrients (Ahtiainen and Kenttämies 1985).

For the part of site preparation the results presented now are new and no corresponding researches have been accomplished elsewhere. The amount of the leaching of nutrients and also its duration vary as for the element. In general lines we can state that leaching is greatest 2 - 3 years after site preparation, after which the values are near the level before preparation. It seems that potassium, a lot of which is also removed with throughfall (Päivänen 1974), is leached for a considerably long time compared e.g. with nitrate nitrogen. At a very early stage of decomposition after clear cutting a lot of potassium is also released from the needles (Kubin 1977). In addition to nitrate it is also worth noticing the quite strong leaching of ammonium nitrogen in the years after soil preparation.

The total significance of leaching for the nutrients of the regeneration area is not presented in this connection. That would require an accurate knowledge of precipitation and also of measurements of the quantity of the runoff. There are annual observations about the quantity of the runoff from the whole area and also of rain water but there are only a few measurements of the nutrients from it. The analyse of these results and of the observations that are not included in this study will be done later.

In conclusion there is reason to state that the undertaken treatments increase the leaching of nutrients but the duration of their peak values is relatively short. The amount of the loss of nutrients depends on the site and on the quantity of the runoff. When one considers the environmental effects and also the loss of nutrients of the site there is reason to pay more attention to what kind of areas are selected to site preparation and what kind of methods are used. It is also necessary to avoid conducting surface water into open waters.

Besides, we must emphasize the importance of ground vegetation. As the nutrient requirement of a stand is small when the trees are still seedlings, the ground vegetation grows luxuriant and binds nutrients to the biological cycle and thus prevents them from getting leached into both surface and ground waters.

ACKNOWLEDGEMENT

In the preliminary phases the laboratory analyses were participated besides me by several members of a group working in the Botanical Department of Oulu University. Similarly have several people from the Research Station of Muhos participated in the work in its different phases from 1979 onwards. The practical site preparations conserning the founding of the experimental field were performed by the owner of the area, Kajaani Oy, whose positive attitude has greatly contributed the study. I acknowledge my gratitude to all those who have taken part in the research.

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SITE PREPARATION, STOCK SELECTION AND WHITE SPRUCE SEEDLING PERFORMANCE IN WESTERN CANADA

R.G. McMinn, M. Grismer and L.J. Herring

ABSTRACT: Trial results are presented to indicate that appropriate site preparation and stock type selection can be significant factors for regeneration success in the boreal forests of northern Alberta and British Columbia where climatic and site differences are great over relatively short distances. Regeneration prescriptions should be site specific for optimum seedling performance.

INTRODUCTION

While increasing soil temperature is a universally important objective of site preparation for reforestation of northern forests, the forests of northern Alberta and British Columbia grow in a wide range of climates and sites. Consequently, site preparation and stock type prescriptions must be site specific to achieve optimum results. For example, soil moisture on some sites may be excessive and on others deficient; competing vegetation may be dense enough to smother seedlings, reduce light intensity and compete for moisture and nutrients or it may be inconsequential; and the presence of fine-textured soil may impose particular constraints on site preparation.

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Ecological Classifications developed in both provinces provide a framework for regeneration prescriptions (Corns and Annis 1986, McLeod and Meidinger 1985, Pojar et al 1984). This paper gives examples to show the benefits that can accrue from site preparation treatments specific to particular ecological conditions. Appropriate planting stock can also be an important ingredient of success with or without site preparation. Some of the trials reported have been ongoing long enough to indicate that the benefits of favorable regeneration practices extend beyond the establishment period.

SITE PREPARATION BY SCALPING

Removal of shading vegetation and surface organic matter (humus or L,F,H horizons) insulating the mineral soil from the heating effects of the sun increase soil temperature (table 1). Such increases are likely to be a significant factor benefitting seedling performance because even with site preparation, the temperature levels indicated as optimum by growth chamber experiments (Dobbs and

McMinn 1977) are only infrequently reached.

Table 1--Soil temperature 5cm below the soil surface during a warm July afternoon and vegetation cover during the second growing season following site preparation.

Treatment	Temperature °C	Vegetation cover %
Untreated	14	59
Scalping	20	22

Exposure of mineral soil and removal of shading vegetation by scalping off surface layers above medium-textured soil can provide a favorable seedling response for at least 10 years after planting (table 2).

Table 2--Performance of container grown white spruce 10 years following outplanting in a site with a sandy soil and dense competing vegetation.

Treatment	Survival %	Height cm	Volume[1] cm^3
Untreated	40a[2]	136a	370a
Scalping	89b	222b	1590b

1/Stem volume equals height times one third stem area at ground level.
2/Values in each column followed by a different letter differ significantly ($p=0.05$).

The increased root growth promoted by increased soil temperature more than compensates for the initial unavailability of the nutrients in the surface layers pushed aside by scalping to expose mineral soil. Where scalped patches are small or seedlings are planted toward the edge of bulldozer scarified strips, enhanced root growth resulting from increased soil temperature can relatively quickly enable seedlings to reach the nutrients of adjacent undisturbed soil.

Unlike medium-textured soils, fine-textured soils, which make up a significant proportion of the forest soils of northern Alberta and British Columbia, constitute a poor medium for the growth of planted seedlings following scalping. Inhibition of root extension in compact, fine-textured subsurface soil may result in roots being confined to the planting hole for an extended period. Without access to the nitrogen of surface layers seedlings become chlorotic and they may suffer moisture deficits when soils are dry.

Site preparation of fine-textured soils should allow seedlings immediate access to surface organic matter as well as exposing mineral soil (to increase soil temperature) and control competing vegetation. Favorable results have been obtained using mixing and inverting methods which provide a mineral soil surface above the inverted humus.

SITE PREPARATION BY MIXING

Mixing the surface organic matter with the underlying mineral soil results in a soil surface which is essentially mineral in characteristics as well as making the nutrients of upper layers immediately available to planted seedlings. Soil temperature is enhanced by the new mineral soil surface. When mixing is complete enough to control competing vegetation, planted seedling receive an initial benefit and a continued advantage compared with scalping and no treatment (table 3).

Table 3--Performance of 2+0 bare root white spruce 13 years following outplanting in a site with fine-textured soil and dense competing vegetation.

Treatment	Survival %	Height cm	Volume[1] cm^3
Untreated	75a[2]	297a	3120a
Scalping	87b	320b	3580b
Mixing	90b	403c	5830c

1/Stem volume equals height times one third stem area at ground level.
2/Values in each column followed by a different letter differ significantly ($p=0.05$).

High speed or repeated mixing controls competing vegetation. Incomplete, low speed mixing, however, may exacerbate the negative effects of competing vegetation because weeds also benefit from the availability of nutrients and from soil warming.

The high speed (300 rpm) of the Rotoclear has provided effective vegetation control in experimental plots without the use of herbicides, presumably by comminuting vegetation sufficiently to suppress resprouting. The Rotoclear, however, was developed for agricultural use and in its present form is rather cumbersome and expensive for forest operations. A scaled down version is reported to be under development.

The rotors of farm rotovators do not seem to turn fast enough to adequately comminute and control aggressively competitive vegetation unless repeated passes are made, an impractical procedure for forest use. High rotor speed, on the other hand, is likely to cause excessive implement wear.

Consequently, even though mixing can be a biologically effective method of retaining the fertility of upper soil horizons immediately available to planted seedlings, the constraints on mixing (high speed necessary for adequate vegetation control and excessive implement wear in stony ground) limit its usefulness as a method of forest site preparation.

SITE PREPARATION BY INVERTING

Planting spots consisting of an inverted layer of surface organic matter covered by mineral soil provide planted seedlings with the benefits of enhanced soil temperature (resulting from mineral soil exposure) and immediate access to the nitrogen of the inverted organic matter. Competing vegetation is also controlled if the mineral soil covering is deep enough. Both inverted humus mounds and plowing provide mineral soil covered inverted surface organic matter planting spots which can result in more favorable seedling performance than scalping fine-textured soils (tables 4 and 5).

Table 4--Performance of 2+0 bare root white spruce seedlings 5 years following outplanting in a site with relatively fine-textured soil and dense competing vegetation.

Treatment	Survival %	Height cm	Volume[1] cm^3
Untreated	64a[2]	45a	7a
Scalping	89b	45a	11b
Mound+ 2cm cap[3]	85b	71b	27c
Mound+ 6cm cap	92b	70b	30cd
Mound+12cm cap	88b	72b	32d

1/Stem volume equals height times one third stem area at ground level.

2/Values in each column followed be a different letter differ significantly (p=0.05).

3/Inverted humus mound with 2 cm depth of mineral soil capping.

Table 5--Performance of white spruce seedlings 2 years after outplanting in a fine-textured soil following plowing and no treatment.

Treatment	Stem volume[1] cm^3
Untreated	1.2a[2]
Plowing	2.7b

1/Stem volume equals height times one third stem area at ground level.

2/Values followed by a different letter differ significantly (p=0.05).

Inverted humus mounds are advantageous on wet sites because seedlings are in raised planting spots. However, where rainfall is low during the growing season, the mineral soil capping of mounds may dry out subjecting seedlings to moisture stress. Although deep mineral soil cappings may produce better results than shallow cappings (table 4), deep cappings may accentuate drying out problems. Deep planting has been found to alleviate the problem of cappings drying out. The roots of deep planted seedlings are in contact with the soil beneath the mound which, although cool, remains moist. Evaporation and transpiration losses from the soil beneath mounds is limited when competing vegetation is controlled by adequate depth of mineral soil capping. Deep planted seedlings can utilize the warm upper layers for root growth and nutrient uptake when they are moist and the moist lower layers to sustain adequate seedling moisture when the upper layers are dry.

The possible advantages of long rooted (23cm) container grown seedlings are being investigated. The use of long rooted seedlings should obviate the need and possible disadvantages of partially burying the foliage of seedlings with standard root lengths in order that roots reach the constant supply of moisture beneath mounds.

On dry sites, plowing, which places the inverted organic matter of the furrow slice directly onto mineral soil exposed by removal of the preceeding furrow slice, may provide more favorable moisture relations than inverted humus mounds. Inverted humus mounds have a double layer of organic matter because the inverted surface organic matter is placed on top of undisturbed surface organic matter. The single layer of organic matter above the mineral soil resulting from plowing is likely to be less disruptive of capillary recharge of moisture than the double layer of mounds. Transpiration of tree seedlings may also be less than on mounds because plowing provides a surface which is essentially flush with the general ground level.

The development of equipment for intermittentplowing or in situ inverted patches could be beneficial for the treatment of fine-textured soils in relatively dry climates.

SIZE AND CONDITION OF PLANTING STOCK

While it might seem economical to use the smallest planting stock that will survive, it is possible that improved performance from large stock may more than pay for the difference in initial cost. Trials with various sizes of container-grown stock planted in unprepared ground have shown that the largest stock had the best performance (table 6). If trends over the first 5 years continue, the large stock would reach stand closure and possibly harvestable size well before the small stock. Shortening rotation age should increase allowable cut and therefore provide immediate return on the higher cost of using large stock.

Table 6--Performance of white spruce seedlings grown in containers of various sizes 5 years after outplanting in an untreated, brushy, backlog site.

Treatment	Survival %	Height cm	Volume[2] cm^3
Small[1/]	70a[3]	43a	7a
Medium	82b	50b	10b
Large	89b	59c	16c

1/PSB 211 styroblocks with cavity volumes of 26cm^3 (2 in^3): medium size PSB 313 styroblocks with cavity volumes of 65cm^3 (4 in^3): large size PSB 415 styroblocks with cavity volumes of 130cm^3 (8 in^3).

2/Stem volume equals height times one third stem area at ground level.

Similar differences have been demonstrated with different stock sizes in prepared planting spots. Large stock planted in biologically favorable spots prepared by mixing grew better than small stock in mixed, scalped and unprepared planting spots (table 7). Definitive information should be sought to determine under what conditions a return on investment can be obtained with the use of large stock plus biologically superior site preparation. Under appropriate site conditions, large stock may compensate for lack of site preparation (table 8).

Table 7--Size at time of planting and performance of white spruce seedlings grown in large and small containers 10 years after outplanting in a moist, fertile site with fine-textured soil following mixing, blade scarification and no treatment.

At planting				
Stock type	Height cm	Mass Top g	Mass Root g	Mass Total g
Large[1]	15a[3]	1.6a	1.6a	3.2a
Small[2]	13b	1.0b	0.7b	1.7b

At 10 years			
Treatment	Survival %	Height cm	Volume[4] cm^3
Large			
Mixing	99a	279a	1817a
Untreated	96a	234b	1288b
Scalping	98a	211c	803c
Small			
Mixing	99a	235b	1077bc
Untreated	93a	204c	722cd
Scalping	97a	189c	515d

1/PSB 415: container stock grown in styroblocks with cavity volumes of 130 cm^3 (8 in^3).

2/PSB 211: container stock grown in styroblocks with cavity volumes of 26 cm^3 (2 in^3).

3/Values in each column followed by different letter differ significantly (p=0.05)

4/Stem volume equals height times one third stem area at ground level.

In the Boreal Zone near Dawson Creek, British Columbia, considerable losses have been experienced through winter damage. Affected seedlings turn red and lose all or part of their foliage as the new growing season begins. Severely affected seedlings die. Incidence of winter damage has been highest with 1+0 container-grown stock exposed to fluctuating winter temperatures by lack of snow cover. Naturally regenerated white spruce are unaffected and two seasons after outplanting planted stock withstands this kind of stress. This contrast suggests that differences in climatic adaptation may be involved.

Table 8--Size at time of planting and performance of white spruce seedlings grown in large and small containers 10 years after outplanting following blade scarification and no treatment.

At planting			
Stock size	Height cm	Diameter cm	Mass g
Large[1]	18.3a[3]	0.26a	2.0a
Small[2]	17.8b	0.23b	1.6b
At 10 years			
Stock/Treatment	Surv. %	Height cm	Vol.[4] cm^3
Small/Scalping	97a	156a	353a
Large/Untreated	95a	228b	1104b

1/PSB 313: container stock grown in styroblocks with cavity volumes of 65 cm^3 (4 in^3)

2/PSB 211: container stock grown in styroblocks with cavity volumes of 26 cm^3 (2 in^3)

3/Values in each column followed by different letters differ significantly ($p=0.05$)

4/Stem volume equals height times one third stem area at ground level.

In order that 1+0 container-grown stock reaches adequate size for outplanting, extended photoperiod may be used to extend the growth period. Even when the supplemental lighting is terminated in time to obtain budset and hardening off before seedlings are lifted, the use of extended photoperiod may interfere with the conditioning needed for seedlings to withstand fluctuating winter temperatures when unprotected by snow cover. Rowe (1964) suggests that environmental conditions during the previous season of growth can exert a strong influence on the expression of certain tree characteristics. Preliminary observations near Dawson Creek suggest that bareroot or two-year old container-grown stock which has not been subjected to artificial photoperiod extension is less susceptible to winter damage than 1+0 stock (Herring 1987). The importance of appropriately conditioning stock for regeneration success merits further investigation.

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SOME ASPECTS ON SITE PREPARATION AND NATURAL REGENERATION IN SWEDEN

Evert Jeansson

ABSTRACT: The first part of the paper deals with mechanical soil preparation for natural regeneration. The extent of natural regeneration and soil preparation in Sweden is reviewed and some principal aspects on the topic are discussed. In the second part a presentation is given of an experiment with natural regeneration and seeding in scarified patches of increasing age in five seed tree stands of different densities.

INTRODUCTION

The concept of site preparation for natural regeneration (NR) includes several silvicultural measures such as clearing of undesired growth, draining, prescribed burning with or without seed trees and mechanical or chemical site preparation. This paper only discusses mechanical site preparation or soil scarification. The two terms are used synonymously.

Scarification with natural regeneration has been subject to increasing interest in Swedish forestry. Introduction of new implements such as power driven disc trenchers has considerably improved the possibilities for effective soil treatment in seed tree stands. Hereby the prospects for successful application of NR-methods have increased. However, for a good result adaption to local edaphic and biotic conditions is essential. Some aspects on this theme are discussed in the first part of the paper.

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Natural regeneration is sometimes called in question on harsher areas and in higher elevations. An experiment has been established on lat. 54 deg. 55 min. N, altitude 365 to 470 m. with the aim to study natural regeneration on a relatively harsh site. In the trial NR is compared with seeding in scarified patches of different ages. Two plots are laid out in sparse seed tree stands and three plots have been established in denser, mature stands. The experiment and some of the results are presented in the second part of this paper.

PRESENT EXTENT OF SITE PREPARATION (SOIL SCARIFICATION) IN SWEDEN FOR ARTIFICIAL (AR) AND FOR NATURAL REGENERATION (NR).

In recent years the area of final fellings in Sweden has varied between 200,000 and 230,000 hectares, figure 1. The major part of this area is reforested by planting or by seeding. Natural regeneration is applied to 25 % or about 50,000 hectares. (Skogsstyrelsen 1986). According to figure 1, the area of seed tree stands amounts to about 15 % of the total regeneration area.

Final cuttings and reforestation measures

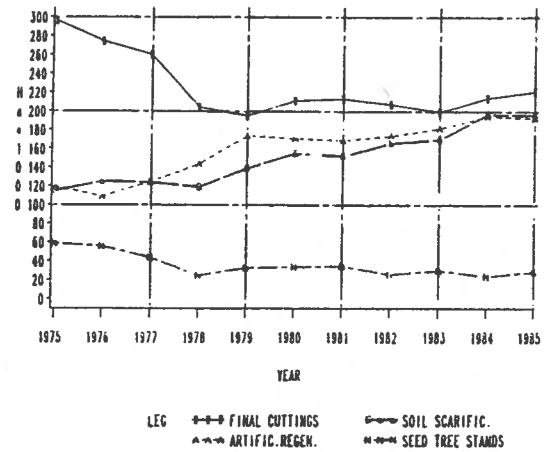


FIGURE 1: Final cuttings, soil scarification, artificial regenerations and seed tree stands in 1000:s of hectares. Consecutive 3-year means 1975–1985, according to the National Forest Survey

Percentage of scarification for AR and for NR

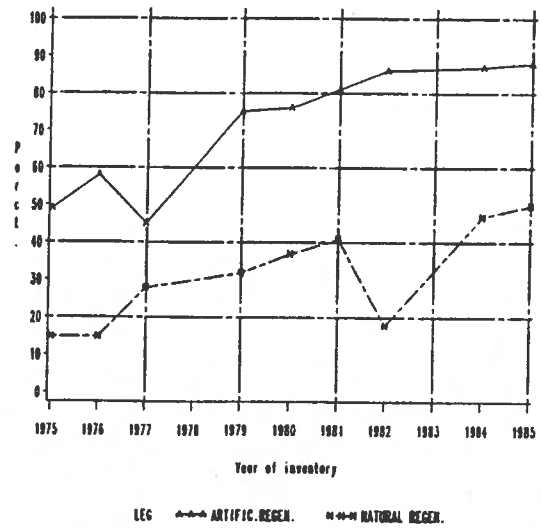


FIGURE 2: Soil scarification by artificial and by natural regeneration. Mean values for the whole country. National Board of Forestry 1986.

This figure refers to occurrence of seed tree stands established in the year previous to the inventory, whereas the value 25 % represents regenerations randomly sampled from objects subjected to final felling 5 years before the inventory (for Northern Sweden 7 years before).

Soil scarification has in later years been applied on over 80 % of the artificial and on about 50 % of the natural regenerations, figure 2. The proportion of scarification for planting and seeding has risen from about 50 % in 1975 to 88 % in 1985. For natural regeneration the increase is from 15 % to about 50 % during the same period.

From 1965 to the present there has also been a pronounced development in the type of machinery used for scarification. In the 60:s and early 70:s patch-scarifiers were in common use. This type of implement is still frequently used but they have been increasingly replaced by disc trenchers performing a more continous soil preparation and treating a higher percentage of the area. The development has also led to heavier equipment capable of a deeper and more thorough soil treatment.

PRINCIPAL ASPECTS ON MECHANICAL SITE PREPARATION FOR NATURAL REGENERATION.

1. Appropriate sites where mechanical site preparation can be advantageous.
2. Suitable time for a scarification operation.
3. Area coverage of and degree of disturbance of the ground by a scarification operation.
4. Aspects on dispersal and accumulation of seeds by wind and water, and predation of seeds by animals.
5. Climatic and edaphic considerations of scarification in a seed tree stand.
6. Scarification and utilization of understorey second growth.
7. Forest hygiene, risks for damaging or unstabilizing the seed trees.

1. APPROPRIATE SITES. In the case of natural regeneration soil scarification is in general advantageous on fresh and moist forest sites with relatively thick humus layer i.e. Myrtillus, Hylocomium and Polytrichum types. On drier sites such as pine heaths with bottom vegetation of lichens or lichen-Vaccinium vitis idaea, a scarification operation can be questionable. On these types of forest sites the success of natural regeneration is sometimes better outside scarified plots than inside. Wet sites and sites with frostheaving mineral soils require special considerations. The draining of the ground is here essential. A dense seed tree stand has a good draining effect, but ditching or other measures could be justified. Soil scarification on wet sites should prefer-

ably aim at disturbing or upturning of the humus layer without exposing the mineral soil. It is important to consider the air permeability of the soil, especially for fine textured and water retentive soils (Black 1968). Concerning the influence of altitude Teikmanis (1956) states: "The dependence on the altitude is obvious for natural regeneration but not as noticeable on scarified areas as on localities with no soil preparation."

2. SUITABLE TIME FOR A SCARIFICATION OPERATION. A general recommendation for the most suitable time of application of a site preparation treatment with natural regeneration is just before an expected good seedfall. This raises the question of good seed prognosis. A great deal of work has been carried out in this field (eg. Leikola et al. 1981, Leikola 1982). At best it should be possible to foresee a good seed crop about a year in advance.

However, the local conditions are crucial concerning the seedfall at a specific site. Before a final cut the seed production in a mature stand can be considerable. Following harvest of the old stand, the seed production drops considerably depending on the change to a new environment for the seed trees and often due to insect attacks. This is especially the case on more northern and harsher localities and with seed trees with small and elevated crowns. After some years the seed trees will recover and their seed production increases. Meanwhile, various vegetation invades the site including scarified patches. The patpatches or strips are most effective for germination and plant establishment during the first years. Their effectiveness declines fairly soon though, and after 5 to 6 years their quality is not much better than the surrounding forest ground (Hagner 1962). However, on harsher sites and in denser shelter tree stands the patches can be effective up to 10 years (Bergan 1981).

If recently established seedlings in scarified patches shall be able to effectively compete with existing understorey growth, the scarification ought to be performed as early as possible. Thus, it would be beneficial to scarify prior to final felling in order to take advantage of the good seed supply in mature stands as well as utilizing the seed dispersal at the logging operation (cf. Kinnunen 1985b). This could, however present difficulties with currently available site preparation equipment. Thus development of scarifiers capable of operation in denser stands is motivated.

In the case of an unsuccessful regeneration result, the scarification could be repeated after some years. Re-treatment should preferably be carried out in tracks or strips crossing the earlier tracks. Good results have been reported after such repeted treatment (Swedish National Forest Service pers. comm.)

3. AREA COVERAGE OF AND DEGREE OF DISTURBANCE OF THE GROUND BY A SCARIFICATION OPERATION. The proportion of scarified area and exposed mineral soil should be considered. In difficult terrain the technical accessability can set limitations. Concerning already established second growth some comments are presented below in section 6. Adaption of site preparation measures to varying edaphic conditions over an area should be considered. On drier sand- and gravel-dominated areas of lichen type it may not be advisable to scarify where losses of existing advanced growth could be high. Thicker raw humus layers mostly indicates that a site preparation treatement should have a high degree of coverage. If a special distribution pattern for the new regrowth is desired (e.g. row formation), such a distribution could be obtained by scarification in strips with desired spacing. Disc trenching in two directions with crossing tracks increases the area coverage.

The degree of disturbance by site preparation can vary considerably. A light treatment may be obtained by the logging operation. A patch scarifier gives a more intense treatment and even more so a disc trencher. Ploughing gives the highest impact on the forest ground. The principal aims of site preparation with natural regeneration is to create favourable mircrosites for seed germination and plant establishment, to alleviate competition for water and nutrients and to provide protection from predators and unfavourable weather conditions. Large open scarified patches or tracks with exposed mineral soil are less favourable in many cases as also are tracks with steep, exposed sides formed by disc trenching or by ploughing (cf Kinnunen 1982, Pohtila 1977, Yli-Vakkuri 1961). The risks for seed displacement and predation, surface desiccation, soil erosion and frost heaving are more pronounced here than with smaller patches and lighter soil treatment. Patch scarification is not to be recommended on moist or wet sites where the scarified depressions can fill with water for long periods. On these types of sites it may be desireable to affect the water table with drainage or a denser shelter tree stand. Scarification could preferably aim at a light disturbance or upturning of the humus layer, not exposing the mineral soil.

4. ASPECTS ON DISPERSAL AND ACCUMULATION OF SEEDS BY WIND AND WATER, AND PREDATION OF SEEDS BY ANIMALS. The success of natural regeneration depends primarily on

the availability of sufficient amounts of viable seeds that can germinate and develop on suitable growing spots. Seeds on the ground are exposed to many risks and usually only a low fraction of the initial amount will emerge into seedlings. Dispersal and accumulation of seeds by wind and water onto unsuitable growing places along with predation by birds and animals impairs seed germination and establishment. These factors should be considered in the design of soil preparation implements, planning of operations, and instruction of operators.

Predation by birds and rodents accounts for a large part of seed losses especially in the late winter and in the early spring (Bergsten 1985, Hansson 1975, Heikkilä 1977, Wiklund 1986). Rodent predation can be extreme during years of high population cycles. Exposure of seeds on snow-crusts or scarified patches with open mineral soil implies increased risk for predation.

Protected hideouts where the seeds are sheltered for predators, direct sunlight and waterlogging, are to be preferred when performing a scarification operation. At the Dept. of Silviculture, Umeå, experiments have been carried out involving microtopographies in scarified patches for reducing the risk of predation and improving the establishment conditions for germinating seeds (Bergman & Bergsten 1984).

5. CLIMATIC AND EDAPHIC CONSIDERATIONS OF SCARIFICATION IN A SEED TREE STAND. The climatic and edaphic conditions are different in a seed tree stand compared with those in an open clearcut area. Site preparation will modify the conditions in the topmost soil layers.

The main difference is that the climate in a seed tree stand is more moderate in several respects (Odin et al 1987). The temperature regime is more even and relatively milder and the wind velocity is lower. The interception of rain or snow in the tree crowns and the consumption of water and nutrients by the seed trees reduces the run-off and the leaching of nutrients. However, this also implies that less water and nutrients is available for new seedlings. This can be unfavourable at drier and poorer sites or in general under dry weather conditions. On a clearcut area the snowmelt can come one week or more earlier than in a dense stand. In a seed tree stand the conditions are intermediate. A sparse stand doesn't differ much from an open area. Yet the trees can reduce the surface run-off of meltwater partly by providing shade, thus reducing incoming radiation, and partly by consuming water themselves. The latter lowers the ground water table and increases the water storage capacity in the ground. On sites exposed to summer frosts partial shading by the seed trees can prevent solar radiation damage to the seedlings after a frost night (Hagner 1962, Lundmark et al 1987).

Germinating seedlings in a moss-, lichen-, or thick humus cover have difficulties to reach the mineral soil where the moisture conditions are more favourable. Scarifying will improve the situation and also for some time reduce the competition for water and nutrients. Effects of reduced root competition has been demonstrated by numerous investigations (Tatarinov 1971, Yli-Vakkuri 1961).

The drying out of the topmost soil layer in scarified areas will not be so accentuated in a seed or shelter tree stand as in open areas. The total amount of available water is yet less in a stand and the risk for water-logging of scarified patches is reduced compared with that on a regeneration area without trees.

In the autumn and winter problems with frost-heaving are common for young seedlings growing in certain types of fine-textured, mineral soils. The more even climatic conditions and the reduced amount of free water in the upper soil layers in a seed tree stand reduces the risk for frost-heaving, even on scarified areas, compared to the situation on a clear-cut area. Open exposure of mineral soil should though be avoided on this type of soils.

6. SCARIFICATION AND UTILIZATION OF UNDERSTOREY SECOND GROWTH. Older stands approaching harvest can contain considerable amounts of advanced growth seedlings. This regrowth has developed during a long period of time and is well established in the actual environment. Often these seedlings can contribute considerably to the stocking of the new stand. Utilization of understorey second growth of this kind entails several advantages, not the least giving a "flying start" to the new tree generation (Kalinichenko et al 1973). However, early, preparatory measures are mostly required for a good establishment of advanced second growth (Wretlind 1934, Olsson 1965). Conventional felling methods, together with site preparation, tend to eradicate most of the existing, understorey regeneration. The increase in light and radiation by the release to a more open environment, can be as disasterous to such seedlings, especially in the case of spruce. Kinnunen (1985) reports an example of the reduction in existing, understorey regeneration due to final felling and site preparation. From an initial stocking of 2900 seedlings per hectare before felling, 1800 stems capable of development remained after the cutting, out of which 1150 could be considered as main crop stems. After disc trenching 760

Table 1. Undamaged portion of existing understorey regrowth after felling according to the Kostroma-method compared with conventional felling. (After Chilimov, 1965, referred by Kalinichenko et al. 1973).

Plant hight	Felling meth.	Felling season	before, seedl. per ha	after felling, seedl. per ha	pct undam.pl.
< 1 m	Conv.	summer	6 284	1 646	26.2
-"-	-"-	winter	4 663	2 522	54.1
< 1 m	Kost.	summer	5 867	3 602	61.4
-"-	-"-	winter	6 129	4 801	78.5
> 1 m	Conv.	summer	3 986	849	21.3
-"-	-"-	winter	3 658	648	18.3
> 1 m	Kost.	summer	3 471	985	28.4
-"-	-"-	winter	4 582	1 154	25.2

seedlings were left, out of which 550 were main crop stems. Forest ploughing reduced the total number to 410 and the remaining main crop plants to 280 per ha. The total number of seedlings was thus reduced by 74 % for logging and disc trenching and by 86 % for logging followed by ploughing. However, tabel 1 (after Cilimov 1965, see Kalinichenko et al. 1973) indicates that a considerable amount of the existing understorey, advanced growth can be preserved by adaption of suitable logging methods.

This aspect is also valid for site preparation operations. Choosing of treatment routes as to leave seedlings growing between the patches or strips undamaged and avoid treatment of areas with clusters of advanced undergrowth are simple ways to preserve already established seedlings. The sooner in the regeneration period scarification is undertaken, the more of advanced undergrowth will be preserved. These seedlings are smaller by then and can better survive damage by the operation. Scarification before harvest of the old stand could be a way to level the competiting situation between advanced and new regrowth. Besides, this timing would take advantage of the better seed supply in the old stand and of the seeds dispersed by the logging operation.

7. FOREST HYGIENE, RISKS FOR DAMAGING OR UNSTABILIZING THE SEED TREES. Hygienic aspects are essential in every forest operation. By scarification in a seed tree stand a sufficiently large area around the trees has to be left untreated as not to damage the stems or the root systems and for stability reasons. Wounds to the roots are potential points of entry for pathogens.

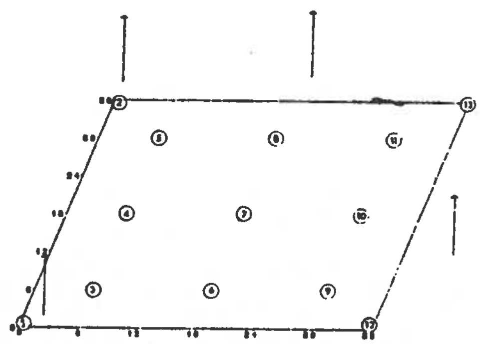
Damaged root systems increase the risk for stormfelling. Windthrown trees are the given brood material for bark beetles and pine-shoot borers. The multiplication of these insects in windthrown seed trees can be very high, up to 40,000 new individuals per stem have been reported. Numbers below 6,000 are more normal,though (Långström 1984). The prime target for the new insect generation is the annual shoots of the seed trees. Heavy attacs can destroy several years of seed production and growth. The release of the seed trees to a new stand environment by the harvest of the old stand also causes extra stress, especially in the case of spruce, increasing the sensitivity to insect attacks. Early removal of windthrown and unhealthy trees is essential for good forest hygiene and is also prescribed by the Swedish Act of Forestry. The reduction of hazards of this kind by careful forest management comes foremost though.

In a broader sense the concept of forest hygiene also includes efforts to avoid risks endangering forest seedlings and juvenile growth. One point here is the unfavourable clustering of seedlings often occurring in scarified patches. Such clusters favour the growth and spread of the snow blight fungus, Phacidium infestans for pine and Lohpophacidium hyperboreum for spruce. One of the few possible steps against a major drain of seedlings by these fungi is to create a more uniform distribution of the seedlings over the area, thus increasing the distance for the mycelium to cover before being able to infect the next individual (Björkman 1948). This implies that a scarification operation should be designed to create small microsites suitable for germination and seedling establishment and distributed as uniformly as possible over the regeneration area.

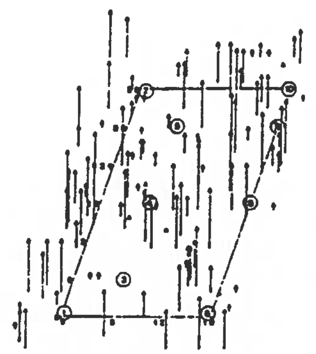
Good forest hygiene also involves a good care of the forest ground. In the case of site preparation this implies that the operation should be carried out as to avoid macro- and micro-erosion, leaching of nutrients, excessive drainage, exposure of frostheaving soils as well as other consequences endangering the site's long-term productivity (cf. Burschel et al 1977).

AN EXPERIMENT WITH NATURAL REGENERATION AND SEEDING COMBINED WITH SITE PREPARATION IN SEED TREE STANDS OF DIFFERENT DENSITIES.

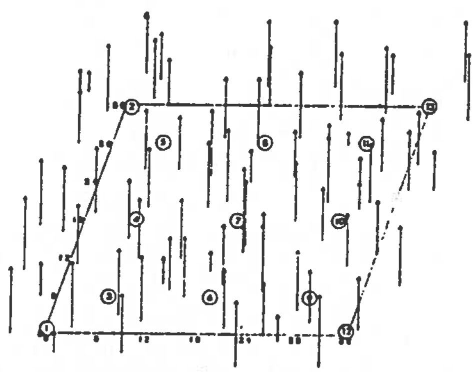
The aim of the experiment is to study the establishment and development of natural regeneration compared to seeding in scarified patches of different ages, located in seed tree stands of different densities.



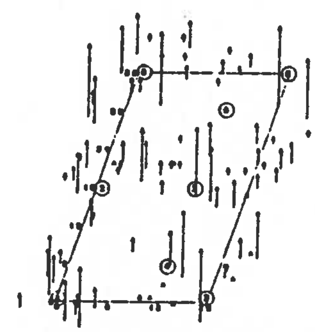
Plot A: Seed tree stand established in 1983 at an altitude of 365 m. 19 seed trees and 16 cub.m. per ha, 100 % pine.



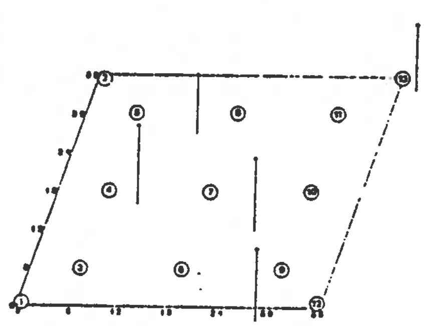
Plot D: Older pine stand at alt. 470 m. 840 trees (48 % pine 28 % spruce 24 % birch) and 151 cu.m. per ha (90 % pine 8 % spruce 2 % birch). No silvicultural operations carried out recently.



Plot B: Old mature stand at alt. 365 m. 355 trees (79 % pine 17 % spruce 4 % birch) and 174 cu.m. per ha (95 % pine 4 % spruce 1 % birch). The stand has been cleared of advanced second growth in the mid 70:s.



Plot E: Older uneven-aged mixed stand at alt. 440 m. 644 trees (15 % pine 67 % spruce 18 % birch) and 114 cu.m. per ha (83 % pine 16 % spruce 1 % birch). No silvicultural operations recently.



Plot C: Pine seed tree stand at alt. 420 m. 24 seed trees and 29 cub.m. per ha. 100 % pine. The stand was release cut and scarified by disc trenching in 1975-1976.

Figure 3. Distribution of seed trees and seed collecting baskets at plot A to E. The height of the lines representing the trees is proportional to the real size of the trees. Numbers in circles denote seed collecting baskets.

LOCALITY.

The trial was laid out in 1983 in five stands, A to E, on Joranliden National Forest, lat. 64 deg. 55 min. N, long. 17 deg. 30 min. E, on altitudes 365 to 470 m. above sea level, see figure 3. Two of the stands are seed tree stands, one (plot A) was established in 1983 and the other, (plot C) was release cut and then scarified by disc trenching in 1975-1976. Plot B was laid out in an older, mature, mixed stand that was cleared of second growth and bushes in the mid 1970:s. Plot D was set in an older pine stand on shallow soil on the bedrock and plot E in an uneven-aged, mixed stand dominated by spruce. On plot D and E no silvicultural measures have been carried out for a long period of time.

The soil on plot A is a medium sand. Plot B to E have soils of sandy-silty moraine, fairly rich in stones. The soil type is iron podsolic and a fresh Vacc. myrtillus vegetation type dominates on all the plots.

TREATMENTS.

18 different treatments have been or are intended to be carried out according to the following table:

1:	No scarific., natural regen. from 1983
2:	Scarif. spring 1983 nat.reg. from 1983
3:	- " - - " - seeding in spring 1983
4:	- " - - " - - " - 1984
5:	- " - - " - - " - 1985
6:	- " - - " - - " - 1986
7:	- " - - " - - " - 1987
8:	- " - - " - - " - 1988
9:	Scarif. spring 1984 nat.reg. from 1984
10:	- " - - " - seeding in spring 1984
11:	Scarif. spring 1985 nat.reg. from 1985
12:	- " - - " - seeding in spring 1985
13:	Scarif. spring 1986 nat.reg. from 1986
14:	- " - - " - seeding in spring 1986
15:	Scarif. spring 1987 nat.reg. from 1987
16:	- " - - " - seeding in spring 1987
17:	Scarif. spring 1988 nat.reg. from 1988
18:	- " - - " - seeding in spring 1988

EXPERIMENTAL DESIGN.

The treatments are laid out in a pattern with 18 rows and 18 patches per row at plot A to C. Plot D and E have only 9 rows each, corresponding to the first and second half of a full size plot.

The 18 treatments are distributed as single method cells in a latin square design with complete sub-blocks containing all 18 treatments within every group of three rows and six consecutive patches (row 1-3, patch 1-6, 7-12, 13-18 etc), figure 4.

The spacing between the patches is 2 metres and the total area per parcel is 36*36 metres (plot D and E: 18*36 metres respectively).

Scarifying: manual patch scarifying has been performed for actual treatments with a patch size of about 60*60 cm. The humus-layer has been removed and the mineral soil loosened to a depth of 5 to 10 cm.

At each plot seed collecting baskets with an area of 0.25 square metres have been set out according to figure 3.

TREATMENT NUMBER FOR ROW AND PATCH NUMBER

Patch number Nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
18	16	10	3	18	15	8	9	11	5	2	13	6	12	17	7	1	14	4
17	13	5	15	11	3	17	14	7	10	1	4	12	9	2	16	8	6	18
16	7	17	9	4	14	10	6	13	8	5	16	15	3	1	18	2	12	11
15	11	1	6	13	12	5	15	16	2	17	18	3	14	8	4	10	9	7
14	18	8	14	16	6	2	12	4	1	10	7	9	15	5	11	17	3	13
13	4	2	12	7	9	1	3	18	17	8	11	14	6	10	13	5	15	16
12	9	18	2	14	10	7	1	12	4	13	15	8	17	11	6	16	5	3
11	14	4	17	15	2	13	10	6	18	16	3	1	5	7	12	11	8	9
10	6	11	1	3	17	16	2	14	13	7	12	5	8	18	9	4	10	15
9	15	13	5	12	8	4	17	9	7	11	14	2	10	16	3	18	1	6
8	12	7	10	9	5	11	8	3	16	18	6	17	1	4	15	13	2	14
7	3	16	8	6	1	18	5	15	11	4	9	10	2	13	14	7	17	12
6	8	12	4	1	18	3	11	17	6	14	10	7	16	9	5	15	13	2
5	1	6	11	2	4	14	16	5	15	9	8	18	13	3	17	12	7	10
4	5	9	18	8	13	12	7	1	14	6	2	11	4	15	10	3	16	17
3	10	14	7	17	16	6	13	2	3	15	1	4	18	12	8	9	11	5
2	17	3	13	10	7	15	18	8	9	12	5	16	11	6	2	14	4	1
1	2	15	16	5	11	9	4	10	12	3	17	13	7	14	1	6	18	8

Row number

Figure 4. Layout of treatment 1 to 18 at plot A to C and D-E. The numbers denote treatment number.

Seeding of actual treatments has been performed with 20 pine seeds and 20 spruce seeds per patch, no seed covering.

Provenances of the seed used: Pine: seed from latitude 66 deg. 30 min, altitude 300 - 400 m. Spruce: seed from latitude 63 deg. 50 min, altitude 150 m. Empty and dead seeds have been removed from the seed lot.

The distribution of the pine seeds has been to the left half of each seeded patch and of the spruce seeds to the right half.

MEASUREMENTS.

The seed baskets have been collected twice a year, in the spring and in the autumn from the autumn 1983. The collected seeds have been analyzed at the seed laboratory, Dept. of Silviculture, and classified in embryo classes 4 - 0 by x-ray technique (Simak 1980). Inventories of number of seedlings for the different treatments have been carried out since 1984. Existing understorey advanced growth has been recorded in 1986.

RESULTS.

Seed Fall:

Each set of seed baskets gives an estimation of the seed fall at the actual plot during the sampling period. The bars in figure 5 represent the total seed fall calculated as mean values of number of seeds in undamaged baskets per plot and transformed to figures per hectare for the period in question, see Appendix I. Due to the relatively small sample of the seed fall some figures are quite approximate.

Figure 6 gives the corresponding information for seeds of embryo classes 3 and 4 i.e. seeds with good germinability. 1983 was a good seed year for spruce and the collected number of spruce seeds from

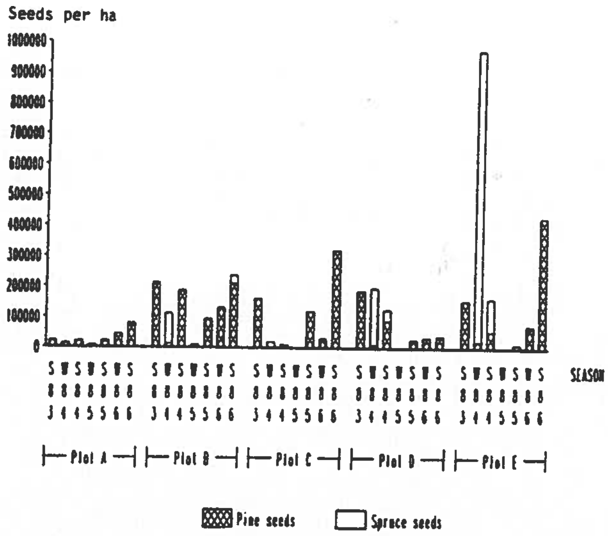


FIGURE 5. Recorded seed fall 1983-1986. Number of pine and spruce seeds per hectare for plot A to E.

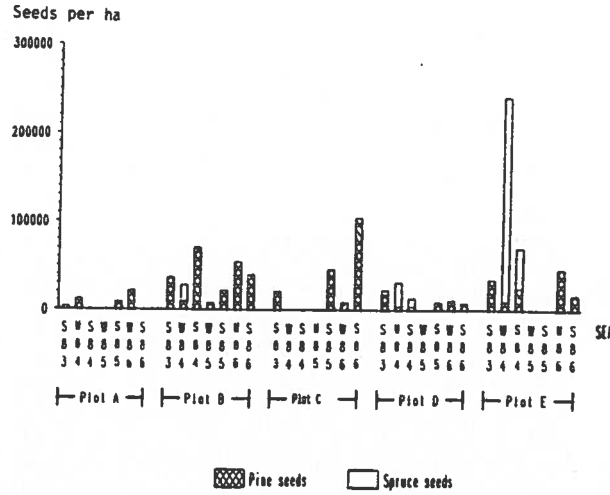


FIGURE 6. Number of pine and spruce seeds of embryo class 4 and 3 per hectare for plot A to E.

plot B, D and E corresponds to a seed fall of for B: 99,000 (19,000), D: 186,000 (27,000), and E: 950,000 (230,000) spruce seeds per hectare during the winter season 1983-84. Figures in parenthesis denote number of spruce seeds of embryo class 4 and 3. The good seed year has also resulted in a good record of seedlings in the scarified patches.

Seedling Establishment:
The inventory results from 1985 and 1986 are listed in Appendix II for natural regeneration and in Appendix III for seeded treatments. Figure 7 gives the percentages of patches with one or more seedlings per plot and treatment according to the inventory in spring 1986. The average number of seedlings per patch, within treatment, is shown in figure 8. For treatment 1, no scarification, the result is very poor. The seedlings occurring are to be referred to as advanced second growth, which will be discussed below.

Scarification And Natural Regenaration:
Treatment nr 2, 9 and 11, treatment nr 5 up to 1985 and nr 6-8 up to 1986. The establishment of seedlings has been gradual. In 1984, one year after scarification of treatm. 2-8, there were nearly no seedlings in the NR-patches. In 1985 the result was significiantly better with seedlings in 81 % of the patches scarified in 1983 at plot B, D and E (mean value per treatment). The good seed fall from 1983, recorded at these plots, has surely contributed to this result. At plot A and C the result had improved in 1985, but still only about 17 % of the patches, scarified in 1983, had seedlings.

In the spring of 1986 the result was still better. At plot B, D and E there were seedlings in about 90 % of the patches scarified in 1983. The mean number of seedlings per patch was 1.9 for plot B and D and 5.2 for plot E counted per treatment. For plot A and C, 60 resp. 30 % of the corresponding patches contained seedlings. The mean number of seedlings per plot was 0.9 and 1.8 respectively. For treatment 9, scarified in 1984, the result was good at plot B (89 %) and E (78 %) while A, C and D only had seedlings in 22 - 28 % of these patches. For treatment 11, scarified in 1985, only plot B and E had seedlings in the spring 1986 with 22 resp. 11 % of the patches inhabited.

Scarification And Seeding:
Seeded treatments: nr 3 in 1983, nr 4 and 10 in 1984, nr 5 and 12 in 1985. The establishment of seedlings has been good. 89 to 100 % of the patches at all the plots contained seedlings already one yea after seeding, figure 7. The mean number of seedlings per patch, out of 40 sown seeds, was 11.8 one year after, 13.5 two years after and 8.9 three years after seeding (only treatm. 3). The figures are corrected for naturally regenerated seedlings.

The number of seedlings in seeded patches has decreased with about 10 % from 1985 t(1986 (mean value for treatment 3, 4 and 1(at all plots, corrected for natural regene ration). The mortality for germinated seec lings is probably higher but it is compensated by new seedlings germinating one or two years after seeding.

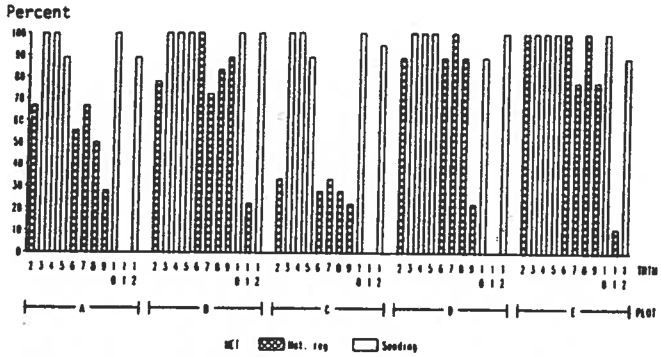


FIGURE 7. Percentages of patches with one or more seedlings in spring 1986 for treatment 2 to 12.

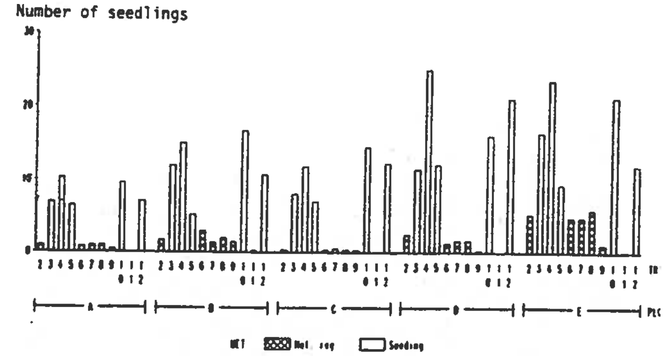


FIGURE 8. Mean number of seedlings per patch in spring 1986 for treatment 2 to 12.

Comparison between treatment 4 and 10 (seeding in 1984, inventory 1985) gives almost identical mean values for the number of seedlings. This indicates no difference between seedling establishment in one year old patches compared to newly prepared ones.

The corresponding comparison between treatment 5 and 12 (seeding 1985, inventory 1986) reveals that seeding in two year old patches only gives about 50 % of the number of seedlings achieved by seeding in newly prepared patches. (Mean value for all plots).

Understorey Advanced Second Growth:
The amount of understorey advanced second growth has been estimated by circular sample plots and calculated as means per hectare for plots A to E. The result is shown in figure 9.

Plot A, B and C were cleared of second growth in the mid 70:s. Presently existing advanced growth originates from leftovers from the clearing or from later established regrowth. At plot A the advanced second growth mainly consists of somewhat clustered thicket stage pine seedlings. Since the final cut of the previous stand they have been suffering from heavy attacks of snow blight. Also at plot B the pine seedlings dominate but the distribution is more scattered. Due to the dense overstorey their height growth is very limited. The attack of snowblight is not so pronounced here. The seedlings at plot C amount to 2,780 per ha, almost exclusively pine. They are mainly established in the tracks of mineral soil or upturned humus from the disc trenching carried out after the release of the seed trees in the mid 70:s. The mean height of the seedlings is only 16 cm.

Plot D and E have not been cleared of second growth earlier and the advanced seedlings here are older. At plot D the

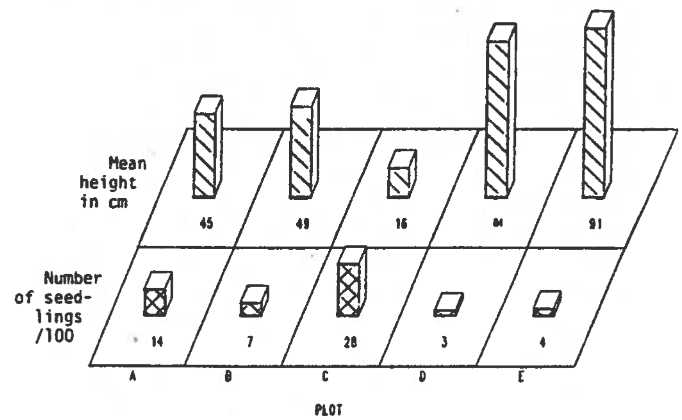


FIGURE 9. Mean number of advanced second growth coniferous seedlings in hundreds per hectare. Mean plant height in cm 1986.

undergrowth consists of about 50 % pine and 50 % spruce while there are only spruce seedlings at plot E. The mean heights of the seedlings, 84 and 91 cm respectively, indicate that they have been quite suppressed in these relatively dense stands.

DISCUSSION.
The collected amount of seeds of embryo-classes 4 and 3 indicates that the seed supply has been satisfactory at plot B, D and E. For spruce the high production of germinable seeds in good seed years (1983) is noticeable. The intervals between good seed years for spruce can be fairly long though, especially at higher altitudes and more northerly locations. The last but one good seed year for spruce in this area was in 1975. However, considerable amounts of viable spruce seeds have also been at hand between the seed years. The supply of pine seed is more evenly distributed throughout the years, but also for pine there is a marked periodicity depending on climatic conditions. The number of seed trees and

their condition is crucial for the local seed production. After a harvest operation or a period with major wind-throw the population of bark beetles and pine shoot borers increases. These insects impair the production of spruce and pine seeds considerably. This has been the case at plot A and C, though the poor result recorded also is a consequence of the few seed trees left on these plots.

The seedling establishment for treatments with natural regeneration reflects the seed fall. The necessity of soil scarification on the actual site type is evident. Between the scarified patches hardly any new seedlings at all have been found. The gradual growth of the number of seedlings in the scarified patches is also manifest throughout all the plots. The number of seedlings per patch has increased from 1.7 in 1985 to 2.0 in 1986 for treatments 2, 6, 7 and 8, or by about 20 %, calculated as a total mean.

For seeded patches the result is good on all the plots. A tendency toward better establishment is yet evident on plot B, D and E, i.e. in the denser stands. This is valid also when considering the higher number of naturally regenerated seedlings on these plots.

By seeding, the maximum number of seedlings occurs after one or two years. Thereafter the number starts to decline. For treatment 3 the mean number of seeded seedlings per patch has fallen from 10.6 to 8.9 or about 15 % from 1985 to 1986 (3 years after seeding). For treatment 4 and 10 the decrease has been about 8 % between 1 and 2 years after seeding. The figures are corrected for natural regeneration.

The density of the overstorey stand is decisive for the establishment and development of advanced second growth (cf. Kalinichenko et al 1973). At plot B, D and E the older stand is so dense that only scattered advanced seedlings have been able to survive, and their present development is very poor. The establishment of advanced understorey growth is very dependant on silvicultural measures carried out earlier. On plot A, B and C a clearing of second growth was performed in the mid 70:s. Some seedlings were evidently left over from this operation while some of the new advanced growth has developed later.

On plot A the number of older seedlings amounts to about 1400 stems per hectare. However, they are so clustered and impaired by snow blight that they their contribution to the new stand probably will be very limited.

The advanced regrowth on plot C derives from silvicultural measures for natural regeneration taken in the mid 70:s. After release cut of the seed trees, soil scarification was carried out by disc trenching. Up to now about 2,800 seedlings per ha have been established with a fairly good distribution over the area. They are mostly growing in or just beside the trencher tracks. The number of seedlings is still increasing and the prospect for a well-stocked pine stand in the future is good on this site.

CONCLUSIONS.

Some conclusions can be drawn already at this early stage from the findings presented above.

1. In mature stands the seed supply has been sufficient for natural regeneration even on this relatively harsh area.

2. Occurrence of both pine and spruce in a seed tree stand means that advantage can be taken of good seed years for both species (plot B, D and E).

3. The seed trees on plot A and C are to few for satisfactory seed supply. Windthrow and attacks of pine shoot borers have also impaired the seed production.

4. Scarified patches in denser stands fill faster with litter than is the case on more open ground. However, they are more effective for germination than untreated forest ground three years after scarification.

5. The establishment of naturally regenerated and seeded seedlings has been bette in the denser stands B, D and E compared to the more open stands A and C.

6. The establishment of a natural regeneration spans several years. Seeded patches reach their maximum stocking one or two years after the seeding, whereupon the number of seedlings starts to decline

7. Seeding in one year old scarified patches gave about the same result as seedir in newly prepared patches.

8. Seeding in two year old patches gave only 50 % of the emergence of seedlings in new patches.

9. The stand densities on plot B, D and E are too high for a successful establishment of advanced second growth in the actual area.

10. Existing advanced growth will probabl contribute, even if to a limited extent, to the stocking of the new stands on all the plots.

11. Several windthrows have occurred in the release cut seed tree stands (plot A and C) but not in the untouched stands B, D, and E.

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Appendix I. Collected seeds for plot A to E during summer and winter seasons 1983 to 1986 transformed to thousands of seeds per hectare.

Ebc. 4-3 = Seeds of embryo class 4 and 3.

	1983	1984		1985		1986	
Plot A:	Su.	Wi.	Su.	Wi.	Su.	Wi.	Su.
Total number:	21	12	20	7	22	44	80
-"- pine s:	21	12	20	7	19	44	73
-"- spr. s:	0	0	0	0	3	0	7
Ebc. 4-3 tot:	4	12	0	0	9	22	0
-"- pine s:	4	12	0	0	9	22	0
-"- spr. s:	0	0	0	0	0	0	0

Plot B:	Su.	Wi.	Su.	Wi.	Su.	Wi.	Su.
Total number:	212	111	188	8	95	131	237
-"- pine s:	212	12	182	8	95	131	210
-"- spr. s:	0	99	6	0	0	0	27
Ebc. 4-3 tot:	37	28	71	8	22	55	40
-"- pine s:	37	9	71	8	22	55	40
-"- spr. s:	0	19	0	0	0	0	0

Plot C:	Su.	Wi.	Su.	Wi.	Su.	Wi.	Su.
Total number:	160	18	10	0	120	31	320
-"- pine s:	160	0	10	0	120	31	320
-"- spr. s:	0	18	0	0	0	0	0
Ebc. 4-3 tot:	22	0	0	0	46	9	104
-"- pine s:	22	0	0	0	46	9	104
-"- spr. s:	0	0	0	0	0	0	0

Plot D:	Su.	Wi.	Su.	Wi.	Su.	Wi.	Su.
Total number:	187	195	124	0	27	34	40
-"- pine s:	182	9	89	0	27	34	40
-"- spr. s:	5	186	35	0	0	0	0
Ebc. 4-3 tot:	22	31	13	0	9	11	8
-"- pine s:	18	4	4	0	9	11	8
-"- spr. s:	4	27	9	0	0	0	0

	1983	1984		1985		1986	
Plot E:	Su.	Wi.	Su.	Wi.	Su.	Wi.	Su.
Total number:	154	970	160	0	13	73	429
-"- pine s:	154	20	55	0	13	73	429
-"- spr. s:	0	950	105	0	0	0	0
Ebc. 4-3 tot:	34	240	70	0	0	47	17
-"- pine s:	34	10	25	0	0	47	17
-"- spr. s:	0	230	45	0	0	0	0

Appendix II. Natural regeneration, seedling establishment, inventory results from 1985 and 1986.

TRTM = treatment number.
NPS = number of patches with one or more seedlings.
NPSPCT = percentage of patches with one or more seedlings.
MVS = Mean number of seedlings per patch.

PLOT	TRTM	Scar. year	Inventory 1985 NPS	NPSPCT	MVS	Inventory 1986 NPS	NPSPCT	MVS
A	2	1983	2	11	0.22	12	67	0.89
A	5	1983	3	17	0.67	Seeded 1985		
A	6	1983	3	17	0.17	10	56	0.72
A	7	1983	3	17	0.22	12	67	0.89
A	8	1983	2	11	0.17	9	50	0.94
A	9	1984	.	.	.	5	28	0.44
B	2	1983	12	67	1.17	14	78	1.67
B	5	1983	14	78	1.22	Seeded 1985		
B	6	1983	15	83	1.89	18	100	2.94
B	7	1983	7	39	0.56	13	72	1.28
B	8	1983	16	89	1.50	15	83	2.00
B	9	1984	9	50	0.67	16	89	1.39
B	11	1985	.	.	.	4	22	0.22
C	2	1983	3	17	0.17	6	33	0.33
C	5	1983	4	22	0.28	Seeded 1985		
C	6	1983	3	17	0.17	5	28	0.28
C	7	1983	4	22	0.33	6	33	0.50
C	8	1983	4	22	0.28	5	28	0.33
C	9	1984	1	6	0.06	4	22	0.28
D	2	1983	8	89	1.78	8	89	2.44
D	5	1983	4	44	0.44	Seeded 1985		
D	6	1983	7	78	0.89	8	89	1.22
D	7	1983	8	89	1.33	9	100	1.67
D	8	1983	8	89	1.78	8	89	1.67
D	9	1984	2	22	0.22	2	22	0.22
E	2	1983	9	100	4.56	9	100	5.22
E	5	1983	7	78	4.11	Seeded 1985		
E	6	1983	9	100	5.22	9	100	4.78
E	7	1983	8	89	4.89	7	78	4.78
E	8	1983	9	100	4.67	9	100	5.89
E	9	1984	7	78	1.11	7	78	1.00
E	11	1985	.	.	.	1	11	0.11

Appendix III. Seeded treatments, seedling establishment. Inventory results from 1985 and 1986.

TRTM = treatment number.
NPS = number of patches with one or more seedlings.
NPSPCT = percentage of patches with one or more seedlings.
MVS = Mean number of seedlings per patch.
* ---- * = values recorded before seeding.

PLOT	TRTM	SCAR	SEED	Inventory 1985 NPS	Inventory 1985 NPSPCT	Inventory 1985 MVS	Inventory 1986 NPS	Inventory 1986 NPSPCT	Inventory 1986 MVS
A	3	83	83	18	100	7.83	18	100	6.94
A	4	83	84	18	100	11.56	18	100	10.22
A	5	83	85	* 3	17	0.67 *	16	89	6.50
A	6	83	86	* 3	17	0.17 *	10	56	0.72 *
A	7	83	87	* 3	17	0.22 *	12	67	0.89 *
A	8	83	88	* 2	11	0.17 *	9	50	0.94 *
A	10	84	84	17	94	10.00	18	100	9.56
A	12	85	85	.	.	.	16	89	7.11
B	3	83	83	18	100	12.56	18	100	11.94
B	4	83	84	18	100	16.06	18	100	15.00
B	5	83	85	*14	78	1.22 *	18	100	5.17
B	6	83	86	*15	83	1.89 *	18	100	2.94 *
B	7	83	87	* 7	39	0.56 *	13	72	1.28 *
B	8	83	88	*16	89	1.50 *	15	83	2.00 *
B	10	84	84	18	100	16.89	18	100	16.67
B	12	85	85	.	.	.	18	100	10.67
C	3	83	83	18	100	8.44	18	100	8.11
C	4	83	84	18	100	10.94	18	100	11.78
C	5	83	85	* 4	22	0.28 *	16	89	7.00
C	6	83	86	* 3	17	0.17 *	5	28	0.28 *
C	7	83	87	* 4	22	0.33 *	6	33	0.50 *
C	8	83	88	* 4	22	0.28 *	5	28	0.33 *
C	10	84	84	18	100	15.28	18	100	14.44
C	12	85	85	.	.	.	17	94	12.22
D	3	83	83	9	100	12.56	9	100	11.44
D	4	83	84	9	100	25.22	9	100	24.89
D	5	83	85	* 4	44	0.44 *	9	100	12.00
D	6	83	86	* 7	78	0.89 *	8	89	1.22 *
D	7	83	87	* 8	89	1.33 *	9	100	1.67 *
D	8	83	88	* 8	89	1.78 *	8	89	1.67 *
D	10	84	84	8	89	18.00	8	89	16.00
D	12	85	85	.	.	.	9	100	21.00
E	3	83	83	9	100	19.89	9	100	16.33
E	4	83	84	9	100	23.78	9	100	23.44
E	5	83	85	* 7	78	4.11 *	9	100	9.33
E	6	83	86	* 9	100	5.22 *	9	100	4.78 *
E	7	83	87	* 8	89	4.89 *	7	78	4.78 *
E	8	83	88	* 9	100	4.67 *	9	100	5.89 *
E	10	84	84	9	100	25.22	9	100	21.22
E	12	85	85	.	.	.	8	89	11.89

SPOT SCARIFICATION IN A MOUNTAINOUS SCOTS PINE FOREST IN NORWAY

Preliminary Results

Sverre Skoklefald

ABSTRACT: Exposed mineral soil gave a good basis for germination and seedling survival in mountain forests of Scots pine of *Cladonia* type. However, there was little increase in height during the first years, especially in seed tree stands of high density.

INTRODUCTION

Norway, which is a typical mountainous country, has also large areas of forest where the operational conditions are difficult. In addition the content of stones and blocks is large and the soil depth often shallow. This is the main reason for the lack of mechanical soil scarification up to this time. However, in latter years interest for scarification has increased. For example, the yearly scarified area in Hedmark county, which has the best operational conditions in the country, has increased from about 300 hectares in 1975 to about 2300 hectares in 1986. This corresponds to nearly 20% of the yearly regeneration area.

A series of experiments has shown that mineral soil gives a better chance for germination and seedling establishment than intact vegetation, both by natural regeneration and by sowing. Of Norwegian scientists, Professor Mork was amongst the pioneers in silviculture. As early as 50 years ago he pointed out that at a latitude of 64°N, the temperature was far under the optimal for germination of spruce seeds (Mork 1933). By removing vegetation and humus the temperature in the germination layer increased up to 3.5°C in clear-cut areas. Mork also demonstrated the positive effect of raised temperature on germination rate and germination capacity. This was of vital importance, particularly for unripe seeds which needed a long time to germinate. Seedlings which germinated at low temperatures were small and underdeveloped in the autumn, and during the winter the seedling mortality was high.

During a later investigation (Mork 1946) it was ascertained that raw humus covered with dense heather (*Calluna vulgaris*) had a particularly strong heat-insulating effect. Compared with conditions under heather, one could by soil scarification raise the temperature of the soil at 1 cm depth by up to 8.7°C on a warm day. These temperature measurements were taken in Southeast Norway at about 700 meters above sea level.

Although different kinds of vegetation lower the temperature in the underlying layers, the temperature can, under certain circumstances, become very high when for example a coverage of moss or lichen dries out in hot and dry periods. Bjor

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(1971) found up to 63°C in the moss/lichen layer under a Scots pine stand in South-east Norway, while Bergan (1974) registered nearly 65°C in moss layer on a clear-cut area in North Norway (N.Lat. about 69°). In exposed mineral soil the temperature is never so high because mineral soil has a much greater heat conductivity and heat capacity than moss and humus layers.

Although exposure of mineral soil has a positive effect on temperature conditions in germination and seedling establishment, the effect on soil moisture is probably of even greater importance both for germination rate and germination capacity. At low levels of moisture both germination rate and germination capacity were greatly reduced, but also specially high humidity had a negative effect.

Periodical drying out of the seeds is probably the greatest impediment to germination (Bjor 1965). The seeds' moisture content varies greatly with weather conditions, but exposed mineral soil gives the best physical conditions for germination. Also seedling establishment is influenced positively by the more stable humidity in a mineral soil, so that seedling mortality as a result of drought seems to be considerably lower than in humus. Poor germination and establishment is to a great extent due to overoptimal and in some cases lethal temperatures combined with surface drying up (Bjor 1971).

Also several other Norwegian investigations describe the positive effects of scarification. Mork (1949) advised that the upper layer of mineral soil should be broken up. Hard-packed mineral soil, which is often found under a raw humus layer, was a poor seedbed, both because the seeds are easily found by birds and other seed-eating animals and because germinants have difficulty in establishing firm roots.

Besides producing a higher number of seedlings than other seedbeds, exposed mineral soil gives an increased rate of growth (Bergan 1981, Skoklefald 1965). Bergan's experiments also showed that it was possible to establish natural regeneration under an unexpected high number of shelter trees of Scots pine. The best results were obtained by releasing the seedlings already five years after germination, but scarification resulted in the seedlings living considerably longer than in intact vegetation.

The Norwegian investigations referred to here were all of experimental character, where all scarification was done by hand with clearly defined seedbeds. However, since mechanical scarification has become more usual, detailed projects have been started in order to evaluate the effect of scarification on sowing and natural regeneration (Solbraa 1987). Results up to now would seem to conclude that sowing gave a better regeneration than natural seed fall. There was little natural regeneration above 650 meters over sea level (South-east Norway), while sowing was fairly successful. The experiments were carried out in clear-cut areas and as expected, there was a marked decrease in natural regeneration in proportion to the distance from potential seed trees.

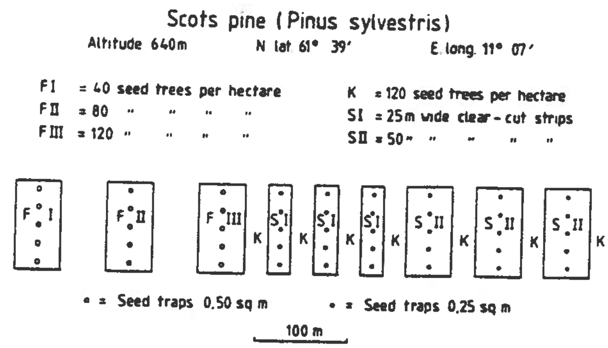

Figure 1. --Sketch over the experimental area.

MATERIAL AND METHODS

The experimental area lies in Hedmark county in South-east Norway (fig. 1). Before regeneration cutting the average standing volume was about 70 cubic meters per hectare, dominated by slow-growing *Pinus sylvestris* with sporadic growth of *Picea abies* and *Betula pubescens*. In the field layer *Calluna vulgaris* was dominant with elements of among others, *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Empetrum hermaphroditum* and *Deschampsia flexuosa*. The bottom layer was thickly covered with lichen and also a good deal of moss, particularly *Pleurozium schreberi*. The vegetation was characteristic of a dry and infertile forest type, mainly *Cladonia* type. Advance growth of Scots pine was scattered over the whole area. The zero-square percentage based on 4 sq.m sample circles (Braathe 1966) varied from about 40 to about 80. During the regeneration cutting in the winter of 1974, scattered spruce and birch were removed from both inside the effective experimental area and in the buffer zones. By the seed tree cutting 40, 80 and 120 trees per hectare respectively were left, separated by 50 m wide buffer zones. In addition, all trees were cut in a series of parallel 25 and 50 m wide strips. These were separated by 25 m wide zones with 120 trees per hectare to provide seed supply.

Cone production was determined by yearly countings by field-glasses of all cones visible from the south side of the tree-crowns. The seed fall was registered continuously by the use of seed traps with a collection area of respectively 0.50 and 0.25 sq.m as shown in figure 1. The sampling surface of the bigger traps was located about 1.6 meters above the ground and the smaller ones on the level of the ground surface. All seeds were X-ray analysed and classified according to the method described by Müller-Olsen and Simak (1954). Spot scarification was carried out manually 2, 4, 6, and 8 growing seasons after the regeneration cutting, both under the seed tree stands and on the clear-cut strips. The scarification was done with a sharp-edged spade and within a frame of 50x80 cm. This made spots of equal size, and as far as possible, also of equal quality. The ground vegetation including the humus layer, was removed without disturbing the mineral soil underneath. Every time 40 scarified spots were made in each of the seed tree stands and on each of the 50 m wide clear-cut strips. On the 25 m wide strips the number of scarified spots was reduced by half.

The dynamics of germination and seedling establishment was determined by marking the seedlings already in the year of germination with plastic sticks of different colours so that each annual series had its own colour. In that way it was possible to estimate the number of seedlings of different ages during the research period.

RESULTS

As expected the cone production varied greatly from one year to another (fig. 2). In the three first years after regeneration cutting, the observed amount of cone-setting was low, but maximum cone setting occurred already during the fourth year after felling. There is a clear tendency towards higher cone production in the most sparesely stocked seed tree stand - this was the case during the last half of the test period. Although the amount of cones varied greatly from tree to tree, nearly 100% of them produced cones in average to good seed years. Thus in 1977, 78, 80, 82, 83, and 85 between 95% and 100% of the seed trees had cones. The average number of cones per tree was respectively 131, 105 and 106 for FI, FII, and FIII.

It is characteristic of Scots pine that some seeds are shed almost every year also in the mountain forests, but the variation from year to year is very great (fig. 3). Seed year 1977 gave maximum seed fall but regeneration is on the whole affected by the many years of low seed production. The average yearly seed fall in the period 1974-85 was estimated at respectively 14, 23, and 35 seeds per sq.m. In the two seed tree stands with the greatest number of trees, opened cones were relatively often found in the seedbags and in such cases the number of seeds was usually considerably higher than in the other bags. The amount of seed is therefore somewhat overestimated where the number of trees is high.

In years with low summer temperatures the seeds were not morphologically fully developed. For example, of the total number of filled seeds, only respectively 35% and 53% had fully developed embryo (class IV) in the years 1977 and 1978. Monthly seed collections in seed tree stands showed that most of the seed was dispersed during May and June. In some years a relatively large amount of seed fell in July.

In the clear-cut strips (SI and SII) where the seed traps were only emptied each spring and autumn, the average yearly seed fall was 15 and 11 seeds per sq.m. As the traps are placed along the middle of the strips, the seed fall should be higher nearer the edge of the seed tree stands.

Detailed investigations of seed germination have not been done, but all 1-year old seedlings were registered and noted in the yearly records.

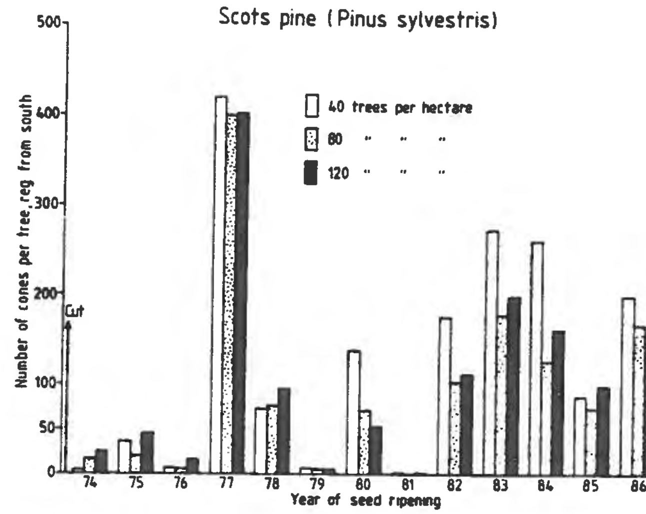

Figure 2. --Cone production in seed tree stands during the years 1974 - 1986.

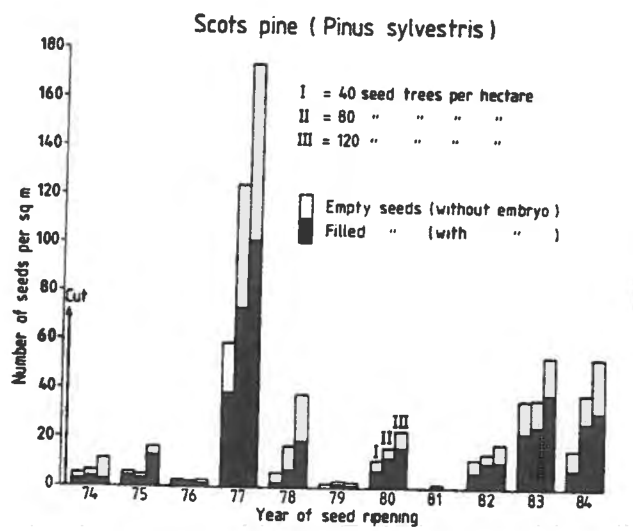

Figure 3. --Seed fall in seed tree stands during the years 1974 - 1986.

Figure 4 shows an example of the dynamics of regeneration in seed tree stands where spot scarification was carried out two growing seasons after seed tree cutting. The material covers seedlings germinated in the period 1976-84. Even though the seed fall during the investigation period was usually modest, some new seedlings were found almost every year, and seedling mortality was low. There is no great difference between seed tree stands of varying density as regards the patterns of regeneration, but in relation to the amount of seed recorded, the result has been best in the seed tree stand of lowest density. The seed fall in the two seed tree stands with most trees has probably been overestimated, while the seed fall in the most sparesely stocked may have been underestimated. Even though broad buffer-zones were used in this

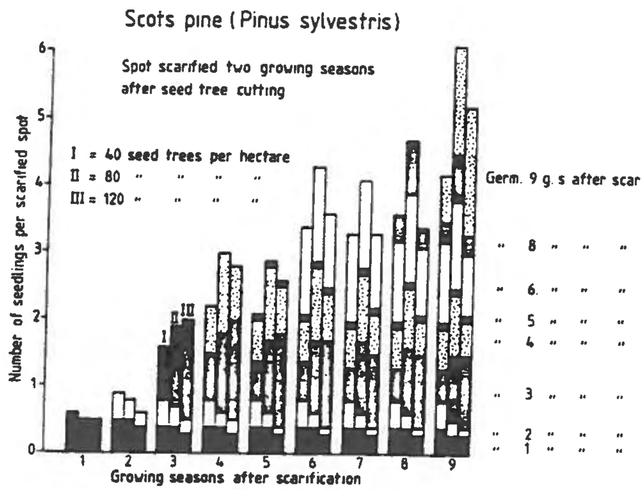

Figure 4. --Seedling population composition 1-9 growing seasons after scarification.

experiment, one must reckon with a certain amount of border infiltration in the amount of seed dispersal.

On the whole the results indicate that spot scarification on dry sites stocked with pine creates good conditions for germination and seedling establishment through several years, both with relatively high and low numbers of seed trees.

Table 1 gives a general view over the regeneration situation 11 growing seasons after the regeneration cutting. Scarification carried out in 1977, immediately before the best seed year of the experimental period, gave also the best result. There was on the other hand no great difference between seed tree stands of different densities (FI-FIII). The result was poorest on the 50 m wide clear-cut strips, but even though the number of seedlings was low, 75% or more of the scarified spots had one or more seedlings. Results would seem to indicate that seed fall has been quite evenly distributed and that there has been little variation in quality between scarified spots.

Registration of the tallest seedling in each scarified spot, carried out 10 growing seasons after regeneration cutting, showed that the seedlings had grown very slowly. As an example, for seedlings germinated in 1978 the average height was only 3 cm in seed tree stands with 80-120 seed trees per hectare, against 6 cm where 40 trees were left. On the 25 m and 50 m wide clear-cut strips the average height was 13 and 10 cm. The seedlings were 6 years at the time of registration. The results show that even though scarification gives a relatively high number of seedlings, also in dense seed tree stands on poor sites, the seedlings cannot develope as long as the seed trees are maintained.

Registration of natural regeneration in intact vegetation six years after regeneration cutting, showed that the number of plants had decreased somewhat, both in seed tree stands and on

Table 1 - - Total number of seedlings per scarified spot (N) and percentage of spots with one or more seedlings (P) 1984.

Scarified Year	F I		F II		F III		S I		S II	
	N	P	N	P	N	P	N	P	N	P
1975	4.0	88	6.1	98	5.1	83	3.4	92	2.2	79
1977	7.4	100	5.7	100	7.9	98	4.8	95	3.0	90
1979	5.8	93	4.1	93	3.8	85	2.3	75	1.7	75
1981	5.2	98	5.8	100	4.5	95	3.1	95	2.2	85

1/ Symbols F I, F II etc. see Figure 1.

clear-cut strips. Few new plants were found, and the zero-square percentage had increased (variation from 65-85).

CONCLUDING REMARKS

The preliminary results presented here, indicate that spot scarification in Scots pine forests at high altitudes can utilize the modest amount of seed very well. Some seedlings appear nearly every year and seedling mortality has been low up to now, probably particularly because the competition with other vegetation is so negligible on these dry and infertile sites. In order that seedlings may develope satisfactory, the seed tree stands with a low number of trees should be used, - if not, the seed trees must be removed after a relatively short time. Even in clear-cut areas the seedlings' height increment is very slow in the first phase, probably mainly on account of low summer temperature and poor nourishment. It will therefore take several years for the seedlings to grow over the average depth of snow.

In mountain forests in South-east Norway the plants of Scots pine are often exposed to heavy attacks of fungus infections. Before the plants grow over the snowcover the problems are particularly caused by *Phacidium infestans*. During these experiments attacks of *Phacidium infestans* were observed as well, especially on the clear-cut strips where the plants were tallest.

The *Cladonia* type has as a rule a considerable amount of advance growth, and in the lowlands there are seldom any problems in obtaining successful natural regeneration without any soil preparation. However, in higher altitudes where the seed supply is low and the plants partly are severely damaged by *Phacidium infestans* and other fungi, there are often great problems in getting satisfactory results. The mature stands, dominated by Scots pine, are as a rule sparesely stocked, and during a long period plants of extremely varying age and height have been established. In some of these cases the advance growth may be a fairly good basis for a new forest generation, but usually the regeneration is rather scattered. By eventual mechanized scarification a great part of the advance growth is probably destroyed and the regeneration period may be long, particularly on account of the seedlings' weak growth in the first years of their life.

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TECHNIQUES AND TECHNOLOGIES OF USING CONTAINERIZED PLANTING STOCK ON CLEARANT AREAS WITH WATERLOGGED SOIL IN THE USSR NORTHWEST

D.V. Ogievsky

ABSTRACT: Various machines and mechanisms are considered which provide transportation of the containerized planting stock (CPS) to the forest culture areas and planting into waterlogged soil. The peculiarities of the area and soil preparation are characterized in case of a cultivation of clearant areas in various growing conditions. Techniques and technologies of using CPS are proposed as well as their differentiation according to areas with different soil moisture content, including the cases of discrete and continuous soil cultivation. The prospects of using CPS in the USSR and mechanizations of planting cultures with the use of CPS in the USSR are described.

Key words: containerized planting stock(CPS), clearant areas, waterlogged soils, forest cultures, mechanization of planting.

INTRODUCTION

The problems of production and using the CPS (Maslakov et al., 1981) have been under investigation at the Leningrad Forestry Research Institute for a long time. At present many aspects of technology of forest cultures creation have been developed; various forest planting machines and mechanisms have been designed.

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Considering the designs of mechanisms and proposed technologies it is essential to emphasize that in general the problem of mechanization is still at the stage of experiments in many countries, the work on the modification of mechanisms is very intensive, therefore at present it is hardly possible to compute particular technical and economic characteristics of technologies for forest cultures creation with the CPS use, i.e. most of the figures below will be approximate. Nevertheless, the information available is quite sufficient to detect the main trends in the CPS use on clearant areas with water-logged soils in the USSR Northwest.

Firstly, the machines and mechanisms operating within the technological schemes of forest culture creation under the above conditions will be described.

The CPS from greenhouses and nurseries is transported to the forest-culture areas by a special mechanism UPS-4000A mounted on a truck ZIL-131 of a high cross-country capability.

A loading device and a renovable frame are mounted on the truck to place six pallets in 3 decks one on another. The UPS-4000A capacity is up to 4,000 seedlings of "BRIKET" (the substrate lump volume being of 400 cm^3).

In case of necessity one or two trailers with mounted UPS-4000A mechanisms may be attached to the ZIL-131 truck.

In this case the truck carries up to 12,000 of "BRIKET" seedlings.

Except UPS-4000A mechanism, a container truck ONK-28.8 is widelt applied in the USSR forestry; this container truck has been designed at the "Silava" Scientific and Production Association (Broks, 1984). It is based on the KamAZ truck. In spite of two container trucks available, one of which is of a high cross-country capability, we do not think that the problem of the CPS transportation to the forest-culture areas is solved. A safe CPS delivery to the specified area along the roads in the USSR taiga zone require design of transport means on the tractor basis.

CPS PLANTING

The CPS planting is the second operation after transportation; it greatly affects the technical and economic characteristics of technologies of the CPS use in the forest-culture production. Specific CPS features (big mass and dimensions, possibility of planting for a long time period, etc.) result in the fact that in some cases the CPS use technology is not routine, for which new means of mechanization are developed, etc. In general, foreign specialists (Stjernberg, 1985), using small-sized CPS, consider that the growing of forest cultures with the manual CPS planting would prevail in the foreseeable future since no mechanism is able to select the best microconditions for planting as it can be done by man. In this case the mechanized CPS planting would be the second less wide-spread method of forest-culture growing. These considerations are valid for those countries where population density is usually high, woodland areas are not very large, clearant areas are not vast and man power is available. In our opinion, the manual CPS planting won't be perspective in the USSR since the forestry conditions here greatly differ from those in the majority of developed capitalist countries. Only total multi-purpose mechanization and automatization of the production processes of forest-culture-growing with the use of CPS may be perspective in the forestry development of the USSR.

Let us describe forest planting machines and mechanisms used for CPS planting in greater detail (Table 1).

Table 1. Characteristics of Forest-Planting Machines and Soil-Cultivating Mechanisms Used for CPS Planting.

Indices	Mechanisms			
	Forest-planting machine on TB-1 base	SL-2**	SAB-1***	ORM-1.5
1	2	3	4	5
Type of interaction between soil cultivation mechanism & soil	point	continuous furrows	continuous furrows	point
Type of machine moving on clearant area	with stops	without stops	without stops	without stops
Simultaneous soil scarification	+	-	-	+
Simultaneous application of fertilizers	+	-	-	-
Simultaneous application of herbicides or insecticides	+	-	-	-
Number of rows of planted seedlings	1*	2	1	-
Type of planting material applied	CPS	CPS, BR seeds	CPS	-
Number of operators (tractor driver incl.)	1	3	2	1
Tractor trade mark & capacity	LHT-55, TB-1 58.8kWt	LHT-55 58.8kWt	LHT-55 58.8kWt	LHT-55 58.8kWt
System of CPS delivery to planting site	Automatic	Manual via delivery mech.	Automatic	Manual
Stage of development	EM	FSP	FSP	FSP
Cost, in roubles (without tractor)	about 3,000	about 4,000	about 5,000	about 4,000

Legend:
BR - bare-rooted planting stock;
EM - experimental model;
FSP - full-scale production;
* - surface planting (without rows);
** - Use of CPS probably after slight modification;
*** - operates in drained conditions

Forest-Planting Machine (LA) on TB-1 Tractor Basis (Experimental Model)

The machine is to operate on oxalis heath, in complex, bilbery forest conditions on ungrubbed areas with felling debris removed, on burns, wastelands, open woodlands, etc., after preliminary drainage. It provides an even CPS planting no less than 2,500 pieces per 1 hectare on the forest-culture area with up to 800 stumps per 1 hectare; in case of more stumps the planting density is no less than 2,000 pieces per 1 ha.

The forest planting machine on the basis of TB-1 tractor is supplied with a hydromanipulator and a pump station. The tractor is supplied with a technological equipment consisting of the main components: frame, plow, casing with soil chamber, planting device, device to apply fertilizers, device to apply herbicides, platform with a load lift, hydraulic motor, mechanism for stable position, base and drives.

The forest-planting machine moves over the forest-culture area with stops; during these stops microhills are formed with a simultaneous planting of seedlings and application of fertilizers and herbicides. The width of the cultivated stripe is a double maximum overhang of the hydromanipulator arm.

The working cycle starts from a lift of the planting section at a certain height above soil. The tiller drive is switched on, providing its maximum rotation and the tiller is easily dropped onto the soil. When tilling is started the soil mixture is thrown away to the soil chamber where microhills are formed. At the specified time moment the drive of the planting device pusher is switched on.

The forest-planting mechanisms are operated by a tractor driver in the TB-1 cabin.

When microhills are formed, the briquetted seedlings are placed, fertilizers are applied and the soil surface is treated by herbicides, the planting section is raised above soil and moved to the site of the next microhill formation where the cycles is repeated. The site of the next microhill formation is visually determined by the tractor driver with the account of stump number, stones, slash and natural forest regeneration. When planting over an arc of the maximum radius (the maximum overhang of the manipulator arm) is over, the planting section is moved to the arc of a lesserdiameter, moreover the space between the formed microhills is selected proceeding from the requirements of provision an evenly distributed planting over area and maximum conservation of the natural undergrowth.

SL-2 Forest Planter-Sower

The forest planter-sower SL-2 (mentioned below as planter) with accessory section for planting and sowing may be based for CPS planting after modification. The planter provides the forest cultures growing on the plain terrain on microhills (layers) along drained ditches made on grubbed stripes with soils of various mechanical composition: on felling areas with temporary waterlogged soils, on felling areas with permanently waterlogged peats yp to 20 cm deep; on drained swamps and excavated peatlands. According to the operation principle and design the SL-2 planter may be related to the machines of the first generation when the furrow opener is in the constan contact with soil. The supply of the planter with a special device to cover roots with an active drive attached makes the planter much more efficient, it provides the increase of annual load by using CPS more than thirty, and annual yield - almost twice: 30 shifts - to plant seedlings and saplings with bare roots and 70 shifts - to plant CPS.

The planter is combined with tractors with tractive force of 30 kN and more with a hanging-on attachment on the back (LHT-55, LHT-100, T-130BG-3, DT-75B and LHT-100B). The planter consists of the following main parts: a trailer and two planting sections (left and right).

About 500 pieces of CPS may be placed on every section after modification. The major portion of the CPS is placed in the LHT-55 tractor body. When the forest planting unit starts motion, the tractor moves over the furrow while the central wheel of the planter trailer rolls along the furrow bottom. The planting sections fixed at the specified width of the row-spacing, touch the soil and move along the furrows driven by the trailer. The spherical discs of openers make half-open planting furrows with the walls at the angle of 70-80°. Depending on the type of the planting stock the furrows on the top may be 5-18 cm wide.

The planter may be applied for a single-row case on ungrubbed clearant areas with removed felling debris and up to 600 stumps per 1 ha left. In case of more stumps the planter is applied along stripes with sawn stumps. Its efficiency will be no less than 1 ha per a shift. When the CPS is used the SL-2 efficiency will be lower if compared with the use of usual seedlings. This is explained by great technological time losses for the CPS treatment since the CPS is not technological from the viewpoint of size, mass and handling. An increase of the planter efficiency per a shift is possible due to a decrease of the volume of the soil lump covering the roots which will reduce time losses for the CPS treatment and will enlarge the CPS amount on the forest planting machine.

The use of the SL-2 planter is rather labour-taking (5 workers). A decrease of the CPS dimensions and mass as well as a high-quality planting will reduce the number of workers and will provide an automatization of the CPS delivery.

ORM-1.5 Mechanism for Microhills Preparation

At present various types of plows are applied to make microhills (layers) (PL-2-50, PKNL-500A, PSh-1, etc.), but they operate on open clear areas. One of the ways to increase the forest regeneration efficiency is to eliminate costly and labourous work on stump pulling, i.e. to cultivate ungrubbed felling areas. Therefore, a rotor mechanism has been designed at the Leningrad Forestry Research Institute, which is intended to make point microhills for planting of coniferous saplings and seedlings in containers and with bare roots and to treat soil for natural soil regeneration. The mechanism should be applied on new clearant areas with drained and temporary waterlogged and mineral soils with up to 1100 stumps per 1 ha.

The operation principle of the mechanism is based on the use of passively rotating 4-blade rotor with its periodic brake to make the hole deeper and to reduce the mass.

The mechanism is assembled with the tractors of traction class 3 and higher (LHT-55, LHT-100). It consists of a frame, a rotor and two brakes.

The rotor mechanism operation on the ungrubbed clearant area is as follows. When the tractor with the hanging-on attachment moves over the clearant area, the rotor rolls on the soil surface and the rotor blades alternately penetrate into soil which is accompanied by a periodic operation of brakes. Due to the use of a connecting mechanism the cam makes four revolutions during one rotation of the rotor. When the cutting blade penetrates into soil, the cam pushes the lever and the brakes are applied to stop the rotor. This produces an extra resistance moment on the rotor shaft and the blade cuts the soil. The brakes act during the cam-lever interaction which corresponds to the rotor turn at 65-70°. During this time the blade goes deep into soil with the soil on the blade surface. Then the brakes operation is over and the blade turns the soil layer accumulated on the blade surface onto the soil surface and puts it next to the hole produced. Moreover, when the rotor rolls over the formed microhill, the turning blade presses the microhill to the surface of the uncultivated soil.

When one of the blades comes into a contact with an obstacle which cannot be overcome (stump, stone, etc.), the microhill is not formed and the rotor overcomes the obstacle by rolling over it. The mechanism operates quite reliably, practically without damage.

In case of ungrubbed clearant areas the rotor mechanism may produce about 70 % of microhills (from the total number of efforts) suitable for planting. A subsequent plantation into the formed microhills requires a preparation of the planting site, which is a labour-taking and low-effective procedure if done manually.

Trends in Forest-Planting Technique Development

The analysis of the forest-planting technique development in various countries makes it possible to separate the main stages in the design of the forest-planting machines (Stjernberg, 1985), which may be classified according to the mode of moving along the clearant area as follows:

- I generation - forest-planting machines of continuous motion and furrow making;
- II generation - forest-planting machines of continuous motion and pediodic furrow making;
- III generation - forest-planting machines for point planting:
  - (a) continuous motion along the clearant area;
  - (b) discrete motion along the clearant area.

The forest-planting machines of the Ist generation (design was started during 1920-1930's) were characterised by a permanent contact of the soil-cultivating mechanism with soil during operation (the priciple of continuous furrows). These machines are widely applied in the world at present. They require a careful soil cultivation before planting. The forest-planting machines of the IInd and IIIrd generations are characterised by a short-time contact of the soil-cultivating mechanism with soil (the principle of interrupted furrows) or by a point contact (when soil is cultivated at a point while the soil-cultivation mechanism at the moment of operation is motionless relative to the soil surface). The first forest-planting machine of the IInd generation appeared in 1965 only. It manifested much better results when operating in difficult conditions (on areas with numerous obstacles) if compared with the Ist generation machines. This is the reason that late in 1970's a development of more perspective machines of point operation was initiated. All foreign forest-planting machines of the IIIrd generation are based on the tractors of "Forwarder" type; the operation of these machines is controlled by mini-computers. Since the experience with forest-planting machines of the IInd and IIIrd generations is rather poor the information available is insufficient to make any conclusion which generation (the IInd or IIIrd) is most perspective. A perspective use of forest-planting machines with discrete motion along the clearant area (III(b) generation) is most doubtful. In general, these machines are of a low productivity.

Considering the Soviet designs of machines and mechanisms from the above positions, the forest planter is related to the III(b) generation of forest-planting machines and SL-2 planter - to the Ist generation. Besides, soil cultivating machines have been designed at the Leningrad Forestry Research Institute, which may be used to plant forest cultures with the use of CPS (ORM-1.5). In general, the use of simpler and cheap mechanisms and forest-planting machines is preferable for the USSR at present, if compared with the majority of other countries. This is explained by specific features of thé forestry in the USSR and by impossibility to provide numerous enterprizes with costly and powerfult-techniques - forest-planting machines of the IInd and IIIrd generations. Nevertheless, the machines of the IInd and IIIrd generations will be widely used in the future since they ensure several operations during one run of a tractor along the felling area, e.g. preparation of soil, planting application of fertilizer and herbicides. The operation of such machines saves much energy, reduces labour losses and number of shifts. Concurrently, the use of these machines would hardly save money since the assignment for amortization of costly techniques is quite significant.

One of the most perspective Soviet designs of forest-planting machines is a mechanism on the basis of TB-1 tractor. Its wide use will be possible after elimination of the following shortcomings:

- irregular distribution of plants over area;
- increase of productivity of operation;
- increase of reliability of tiller operation in case of an obstacle in soil.

TECHNOLOGY OF FOREST CULTURES CREATION

A particular technology is selected for forest cultures creation proceeding from the nature of soil moisture content and soil fertility. The forest fund in the RSFSR Northwest characterized by at least temporary soil waterlogging, is classified into the types of the habitat conditions in the following way.

Forest with Hylocomium, Haircap-moss Forest and Groups of Forest Conditions with Temporary Soil Waterlogging

In case of temporary waterlogged areas a technology is proposed to work in May-September. In humid bilberry heaths and haircap-moss forest the work may be done at any time during the vegetation period: when mechanisms may operate despite of waterlogging, i.e. during most of the dry period when summer is wet, and during May-August when summer is dry.

When the period with waterlogged soils is short the whole area is divided into stripes 30-40 m wide. "Technological coridors" (3-4 m wide) are made to provide the passage of machines and mechanisms; they are made by tilling or stump sawing on the boundaries of these stripes. These "technological coridors" are arranged around the whole area. The "coridors" are also arranged within the stripes, if necessary the stumps are grubbed. The coridors within the stripes are necessary for subsequent forest thinning, boundary coridors are required for area cultivation. The lengths of these stripes depend on the conditions of the most suitable cultivation of the area.

Plots with temporary waterlogging are also divided into stripes 30440 m wide. Tehnological coridors are made between the stripes in the same way, but within the coridors the stumps are grubbed on the stripe 3,0-3,5 m wide. These technological coridors and consequently the grubbed stripes are on the lines of the greatest slope of the terrain. If the direction of the maximum slope cannot be determined visually or from plant distribution, an elementary altitudinal survey of the area is made. The plot perimeter is contoured by technological coridors, made by tilling or grubbing of stumps. After the work on the plot cultivation the drains are made in the ungrubbed stripes by plow ditchers (PKNL-500, LKN-600) which are joint by a collector laid over the contour passage. The collector, depending on the conditions of soil moisture content, may be done by plow ditchers (passive mechanism) or by excavators (active mechanism). The pass length is fixed with the account of slope, it should not exceed 100 m. This type of drainage network is termed "minor reclamation".

Soil cultivation and planting of cultures are made simultaneously. This is possible when the CPS is applied. The work is done by ORM-1.5 mechanism and by LA combine. In oxalis and bilbery forest and in hard forest-growing conditions both ORM-1.5 mechanism and LA combine may be applied. In case of haircap-moss forest the combine application is most preferable.

The ORM-1.5 mechanism operation is as follows. The mechanism in combination with LHT-55 tractor, equipped for the CPS delivery when moving straight and parallel to the technological coridors over the fixed stripes, forms a number of microhills. These microhills are produced by turning the soil layer without disturbing the soil horizons. These horizons are composed in such a way that doubled organogenic horizons are found at the base. The dimensions of the microhills are: height - 25 cm, length - 40-60 cm, width - 50 cm (the length is measured along the pass, while the width is measured across the pass). In case of forest with Hylocomium, Dicranum, etc. and shallow organogenic horizons the "survival" of microhills with such composition and size may be quite satisfactory.

In haircap-moss forest and in transition types of the forest when organogenic horizons are highly developed (up to 35 cm) the discrete microhills produced by ORM-1.5 mechanism, due to a low volumetric weight, may poorly "survive" and may have unstable water regime. Therefore, the ORM-1.5 mechanism operation in case of developed organogenic horizons (turf, litter, decaying timber, etc.) is not recommended. Microhills produced by the ORM-1.5 mechanism are not always tightly pressed to the uncultivated soil surface. In 30 % of cases the attempts to make microhills are not a success due to obstacles on the way (stumps, stones, debris, etc.), or the produced microhills have the shape or size not suitable for planting (they are often formed on the edge, or they are too small). Therefore, the number of mechanism runs should be higher to provide the required planting density despite gaps. In general, the runs should be spaced 2.5 m. In this case about 2,600 microhills suitable for the CPS planting would be available on the area of 1 ha.

Concurrently with the microhills formation the worker, being in the body of the tractor, throws, by a tray, briquetted seedling near every properly-formed microhill. The workers who follow the tractor make the following manual operations; they prepare the site for planting in the microhills, they pick the priquetted seedling and adjust it into the microhill. Since the natural soil composition is disturbed, the work on the preparation of the hole in the microhill is less labour-taking if compared when the seedling is planted into the virgin land. The tractor carries 800-900 pieces of the CPS. To provide an effective operation of the mechanism, it is recommended to envisage sites with the CPS storage to pick them during the mechanism run. A special tractor may be used to deliver the CPS along the technological coridors.

The LA combine operation under such conditions will be as follows. The LA combine has a movable arm 5 m long. During the run it makes a stripe 10 m wide. It provides 3 or 4 runs on the stripe 30-40 m wide. The combine makes up to 25 microhills during one stop. Discrete microhills formed by a tiller have a shape of a truncated pyramid and they consist of organic and mineral soil with the optimum volumetric weight (0.7-1.2 g/cm^3) all over the microhill volume. This is the main difference of the microhills from those made by the ORM-1.5 mechanism; the latter consist of layers with various volumetric weights. Microhills made by the LA combine have the following dimensions: height - 30 cm, width and length of the base - 60 x 60 cm. They are located over arcs. Since microhills are made by a tiller and the sites are selected by a worker individually, 100 % of microhills are practically suitable for planting the CPS. The microhill composition and shape in forest with Hylocomium, Dicranum, Rhytidiadelphus and in complex types of forest-growing conditions as well as in haircap-moss forest on peat and peaty soils provide a complete "survival" of microhills. In case of about 1,000 stumps on the plot of 1 ha the LA combine made up to 3,000 microhills per 1 ha with practically complete conservation of the undergrowth. Concurrently with the microhill formation a hole is made in it and the CPS is planted; moreover, the covering of the hole is made pouring the soil around the plant which provides a high quality of the work done. Thus, the LA combine operation provides a mechanization of two labourous operations such as preparation of soil and planting of the CPS. The tractor carries the CPS storage of 1,200 pieces, consequently, the combine is loaded by the CPS twice when it operates on the area of 1 ha. Another tractor may be used to deliver the CPS to the combine.

When the ORM-1.5 rotor mechanism is applied for soil cultivation and planting, undesirable plants are removed, if necessary, by routine methods. The rows of cultures are thinned by manual "Sekor" mechanism. When LA combine is applied a preventive thinning is made which is as follows: there is a special arrangement on the combine which makes a chemical treatment of the area around microhills immediately after planting. This arrangement is equipped with special controls to change the doze of chemicals in accordance with the type and degree of area overgrow.

If microhills are made by the ORM-1.5 mechanism, the fertilizers are applied manually, while microhills made by the LA combine are treated by fertilizers using a special mechanism mounted on the arm, simultaneously with planting. Fertilizers are put into a hole 5-10 cm deep apart from the planting site. Fertilizer dozes may be different.

Undesirable trees are removed from technological coridors spaced every 30-40 m by the same mechanisms as in the above technological scheme.

Protection against fire is proveds by the same scheme.

Sphagnum, Horsetail-Sedge and Herbaceous-Marsh Groups of Forest-Growing Conditions

The creation of forest cultures in these groups of forest-growing conditions was very difficult. These conditions are characterized by permanent stagnant, flowing or transit waterlogging and the use of mechanisms is possible there only in summer when the planting stock began to grow. The CPS makes it possible to work in time suitable for the run of mechanisms and to keep the required agricultural dates. This is of a particular importance for herbaceousmarsh group of conditions where soils are rich and the planted cultures may be very productive there. The basis of the technological scheme under such conditions is the traditional technology of the Leningrad Forestry Research Institute developed for the conditions with water surplus (Shutov, 1985) when the work is done during the driest period providing the motion of mechanisms and high-quality work.

On such areas stumps are grubbed away by stump pullers (D-496A, D-513A, D-695) and stripes 3,5-4,0 m wide are made along the area with the maximum slope; the distance between the centres of these stripes is 7-8 m. Stripes are also made around the plot. These contour stripes are used for passing the machines and mechanisms and for drain ditches. Dense ditches are explained by water surplus. When the work is over the ditches are joint by a collector digged by an excavator. The collector discharges into drainage network. In case of necessity an over-slope ditch is made. The mechanism run in these conditions should not exceed 100 m.

Depending on the particular conditions, the following mechanisms may be applied for soil cultivation:

- heavy gutter plow PKNL-500 in case of numerous boulders;
- auger plow PL-2-50 and PSh-1 in case small bouldered area;
- auger plow PSh-1 or PL-2-50 in case severe overgrowth by herbaceous vegetation, since these plows provide the passage of mechanisms after planting.

A selection of the soil-cultivation mechanism should eliminate the effect of the most "harmful" factor. Microhills made by the above plows should be at least 55 ± 5 cm wide, and 25 ± 5 cm high irrespective of the position of the drain ditch; their composition should be suitable for the CPS planting. The length of the microhills is 2.8-3.0 km per 1 ha.

The planting of cultures by SL-2 planter is made in combination with the LHT-55 tractor; it moves above microhills. The working organ makes a continuous furrow 5-15 cm wide and 14 ± 3 cm deep. The working organ places the CPS into the furrow slightly pressing it during 0.2 sec until the CPS meets the covering device. The mechanism carries up to 600-1.000 plants in briquettes. If plants are spaced 1 m and cultures are planted on the area of 1 ha, the mechanism should be filled by new portions of briquetted stock 3-5 times. The CPS may be delivered by a wheeled tractor during dry time, the tractor will move along the contour stripes. It should be noted, that the preparation of the area according to this technological scheme is of an utmost importance since a great number of additional portions of the CPS is required. Otherwise it will require much time for delivery and loading of new CPS portions and the efficiency of the work will be lower.

If they apply plows providing the passage of mechanisms after the planting of cultures, undesirable plants may be eliminated by chemicals using the forest chemical device ALH and tractor forest sprayer TOL. If they apply plows which do not provide such passage of mechanisms, the undersirable vegetation should be eliminated by using a manual "Sekor" tool.

Application of fertilizers is quite necessary for poorfertile conditions (sphagnum and horsetail vegetation). Techniques and technologies for this operation have not yet designed. In highly fertile conditions (herbaceous and spirea vegetation) application of fertilizers is not reasonable.

Undersirable trees are eliminated chemically using ALH device; therefore technological coridors are left unplanted every 30-40 m.

The water collecting ditches in the second technological scheme are used to stop the fire.

Thus, two technological schemes are described to create forest cultures using the CPS. The data obtained show that the first technological scheme may be applied on the area of 55 % of the forest fund in the RSFSR Northwest characterized by waterlogged soils; the second scheme may be applied on the remaining 45 % of the area;

- moistening regime, specific features of area overgrowing by various vegetation and fertility characteristics are key characteristics to select particular technology;

- preparation of the area and peculiarities of planting site formation (density of drain ditches, continuous or discrete microhills) depend on the regime of moistening;
- specific features of area overgrowth and fertility characteristics determine a set of agrotechnical measures essential to create forest cultures;
- in connection with the work done on the modification of machines and mechanisms used in the technological schemes for forest culture creation it is impossible at present to give accurate technical and economic parameters of these technologies, preliminary data, however, show, that the cost of these cultures creation will not differ greatly from the cost of traditional planting. But the use of the CPS will prolong the dates of work on forest culture planting substantially.

CONCLUSION

Thus, specialized technologies with the CPS use in the forestry are under development in the USSR at present. The design of fundamentally new forest-planting machines and mechanisms operating automatically and of simple mechanisms providing the CPS transportation and soil preparation on clearant areas is very intensive.

In the USSR the CPS may be widely spread only in case of multi-purpose mechanization of all the production processes starting from seedlings growing up to a creation of productive plantations. At the present stage of forestry development in the USSR the creation of forest cultures with the CPS use is made in general by simple forest-planting machines and mechanisms of the Ist generation (permanent contact of the working organ with soil during operation) or by simple soil-cultivating mechanisms (for example, ORM-1.5). This is explained by the specific features of the material- and -technical basis development of forestry in the USSR. But in the future only the planting machines and mechanisms of the IInd and IIIrd generations (discrete or point interaction between the working organ and soil during operation, point planting, combining and automatization of the production processes) may provide a multi-purpose solution of the forest-regeneration problem with the use of the CPS.

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GUIDELINES OF THE NATIONAL BOARD OF FORESTRY FOR SITE PREPARATION IN LAPLAND

Kari Pelkonen

BACKGROUND FOR PRESENT GUIDELINES

The present guidelines of the National Board of Forestry are the result of long development. On grounds of increased research results and experience they have continuously been revised, and will be revised in the future. Thus a review of the earlier practice is necessary in order to understand what has been done in Lapland during the past few decades and what is done today.

The National Board of Forestry administers about 42 per cent of the forestry land in the Province of Lapland. Until WW II, logging activities were carried out only on a small portion of this area. Cuttings were mostly focused on pine stands close to waterways. As a regeneration method, natural regeneration was applied almost without exception.

After WW II, the reconstruction and the revival of the commercial and industrial life of Lapland required the starting of larger-than-before cuttings in the northern woods. Cuttings were mostly carried out in virgin spruce stands. By means of clearcuts, the aim was to regenerate these rather fertile spruce stands with pine. Prescribed burning was the prevalent site preparation method. This method was extensively used in the 1950´s. The largest annual prescribed burning areas exceeded 30,000 hectares.

In the early 1960´s, prescribed burning areas decreased because of the forest fire risk involved and the large number of workers required. The occurrence of some biotic forest damages was also linked with prescribed burning.

The decrease in prescribed burning was also expedited by the fact that mechanical site preparation methods were developing. It was thought that these would greatly replace prescribed burning. Firstly, mechanical spot scarifying became common. It was applied for a large variety of site types, and the results of regeneration were very varying.

The extensive failures in artificial regeneration slowly resulted in the abandonment of spot scarifying. One of the reasons for the failures were the exceptionally cold and humid summers in the early 1960´s.

In the mid-1960´s scarification was substituted by wing ploughing which had developed to a practical method. The results in artificial regeneration on wing ploughed sites were promising, and it was generally believed that wing ploughing was the final solution to the problems in artificial regeneration in Lapland. During the 1950´s and 1960´s, practical site preparation was not based on any detailed guidelines. Methods and their use were mentioned in circulars of general nature, and thus the areas where these methods were used, turned out to be rather extensive.

The first guidelines for site preparation on regeneration areas were given as late in 1973. The introduction of the guidelines constituted a remarkable improvement to the earlier practice. In these guidelines Finland was divided into two parts. The line was drawn in the lake and river system of River Oulujoki; the areas north and south of this had guidelines of their own.

In the guidelines for Northern Finland, the soil types were divided in three groups, within which one could choose from 2 to 3 different site preparation methods. These guidelines already recognized all the currently applied mechanical site preparation methods. Prescribed burning, on the other hand, was not mentioned at all. The guidelines were drawn in collaboration with forest researchers using the knowledge available at that moment. They provided a fairly good setting for the choice of a correct site preparation method. In practice, wing ploughing became, however, the prevailing method, because of the great faith in the advantages of ploughing; also some factors concerning the use of equipment contributed to this development

DEVELOPMENT OF PRESENT GUIDELINES

The basis for the present site preparation guidelines was created in the guidelines for artificial regeneration given in 1978. These guidelines, first of all, defined the areas for use of various site preparation methods. In more detail, areas for use were given in the so-called regeneration chain tables drawn separately for Southern and Northern Finland.

Here Northern Finland comprised nearly as large an area as in the guidelines given in 1973. Otherwise the guidelines were much more detailed than earlier, and the choice of the site preparation method was affected by a larger number of factors than earlier.

These guidelines were defined more closely in 1981, when site preparation guidelines were drawn for each of the three regions of the National Board of Forestry. The area of the Province of Lapland got four different regeneration chain tables: one for the commercial forests in the northern protection forest zone, second for the mineral soils of commercial forests, third for the peatlands in commercial forests, and fourth the mineral soils of the commercial forests in the District of Inari. The details in the tables had been further specified. The choice of site preparation method was affected by the following factors:

site type
soil type
thickness of raw humus
stoniness
hydrology

Methods to choose from were:

prescribed burning
disc trenching
spot scarifying
wing ploughing
mounding

Practice has proven these guidelines to be successful. They give good grounds for sufficiently precise consideration of the soil factor affecting artificial regeneration. The site preparation methods for the Region of Northern Finland were renewed in 1985. It was not considered necessary to change the regeneration chains defined in 1981. On the other hand, the new guidelines emphasized very detailed planning that takes into account the variations in soil type. Also the importance of local expertise when choosing regeneration methods was emphasized. Wing ploughing should be used only to a limited extent on sites where it, from the viewpoint of regeneration, is necessary. The reason for this is the pressures on wing ploughing caused by other forms of land use and the failures in the wing ploughed areas that have not so far been explained. The use of prescribed burning, on the other hand, is increased where it is applicable.

Prescribed burning has enjoyed a renaissance. This has been made possible by the new technology with increased fire safety and reduced labour costs. The annual record in Lapland has been 2,000 hectares on prescribed burning, and this record will be broken.

The current guidelines for site preparation emphasize close consideration of the other uses of forests, such as reindeer husbandry, game management, landscape protection and recreation, in planning and carrying out of the work.

Earlier it has been difficult to comply with the guidelines because of lack of appropriate equipment and the consideration of costs.

In the 1980's there has been strong development to get appropriate equipment. The results of this work were the more applicable disc trenchers and spot scarifiers. Another development line has been the so-called multi-purpose site preparators. The goal has been a site preparation unit which can make a varying preparation result according to the requirements of the soil. Thus the transfer costs caused by the use of various separate pieces of equipment can be saved. This line of development has already resulted in some efficient practical solutions. To save in costs, the planning of work has continuously been developed.

FUTURE OUTLOOK

Determined development of guidelines and machinery has contributed to the use of purposeful site preparation in regeneration. Development work is necessary also in the future. The basics of site preparation still require research. Especially the growth disturbances and plant mortality in ploughed areas after good initial development require clarification. The practical guidelines will be revised as research knowledge increases. In the field of machine development, the further development of the multi-purpose site preparers continues. The importance of landscape and environment protection in the planning and implementation of work is further emphasized. Especially waterways protection should gain more significance than at present.

EFFECT OF SITE PREPARATION ON REGENERATION RESULTS IN LAPLAND

Eljas Pohtila

ABSTRACT: Site preparation has been common in the forests of Lapland since the 1950s. The receptivity of prepared soil to regeneration degrades quickly, which makes it difficult to choose the optimal date for site preparation in natural regeneration. Burning, scalping and disc ploughing make a better combination with sowing than with planting; and wing ploughing makes a better combination with planting than with sowing. Burning alone does not guarantee adequate germination after sowing.

EARLY PRACTICE

Site preparation has been common in the forests of Lapland since the 1950s when a concerted large-scale regeneration of over-aged stands was begun (Fig. 1). Site preparation connected with sowing and planting has been done experimentally in Lapland since the beginning of this century. The experiments carried out by Renvall (1912, 1919) in the northernmost Lapland are worth mentioning first. He found that sowing was very successful where the humus layer was thin (< 1.5 cm); where the humus layer was thick (> 2 cm), however, sowing gave poor results. He also found that wild fires usually improved conditions for seedling growth.

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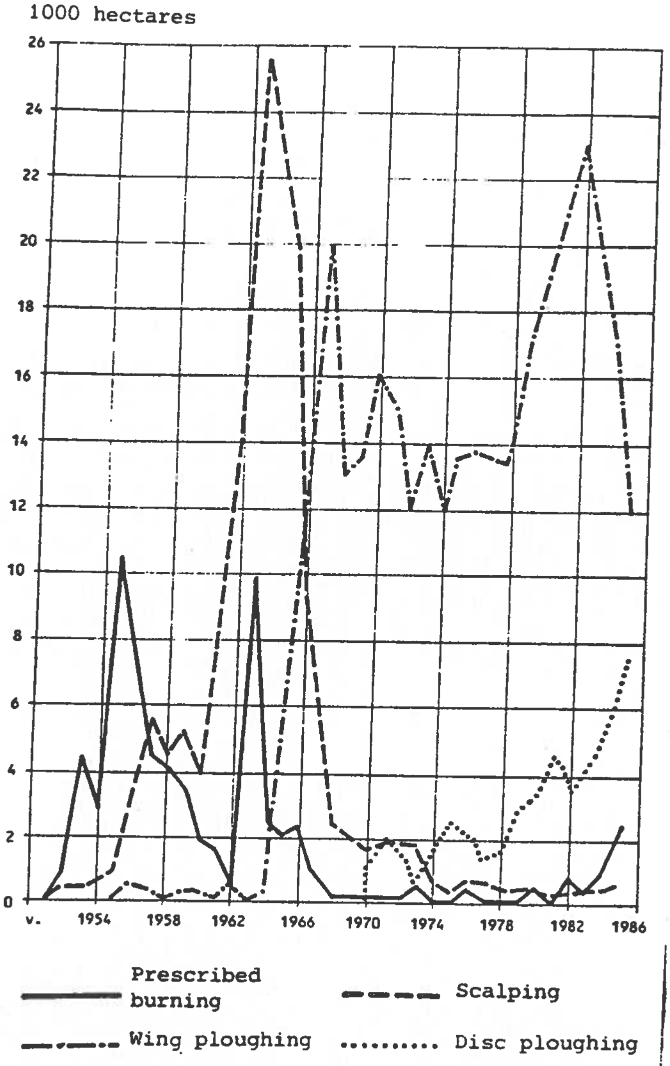

Figure 1. Site preparation in Lapland in 1952 - 1985.

The experiments carried out by Heikinheimo (1939) during the 1920s and 1930s were important and indicative for future silviculture in Lapland. Sirén (1952) continued these experiments in the 1950s. The procedure especially suitable for the reforestation of over-aged stands proved at that time to be clear cutting, prescribed burning, scalping and sowing of pine. When mechanical scalping was adopted, it was regarded as the final solution to soil preparation problems.

INCREASE OF PLOUGHING

In the 1960s the needs of site preparation had to be re-evaluated when cool summers caused severe damage to artificially reforested sapling stands considered to be already established. There were failures especially in attempts to change old spruce stands into young pine stands. Etholén (1972) has documented these failures thoroughly. Ploughing of forest soil was adopted as a new method, since the failures were considered to be at least partly due to insufficient soil preparation. Wing ploughing proved to be a very reliable method and not significantly hampered by the stoniness of the glacial till. In addition to creating spaces for planting stock, ploughing also considerably facilitated planting work. These factors together revealed ploughing to be a versatile method, which made other site preparation methods almost completely obsolete. Ploughing has been used in connection with natural regeneration too.

RECENT RESEARCH ACTIVITIES

The failures of the 1960s led to the launch of new research. Modern mechanical soil preparation methods had to be compared with the old ones in connection with different approaches to regeneration. At the beginning of the 1970s both Scots pine and Norway spruce gave rich seed crops, which were collected into stores in such abundance that it was possible once again to use direct seeding, and even broadcast sowing, in practice. Modern soil preparation methods improved the germination of seeds and emergence of seedlings, and reduced seed use, in turn intensifying broadcast sowing. It was also possible to obtain information from the broadcast sowing experiments about the effects of soil preparation on natural regeneration.

COMPILABILITY OF DIFFERENT METHODS

The results of these experiments confirmed some earlier ideas about the compilability of different site preparation and regeneration methods (Pohtila 1977, Pohtila and Pohjola 1983, 1985). Prescribed burning, scalping and sowing proved to be a successfull combination also in later experiments in which they were compared with ploughing as well as other methods (Table 1). On the other hand the planted seedlings have had far less success than sowed ones on burned areas. The risk of death is high, especially for seedlings planted immediately after burning. Planted seedlings dry up more easily than sowed ones, which is probably the main reason for the difference, There is no evidence to show that Rhizina root rot (*Rhizina undulata* Fr.) has contributed to the results.

The best site preparation method with planting has been wing ploughing, which, however, has proved to be relatively poor with sowing (Fig. 2). The height growth of both sowed and planted seedlings was, however, faster in these areas than on scalped or disc-ploughed plots.

Table 1. Order of superiority of different method combinations on the basis of survival of seedlings and transplants in the experiment carried out by Pohtila (1977). Forest site types: Empetrum-Myrtillus and Hylocomium-Myrtillus.

1.	Burning + scalping + sowing	81.7 per cent
2.	Ploughing + soving on the shoulder	80.9 "
3.	Scalping + sowing	79.3 "
4.	Ploughing + planting on the shoulder	75.1 "
5.	Ploughing + planting on the tilt	69.3 "
6.	Burning + ploughing + sowing on the shoulder	69.1 "
7.	Scalping + planting	69.0 "
8.	Ploughing + sowing on the tilt	67.1 "
9.	Burning + ploughing + planting on the shoulder	61.3 "
10.	Burning + ploughing + sowing on the tilt	59.3 "
11.	Burning + ploughing + planting on the tilt	58.9 "
12.	Burning + scalping + planting	48.3 "

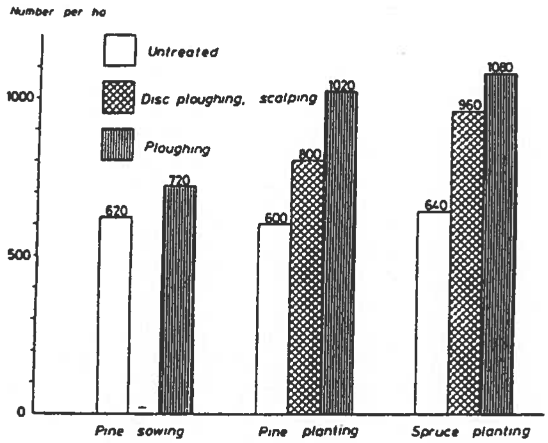

Figure 2. Mean number of seedlings capable of development per hectare in stands reforested in 1970 - 75 by soil preparation methods (Pohtila and Valkonen 1985).

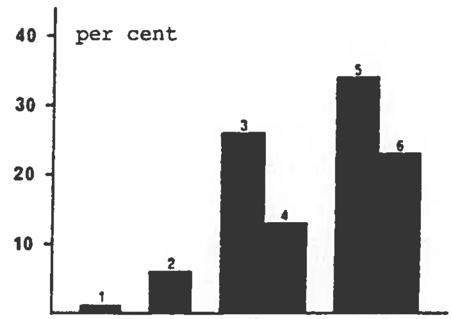

Figure 3. Frequency of damage caused by frost heaving in stocked sowed patches (Pohtila 1977). Substrates: 1 = hoed patch, 2 = burned, hoed patch, 3 = ploughed shoulder, 4 = ploughed tilt, 5 = burned, ploughed shoulder, 6 = burned, ploughed tilt.

One important reason for the failure of sowings on the wing-ploughed plots seems to be frost heaving (Fig. 3). Ploughing in combination with prescribed burning, in contrast to scalping only, has increased the damage caused by frost heaving. In the thin surface layer of ploughed soil the germlings are probably more exposed to the effects of unfavourable weather than are planted seedlings. On the other hand, technical considerations are apparently more important for planting than for sowing. The more thorough the soil preparations, the more easily the planting operations can be done.

Observations on the interaction between site preparation and reforestation methods are to some extent new. Generally speaking, prescribed burning, scalping and disc ploughing make a better combination with sowing than planting, whereas wing ploughing makes a better combination with planting than sowing. After closer study, site quality has also proved to be an important factor. The combination of wing ploughing and planting is favourable for moist spruce dominant sites. On sub-dry pine dominant sites where differences in success between the different combinations of methods have been relatively small, a wider choice of methods is apparently available.

SITE PREPARATION IN BROADCAST SOWING

Broadcast sowing on snow has given inconsistent results. On an average 2 - 3 times more seedlings have emerged on pine-dominant sites than on spruce-dominant ones. Restocking has been best on ploughed plots with the most mineral soil. Seedlings have been recorded most commonly on the shoulder of the ploughed ditch and the furrow made by the disc plough. The poorest substrate for germination in all preparation methods has been humus (Fig. 4). Substrate micro-topography effects restocking as well as the quality of germination. Though the climate in Lapland is generally humid, the ridges created by wing ploughing are obviously too dry to serve as germination substrates. Large patches, and especially the centres of such patches, prepared by mechanized scalping have also proved to be favourable germination sites.

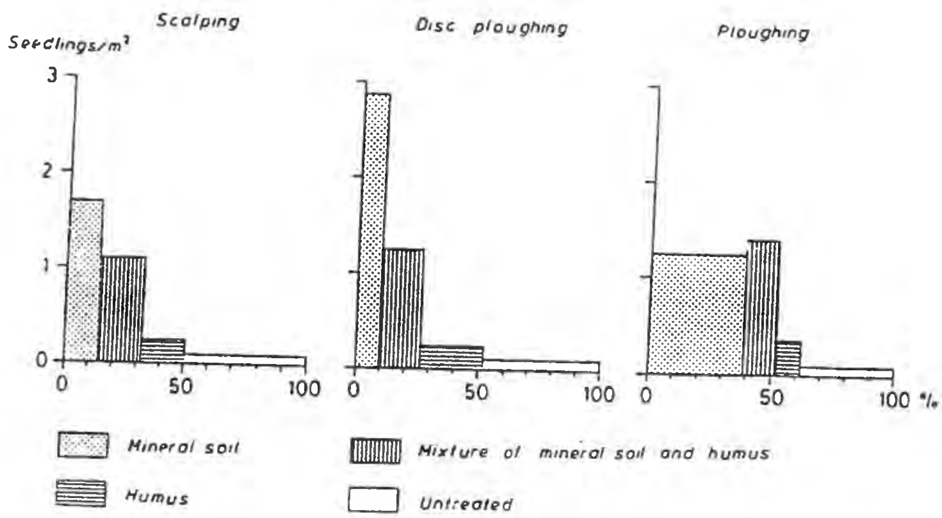

Figure 4. Proportions of different substrates in the compared soil preparations and the average number of seedlings on different substrates emerged from broadcast sowings (Pohtila and Pohjola 1985).

Prescribed burning alone does not guarantee adequate restocking in broadcast sowing. Seedlings have emerged on thoroughly burnt spots with mineral soil but not on non-cultivated plots (Fig. 5).

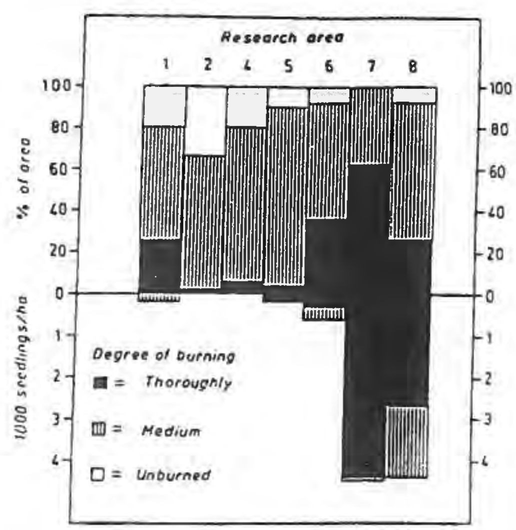

Figure 5. Degree of burning and average number of seedlings emerged from broadcast sowings in different research areas (Pohtila and Pohjola 1985).

By and large, an increase in the amount of soil prepared and in the number of seed sowed correspond with an increase in the number of seedlings. Sirén (1952) presented some estimates about the quantities of seeds needed on different substrates in Lapland to achieve fully-stocked seedling stands. Empirical data, however, are still scant. In principal, it is possible to solve the problem of combining the amount and spreading of seed and site preparation. Even so, the problem remains as yet unsolved.

There are several different techniques for sowing. Much of the equipment used in agriculture can also be used in the forest. Sirén (1957) tried sowing from aircraft as far back as the early 1950s. The technical problems of sowing have apparently been solved.

The results of broadcast sowing can be affected by the choice of date for sowing. Previously, broadcast sowing on snow was considered to be more advantageous than sowing in the summer, an idea proved false by new studies. In Lapland the richest stocks are achieved by sowing in June (Fig. 6). The rule connecting the longer time lag between sowing and germination with the emergence of fewer seedlings also applies in Lapland. June is the peak time for natural seed fall from Scots pine in Lapland (Heikinheimo 1937). To achieve fully-stocked stands (c. 2,000 seedlings/ha) using normal soil preparation and the most efficient sowing date, the minimum amount of seeds needed (laboratory germination 80 per cent) seems to be 0.5 - 1.0 kg per hectare on sub-dry, pine-dominant sites in Lapland. On moist, spruce-dominant sites the need for seeds is higher, 2 - 6 kg per hectare, depending on the site preparation methods.

On completely cultivated soils the corresponding seed requirement is probably about half of the above amounts.

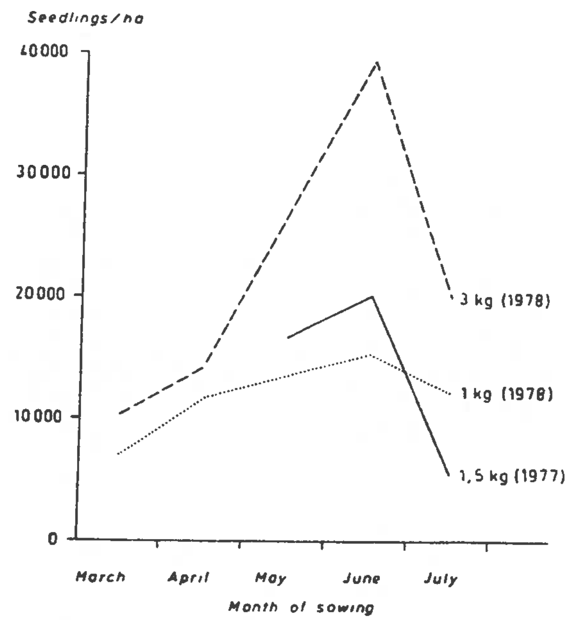

Figure 6. Effect of the sowing date and the amount of seeds on stocking with seedlings in broadcast sowings on ploughed areas (Pohtila and Pohjola 1985).

STABILIZATION OF PREPARED SOIL

Stabilization of the soil after preparation has a negative effect on reforestation results. In particular stocking with sowed seedlings is clearly poorer when the interval between soil preparation and sowing is increased (Fig. 7). Previously, the effect of soil stabilization was considered to be favourable because of a decrease in frost heaving (Pohtila 1977). It would be desirable, however, for there to be only a single winter, between soil preparation and sowing or planting.

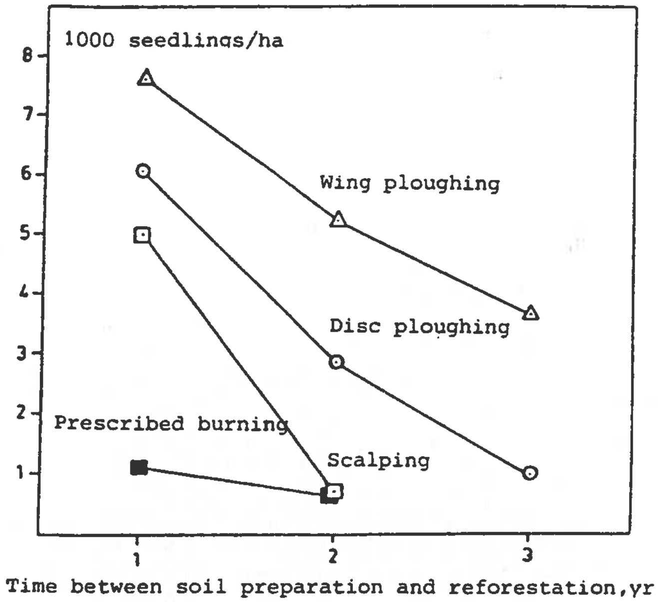

Figure 7. Effect of the interval between soil preparation and broadcast sowing on stocking with seedlings (Pohtila and Pohjola 1985).

The advantage of fresh soil preparation is probably a result of soil porosity. Rain condenses the upper mineral soil layer, thus decreasing the number of favourable sites for seed germination. If the seeds remain uncovered on the bare mineral soil they are exposed to many kinds of damage. To preserve site productivity, cultivated areas should be sown as soon as possible. The risk of nutrient leaching is evident, especially on ploughed sites. Huss and Sinko (1969) have proved experimentally that there is a risk of nutrient leaching, even on burned areas, if reforestation is delayed.

SITE PREPARATION AND NATURAL REGENERATION

The results of the broadcast sowing experiments can also be applied to natural regeneration. Only immediate seeding after site preparation will assure the best possible result. In natural regeneration, however, there is no certainty about the mature seed crop in Lapland. To achieve an abundant cone crop for Scots pine, the temperature sum in the summer preceding flowering, i.e. in the period when the flower buds are formed, should be at least 910 d.d. in Lapland (threshold value +5^{o}C). To have, say, fifty per cent mature seed, the temperature sum in the summer following flowering should be at least 845 d.d. (Sarvas 1970). If the recurrence of warm summers follows the normal distribution pattern, the probability of the coincidence of such summers is, according to weather statistics, only 0.18 x 0.33 = 0.06 in Sodankylä (67^{o}22'N, 26^{o}39'E), for example.

Our practical experience corresponds well with these calculations, so it is difficult to choose the optimal date for site preparation. The interval between soil preparation and natural seeding may be so long that the investment in soil preparation will be wasted. Perhaps regeneration areas with soil preparation should be sowed instead of left in anticipation of natural seeding. If such areas are sowed, large supplies of seed are necessary. We are dependent on natural seed crops until the seed orchards established for Lapland are in full production.

CURRENT PRACTICE

The observations described above have contributed to a situation in which the proportions of site preparation methods used in practice have again changed. Wing ploughing has decreased and disc ploughing increased (Fig. 1). Burning is coming into use again.

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EXPERIENCES WITH LARIX SPECIES IN NORTHERN FINLAND

Max. Hagman

ABSTRACT: This paper gives a short review about the experiences collected over a period of about 100 years of larch cultivation in Northern Finland. Almost all results concern the Siberian larch. Origin and provenance are discussed and results are presented from provenance and seed source trials. Survival and height growth are compared to native Scots pine and it is suggested that on right sites the Siberian larch is a possible alternative. Further research must concentrate on selection of good seed sources and study of genotype/site interactions.

INTRODUCTION

In the Nordic countries there has always been an interest in the possibilities of extending the forest to the mountains, and as early as in the 18th century there are speculations if the larch could be used (Linnaeus 1754). The use of larch for shipbuilding brought the interest of the admiralties in Sweden as well as in Russia to the larch forests and rised the question of possible cultivation.

One hundred years later the construction of wooden warships was no longer of any importance, but the good growth of the larch cultivated and also the impressive figures brought back by foresters making inventories for exploitation of the virigin northern larch forests in Russia aroused a new interest, which resulted in seed import and new cultivations all over the country.

When we here are talking about larch the main species to be discussed is the Siberian larch Larix sibirica Ledebour and L. sukaczewii Dylis).

EARLY HISTORY

In Finland the real impulse to larch cultivation was the rediscovery of the Raivola larch forest on the Karelian isthmus not far from present Leningrad. This forest in which the first part was established in 1738 has been described by several authors (see e.g. Ilvessalo 1916, 1923, Timofejev 1961 and others). In Russian literature it is mentioned as the forest of Lintulovskoj rosce and it is at the present situated in the forest district of Roščinsk, Leningrad oblast.

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Although the foresthadbeen known earlier, its existence had been forgotten but in 1869 the director of the Finnish Forest High School at Evo, A.G. Blomqvist visited the place and called the attention of the Russian authorities and forest scientist to its impressive yield.

This visit prompted Blomqvist to rise the question of larch cultivation in Finland in several papers (Blomqvist 1877, 1887 and 1893) and engaged him in activities to procure larch seed and to produce plants. A center for his activities was the school at Evo. To make himself familiar with the larch forest he made long travels in different parts of Russia and at the same time contacts with people who could provide seed.

Many seed lots were also obtained and distributed. Further enlargements were suggested by the circular letter of 21.11.1889 from the National Board of Forestry about the cultivation of larch in the state forests.

In the north, cultivations were also started but due to the limited sources and the general situation in forestry of those days the cultivations concentrated around foresters' offices, forestry schools etc.

In the Tornio river valley several cultivations were made (Reuter 1918) and other cultivations are listed by Parvela (1930 and 1932) and Tammelander (1914). Correspondence between A.G. Blomqvist and X. Nordling led to the establishment of larch cultures as far north as at Toivoniemi in Kaamanen NW of Inari where also a few other attempts were made by the forester Waennerberg.

Also in Sweden there arose an interest in larch at the same time and many cultivations were made in the northern parts with seeds obtained in cooperation with the Finnish forest service (Schotte 1917).

LATER DEVELOPMENT

At the turn of the century there seems to have been a trend from cultivation forestry towards natural regeneration and there is a decrease in the interest for exotics. The larch, however, continued to be of interest on a small scale and scattered reports also from the north occur (see Ilvessalo 1916).

After the first world war and the Russian revolution access to the old seed sources became limited, except for the Raivola stands since the Raivola larch forest was left in Finland and its administration taken over by the Finnish For‹ Research Institute in 1922.

Seed collections were immediat‹ started in this forest and seed Raivola origin brought to Lapland ‹ the Kivalo Research Forest (Heikinhe: 1956). The good development of ‹ sample plots in Kivalo roused great h‹ for the larch as an alternative spec: in the regeneration of the old spr‹ forest and the cultivations w‹ extended and new provenances brought :

Conditions of war and the transfer the Raivola forest to the Soviet Un: in 1940 and again in 1944 and addition the war in Lapland 1944-1‹ more or less brought the cultivations larch to an end for some time.

When the rebuilding work started and ‹ forestry of Lapland was grea‹ activated in the 1950ties the role the larch was again taken up discussions.

Lack of Finnish seeds led the Natio‹ Board of Forestry to contact s‹ dealers in the Soviet Union with, as will see, very unfortunate consequenc‹ particularly when one considers ‹ scale of the operations compared w: earlier activities.

In 1950 larch plantations in the st‹ forests in Northern Finland w‹ summarized as follows:

Region	Number of cultivations	Area
Northern Finland	4	0.37 ‹
Ostrobothnia	20	11.74 '

In the period 1951 - 1957 there w‹ added the following

Region	Number of cultivations	Area
Northern Finland	6	4.01 ‹
Ostrobothnia	1	0.25 '

thus the total area in 1957 was

Region	Number of cultivations	Area
Northern Finland	10	4.38 ‹
Ostrobothnia	21	11.99 '
Total	31	16.37 ‹

These figures do not include ‹ plantations of the Forest Resea: Institute in its research forests.

Larch in private forest was not lis‹ at that time but in 1971 the North‹ Regional Office of the forest serv: made an inventory of all la: plantations in its region with ‹ intention of local seed collection. T: inventory includes state as well private and research plantations of seed bearing age. At that time approximately 4000 trees were listed as suitable for seed collection.

Later figures have not been compiled but an idea might be obtained from the production of seedlings.

The nurseries of the Northern Regional Office delivered in the years 1958 - 1976 larch plants as follows:

Year	Number of plants
1958	4 000
1959	172 300
1960	267 515
1961	211 000
1962	150 000
1963	34 000
1958 - 63	839 515
1968	2 200
1969	-
1970	-
1971	17 215
1972	14 180
1973	68 355
1974	82 000
1975	65 000
1976	23 550
1964 - 76	272 500

Thus, during the period 1958 - 1976 in total 1 112 015 plants were delivered.

In addition the nurseries of the Ostrobothnian Regional Office delivered in the years 1958 - 1960 a total of 550 700 plants and in the period of 1970 - 1976 the number of plants delivered was 157 000.

It is important to distinguish between the periods 1958 - 1963 and 1968 - 1976 due to the provenances used. This will be discussed later in this paper.

In the period 1977 - 1976 the Pakatti nursery of the Northern Regional Office delivered 77 697 larch plants including 3 672 plants for research experiments.

The figures from the later years reveal a growing interest in the cultivation of larch, no doubt partly due to the increased possibilities for obtaining seed from the new seed orchards.

Thus, the number of plants delivered from the Northern and Ostrobothnian Regional Office nurseries were as follows:

Year	Northern For. Distr.	Ostrobothnian For. Distr.
1977	40 000	27 000
1978	20	51 000
1979	109 700	174 000
1980	187 913	36 000
1981	101 580	234 000
1982	214 588	1 036 000
1983	43 300	1 125 000
1984	82 280	1 147 000
1985	355 593	1 803 000
1986	835 160	1 948 000
1987	120	1 400 000
1977 - 87	1 970 254	8 981 000

Due to the extremely cold winter 1986/87 and the very small amount of snow, larch plants growing in containers at the Imari nursery near Rovaniemi were killed to 90 % and thus the number of plants that could be delivered in the spring of 1987 was minimal.

If we suppose that the larch cultivations were made at spacing of 3 x 3 meters it means approximately 1000 plants per hectare and thus the plants mentioned above, would correspond to a cultivated area of about 1000 ha up to the year 1976 and about 10 000 ha between 1977 and 1987.

The earlier results were, however, not as good as expected. To understand this, we must now turn to the question of the seed sources.

ORIGIN AND PROVENANCES

When introducing an exotic species the choice of the right seed source is of utmost importance. This is particulary clear with the Siberian larch which has a very large distribution and great geographical variation.

Here is not the space to go into a detailed discussion of the systematics of the Siberian larch so the reader is referred to the numerous papers that have been published (Dylis 1947, Bobrov 1972 and further papers listed in these works).

Following Dylis and other Russian authors I have distinguished the western Siberian larch as _Larix sukaczewii_ and the central and more eastern one as _Larix sibirica_.

Unfortunately, very little is exactly known about the origin of the earlier cultivations of larch in Finland. Of the famous Raivola forest we only know that the seed for the first cultivation was ordered from the city of Archangelsk but if it was collected there is unknown.

Since the Raivola forest was extended five times with different seed sources or even with seed collected in the earliest plantations the origin of the different plots is very difficult to trace.

Already Ilvessalo observed that the 1000 grain weight of seeds from the different plots differed but his comparative sowings were, unfortunately, destroyed by chickens in the nursery.

The question of the origin of the Raivola forest has been discussed in detail by Mezger (1935) who expresses the opinion that at least some of the material was from the government Ufa, which means west of the central part of the Ural mountains.

Raivola was, however, not the only seed source used in Finland. The tracing of their origin is just as difficult since the archives at Evo were destroyed by fire and the notations in the field are often incomplete. It is known that much seed was imported east of the Ural, particularly from Nishnij Tagilsk (Granit 1936) and also that seeds were obtained from the regions west of the Ural towards the SW limits of the distribution of the larch.

Frequent seed lots were obtained from Archangelsk but whether this meant the government Archangelsk and in that case, from which parts of it, is unknown. Blomqvist himself mentions larch from the Mesen river valley in connection with the cultivations made at Toivoniemi in Inari but it is uncertain if seeds from Mesen were really the source.

Other sources mentioned, are Pinega, Perm, Nishni Novgorod, Olonets and Vologda, but whether all seed lots really arrived and were used is uncertain. The obtaining of larch seed from Russia seems, even in the old days, to have been difficult.

For the oldest plantations in Northern Finland one may assume that the provenances might have been Raivola, Archangelsk region and, perhaps, also the Nishnij Tagilsk region.

For the younger plantations the records are neither so exact as desirable. The Raivola seed source is, of course, known also in second generation, from cultures in Southern Finland, but since sections of that forest are not recorded we do not know exactly which part was collected.

Imports in the 1930ies were not al well documented and we have to satisfied with such notions Novosibirsk, Pinega, Archange Nishnij Tagilsk etc.

To give an example of the confusion might occur: The provenance of Siberian larch planted at the Ki research forest (No. 26) is expresse Archangelsk, 64° N lat., 40° E l (Lähde et al., 1984). Howe Heikinheimo (1956) mentions that seed for this plantation was obta from a Finnish forest officer Mr. Remes, and that the origin was state the Pinega and Šenkursk regions.

From Russian maps it can be seen t the latitude of the capital of Pinega region, Karpogor is 64° N longitude 44°15' E. The latitude Šenkursk on the other hand is 62°07 and longitude 42°55' E. If the Pi region reaches further to the NW difference between the two origins mi be even greater than 2°.

From the map published by Meleh Čertovskoj and Moiseev (1966) it can seen that the distribution area of Siberian larch in the Archangelsk obl is discontinuous with a gap between Šenkursk and the Karpogor localiti Larger areas of larch forests occur of the city of Pinega and to the along the Mesen river.

Unfortunately, we have no records wh could explain if the seeds obtained Mr. Remes were obtained separately f the two regions or as a mix, and if t were, in the former case, s separately.

Vagueness in descriptions might e have been the main reason for mistake made in the 1958 - 63 per when seeds were imported f "Krasnojarsk". A closer study revealed that the seeds in many ca were collected from Krasnojarskij k but from its most southern parts, also from the Chakasskoj autonom oblast. Other notes mention the "Sa mountains". Unfortunately, none of original documentation, perhaps s from the Soviet Union, has been found.

The alarming reports about performance of these Central Siberi origins, which hence belonged to species <u>L. sibirica Ledeb</u>. forced forest service to look for other s sources.

Fortunately seed orchard activities started in the 1950ties in the south Finland and for the seed orchard No.

at Oitti; plus trees of Raivola provenance were selected. When seed from this seed orchard were available they were used also in the north, particularly since the experimental plots at Kivalo were of the Raivola origin and no drawback had been observed from using this provenance.

In addition, the search for local seed sources mentioned above, and the occurrence of good seed years in the early 1970ies gave an opportunity to collect local provenances. These were also used in the experiments reported here.

We have to remember, however, that many of these local Lapland seed sources consist of only a few trees and so varying degree of self-pollination may occur. In a few cases there is also slight possibilities for hybridization with other species.

Thus, the question of which is the very right origin and provenance of larch for the different parts of Northern Finland is still unsolved.

Guidelines from the natural distribution of the species in the western regions of its area are not so easy to obtain since the natural, original distribution has been disturbed by cutting and roding of land for agriculture during a very long time. As can be seen from various papers by Russian authors (Köppen 1889, Nevrli 1912, Drobov 1914, Tovstoljes 1916, Kuznecov 1927, Iljinskij 1929 and others) the Siberian larch seems to have a discontinuous and somewhat scattered distribution where limited forest areas are separated from each other. The same is observed in the paper by Melehov, Certobskoj and Moiseev (1966) for the Archangelsk and Vologda districts and this problem has also been discussed by Simak (1979).

Attempts have been made to correlate the western distribution of the Siberian larch to climatic and edaphic factors (see e.g. Tolskij 1938). Cajander (1901) who visited the region at the turn of the century was of the opinion that it was mainly the presence of lowland with boggy and poor soils that had prevented the larch from proceeding further westward. He also mentions the effect of the shifting cultivation in the Olonets area as partly promoting, partly preventing the further spreading of the larch.

Some of the best descriptions available for the conditions for larch growth in these parts of Russia are the papers by Hemberg (1877 and 1899) which are still well worth studying.

Also the travel report by Arnborg and Edlund (1962) and that by Simak already mentioned, give good information. The very large literature in the Russian language is, of course, the best source, but it is, unfortunately, out of reach to many of us for linguistic reasons.

Although much advice might be obtained from the knowledge of the species in its natural regions, the final proof will always be the trials in the area where the exote is going to be used. We must therefore now turn to the results, so far, obtained in Lapland and other parts of Northern Finland.

SURVIVAL

The first sign that a species is adapted to a new area is that it survives in the new conditions for a long enough time. Only if the survival is acceptable may we consider growth, yield and quality factors in judging the value of the species.

Our knowledge of the survival of the Siberian larch in the area discussed is for the oldest cultivations limited by the lack of records on the development. Success or failure are reported in a general way but there are nevertheless old plantations which show that the larch has survived for more than 100 years as far north as in Inari.

More details are to be extracted from the sample plots of the Forest Research Institute of which the latest figures are published by Lähde, Werren, Etholén and Silander (1984).

Nevala (1980) made a comparative study of larch and Scots pine cultivations made in 1970 - 1972. The same results were also discussed by Tigerstedt, Pohtila and Nevala (1983). In these experiments, 38 in total, and situated in the effective temperature sum region between 630 and 910 degree days (base +5° C) the survival of larch and of bare root pine plants was studied.

The survival after 9 years was 62.9 % for larch and 10.9 for pine. In the 1971 trials after 8 years the corresponding figures were 90.3 % and 35.9 %. In their experiments from 1972 the results were slightly different in the region with temperature sum less or equal to 800 d.d.: 76 % for larch and 47 % for pine. and in the region with a temperature sum above 800 d.d. where the corresponding figures were 73.5 % for the larch and 58.1 % for the pine.

The very low survival rate of the origins from the Central Siberia have been mentioned several times. These reports from the practice are supported by the results of the experiment No. 46 which planted in 1963. These are shown table 1.

Table 1. Survival and mean height of Larix sibirica Ldb. and Larix sukaczewii Dylis in the experiment No. 46 near Rovaniemi, lat. 66°29'N, long. 26°42'E, alt. 220 m. The experiment was planted in 1963 and assessed in 1980.

Lot No.	Seed lot No.	Species	Origin	Number of replicates	Total number of plants	Survival %	Mean height m
1	57-017	L. sibirica	USSR, Hakassk. Auton. oblast, Sarala 54°50'N, 89°10'E	4 + 9	925	10.6	4.77
2	58-105	L. sukaczewii	USSR, Sverdlovsk oblast, Staraja Ljalja 59°05'N, 59°50'E	4 + 4	425	34.7	3.75
3	58-117	L. sukaczewii	USSR, Archangelsk oblast, no locality given	3	75	81.3	3.61
4	58-118	L. sibirica	USSR, Hakassk. Auton. oblast, approxim. 53°N, 90°E	4 + 3	325	8.0	4.70
5	58-122	L. sibirica	USSR, Altaiskij kraj, approxim. 52°N, 85°E	4	100	14.7	4.58
7	58-120	L. sibirica	USSR, Altaiskij kraj, approxim. 52°N, 85°E, 700 m	4	100	6.7	3.21

As can be seen, the survival of the origins from Altaiskij kraj and the Hakasskoi aut. oblast is almost the same and very low. In the same experiment there is one origin from the eastern slopes of the Ural, fairly close to the old Nishnij Tagilsk-area, and this origin is clearly better than those from more south but even this source is not adapted well enough. In contrast to these, stays the origin from the Archangelsk oblast, although it must be noted that this source is represented by much fewer plants.

The continuous lack of seed of kno origin from northern sources has, far, prevented us from making a lar provenance experiment. On the oth hand, data from the early development cultivations from domestic seed sourc are now available. These experimen were planted in 1974 and 1976 repeated, randomized block experimen and the location and design is shown table 2.

Table 2. Location and design of the Larix-experiments.

Exp. No.	Locality	Lat. N	Long. E	Alt. m	Number of repl.	Plants/ plot	Establ. year	Age of plants	Remarks
501/1	Pello. Ruuhijärvi	66°57'	24°36'	300	6	49	1974	1+1	
501/2	Rovaniemi, Hirvas	66°26'	25°13'	120	6	49	1974	1+1	
501/3	Simo, Ahmavaara 1)	66°05'	25°40'	100	6	49	1974	1+1	
	2)	66°05'	25°29'	150	6	49	1974	1+1	
501/4	Rovaniemi, Tiskivaara	66°30'	25°04'	170	1	59-242	1974	1+1	
556/1	Simo, Yli-Kärppä	65°46'	25°42'	95	10	49	1976	1+1	Autumn plant.
556/3	Kittilä, Kolvalehto	67°57'	25°22'	230	10	49	1976	1+1	"
556/4	Savukoski, Kesäyön-kuusikko	67°31'	27°43'	220	10	49	1976	1+1	"
556/5	Salla, Isomaa	66°39'	28°22'	300	10	49	1976	1+1	"

These experiments were assessed in 5 year intervals and the results are presented in table 3 and table 4.

As can be seen from table 3 the survival had decreased somewhat through the years the mean being in 1979 = 66.1 % and in 1984 = 51.2 %. The variation between the different sites is not very high, neither the variation between seed sources with the exception of the provenances 11 Vuomanlehto and 15 Hannukkalanniemi.

Table 3. Survival in the experiments No. 501/1 - 501/4, assessed in 1979 and 1984 except exp. 501/4 which was not measured in 1984.

Lot No.	Seed No.	Provenance	501/1 1979	501/1 1984	501/2 1979	501/2 1984	501/3 1979	501/3 1984	501/4 1979	X̄ 501/1-4 1979	X̄ 501/1-3 1984	Rank 1984
1	M29-70-90	Rovaniemi, Hirvas	64.0	51.4	73.7	60.4	46.7	34.8	82.0	66.6	48.8	16
2	M29-70-26	" , " , P6105	57.1	48.0	64.6	64.6	63.6	51.7	71.4	64.2	54.7	12
3	M29-70-27	" , (P.Nylander)	67.0	59.9	72.4	62.6	56.7	47.8	83.2	69.8	56.7	10
4	M29-70-28	" , Rautiosaari	63.6	42.9	62.8	49.1	46.2	28.7	-	57.5	40.2	19
5	M29-70-29	" , Maatalousoppilait.	60.2	58.2	60.5	50.2	51.7	48.3	79.6	63.0	52.2	13
6	M29-70-30	" , (P.Paakkolanvaara)	43.2	39.8	60.1	52.2	68.0	57.1	85.5	64.2	49.7	15
7	M29-70-31	Kittilä, hoitoalueen piha	77.2	68.7	81.2	71.6	70.8	65.0	57.6	71.7	68.4	2
8	M29-70-32	" , Alakylä	50.0	47.6	81.4	75.2	66.0	60.2	80.1	69.4	61.0	7
9	M29-70-33	Tervola, (Elsa Lumpus)	56.5	55.4	77.7	77.6	63.0	61.2	58.5	63.4	64.8	5
10	M29-70-34	Kemi, Liedakkala (Niemi Niem.)	40.5	24.8	80.3	54.8	61.6	41.5	13.6	48.9	40.4	18
11	M29-70-51	Kolari, Vuomanlehto	28.9	6.1	65.8	9.4	36.0	7.5	-	43.5	7.6	22
12	M29-70-86	" , Aitamännikkö	75.6	75.5	86.6	79.2	66.4	64.6	32.4	65.3	73.1	1
13	M29-70-88	Ylitornio, Vaarasaari	60.5	36.0	85.0	66.7	52.0	32.6	70.2	66.9	45.1	17
14	M29-70-91	" , Aavasaksa	61.6	55.4	87.8	79.6	54.3	53.6	88.6	73.1	62.8	6
15	M29-70-92	" , Hannukkalanniemi	46.9	17.4	68.5	20.1	47.5	6.8	-	54.3	14.7	21
16	M29-71-59	Rovaniemi, Hirvas	61.6	48.6	84.8	67.7	-	-	-	73.2	58.2	9
17	M29-71-60	" , Muurola	68.7	53.7	84.3	76.3	-	-	69.6	74.2	65.0	4
18	M29-71-61	Kemi, Törmä (E.& P.Vaahtola)	61.9	43.5	89.0	75.0	-	-	81.9	77.6	59.3	8
19	M29-71-62	" , Liedakkala (Niemi Niem.)	49.7	27.9	85.6	67.0	68.4	59.7	78.2	70.5	51.5	14
20	M29-71-63	Simo, Simonniemi	58.2	19.0	92.3	51.1	64.6	42.2	64.9	70.0	37.4	20
21	M29-71-64	Tervola, Saares	71.4	53.1	88.7	82.9	69.4	63.6	77.6	76.8	66.5	3
22	T3-71-sv16	Hausjärvi, seed orchard No.16	67.4	54.4	85.2	69.8	60.9	43.5	-	71.1	55.9	11
Mean of experiment, %			58.7	44.9	78.1	62.0	58.3	46.9	69.1	66.1	51.2	

Table 4. Survival in the experiments 556/1 - 556/5, assessed in 1980 and 1985.

Lot No.	Seed No.	Provenance	556/1 1980	556/1 1985	556/3 1980	556/3 1985	556/4 1980	556/4 1985	556/5 1980	556/5 1985	$\bar{X}$ 1980	$\bar{X}$ 1985	R 1
1	T3-71-SV16	Hausjärvi, seed orchard No. 16	61.1	55.6	41.0	11.6	29.9	5.8	67.5	65.9	49.9	34.7	
2	M29-70-26	Rovaniemi, Hirvas, P6105	65.3	63.3	60.8	27.2	51.0	14.9	85.4	83.1	65.6	47.1	
3	M29-70-32	Kittilä, Alakylä	47.7	42.0	53.6	18.3	46.1	16.7	80.0	73.0	56.8	37.5	
4	M29-71-62	Kemi, Liedakkala, (Niemi Niem.)	50.7	47.2	50.2	14.8	39.4	10.2	72.7	67.8	53.2	35.0	
5	M29-71-64	Tervola, Saares	64.2	60.0	63.0	27.6	59.6	21.8	73.9	67.4	65.2	44.2	
6	M29-70-86	Kolari, Aitamännikkö	53.4	50.0	64.2	52.9	67.8	45.0	85.2	79.4	67.6	56.8	
7	M29-71-63	Simo, Simonniemi	62.8	54.5	58.1	17.5	43.4	8.2	73.2	61.1	59.4	35.3	
8	M29-70-92	Ylitornio, Hannukkalanniemi	52.6	32.6	51.1	9.7	29.0	5.3	-	-	44.2	15.9	
9	M24-70-50	Kuhmo	26.3	22.1	17.0	1.4	16.2	3.3	35.0	32.1	23.6	14.7	
Mean of experiment, %			53.8	47.4	50.7	18.2	42.1	12.9	72.4	66.7	54.0	35.7	

The survival in the experiment No. 556 is a little lower than in the experiment No. 501 but the differences are not large except for the plantations 556/3 and 556/4 where a radical change seems to have taken place between 1980 and 1985. Both experiments are situated in the northern parts of the testing area and the site of experiment 556/4 is a very dense, cold, silty soil. It might well be, that although the plants have grown well at the beginning a combination of these soil conditions and a cold summer has been too much for most of the sources. The provenance Kolari, Aitamännikkö (6) is, however, an exception and is in both cases growing better.

In experiments 501 as well as in 556 the seed source Hausjärvi seed orchard No. 16 was included, and it is encouraging that its performance does not differ too much from the others.

In the experiments here described no comparisons were made with native species, but the same seed sources were partly used also in the species trials whose results are reported as a poster at this meeting. In these experiments the survival rate for larch is around the same as for Scots pine, in some cases a little better in some cases a little worse.

In passing, it might be asked, could good results be obtained by using Scots pine from the same region as the larches? In Northern Finland I have only one experiment (No. 357 at Sotkamo, Loukka, Lat. 63°52' N, Long. 28°17' E, Alt. 300 m), where two eastern pine sources are included. The survival at age 18 years in this experiment is as follows:

Scots pine	%
Sotkamo (local)	24.7
Ranua	64.1
Salla	54.6
Kuusamo	43.9
Enontekiö	43.2
Posio	37.1
Archangelsk obl. Čekujevo	28.3
Olonets obl. Zaonetzsk	8.0

Siberian larch	%
Kitee	45.9
Kemi	43.7

Norway spruce	%
Hyrynsalmi	69.4

Thus, it seems, that it is better to tı only larch in transfers to the west i our conditions.

GROWTH AND YIELD

The general growth and yield of Siberia larch in Finland is well documente (Vuokila 1960). As in the case of th survival, comparative information abou growth and yield in the north i difficult to extract from the oldes plantations. From the paper by Neval (1980) we can see that the total yiel from a 67 year old stand in Kuusamo wa 154 m³ solid volume under bark.

In the paper by Lähde et al. mentione earlier are reported the latest result from the Kivalo plots. From these migh be quoted.

Origin/provenance	Age	Total yield overbark m^3/ha
Archangelsk area	52	162
Nishnij Tagilsk	50	100
Raivola	55	235
Raivola	36	85

The height development of younger stands are recorded from the experiments No. 501 and 556 and are presented in tables 5 and 6.

Table 5. Mean height, cm, in the experiments No. 501/1 - 501/4, assessed in 1979 and 1984 except exp. 501/4 which was not measured in 1984.

Lot No.	Seed No.	Provenance	501/1		501/2		501/3		501/4	x̄ 501/1-4	x̄ 501/1-3	Rank
			1979	1984	1979	1984	1979	1984	1979	1979	1984	
1	M29-70-90	Rovaniemi, Hirvas	44.3	108.5	79.7	153.4	58.0	176.2	68.2	62.5	146.0	10
2	M29-70-26	" , " , P6105	48.8	127.0	64.9	150,0	64.2	196.2	65.0	60.7	157.7	3
3	M29-70-27	" , (P.Nylander)	45.7	101.5	68.9	119.1	54.2	152.2	62.1	57.7	124.3	20
4	M29-70-28	" , Rautiosaari	38.3	93.4	67.0	140.0	53.4	149.7	-	52.9	127.7	19
5	M29-70-29	" , Maataloúsoppilait.	48.0	128.6	63.7	125.7	59.2	184.6	63.6	58.6	146.3	9
6	M29-70-30	" , (P.Paakkolanvaara)	41.5	103.5	72.9	165.0	62.2	198.2	59.5	59.0	155.5	5
7	M29-70-31	Kittilä, hoitoalueen piha	45.8	119.5	79.1	151.6	68.0	214.9	58.0	62.7	162.0	2
8	M29-70-32	" , Alakylä	48.5	125.0	71.5	145.8	58.1	180.4	53.9	60.0	150.4	7
9	M29-70-33	Tervola, (Elsa Lumpus)	39.2	112.4	75.8	152.7	64.9	190.3	42.8	55.7	151.8	6
10	M29-70-34	Kemi, Liedakkala (Niemi Niem.)	32.9	92.1	72.1	126.1	53.0	184.7	48.6	51.6	134.3	18
11	M29-70-51	Kolari, Vuomanlehto	46.4	115.6	66.3	150.6	51.4	163.0	-	54.7	143.0	12
12	M29-70-86	" , Aitamännikkö	41.8	105.7	71.0	140.6	59.4	184.5	55.7	56.9	143.6	11
13	M29-70-88	Ylitornio, Vaarasaari	38.2	80.3	70.8	134.6	51.0	138.1	49.3	52.3	117.6	22
14	M29-70-91	" , Aavasaksa	40.2	99.9	75.6	142.6	58.4	171.8	45.7	55.0	138.1	15
15	M29-70-92	" , Hannukkalanniemi	38.6	96.6	58.9	122.6	53.7	184.4	-	50.4	134.5	17
16	M29-71-59	Rovaniemi, Hirvas	52.3	145.4	78.6	148.6	-	-	-	65.4	147.0	8
17	M29-71-60	" , Muurola	46.7	113.6	82.5	156.0	-	-	53.3	60.8	134.8	16
18	M29-71-61	Kemi, Törmä (E.& P.Vaahtola)	40.1	93.5	78.4	151.1	-	-	53.2	57.2	122.3	21
19	M29-71-62	" , Liedakkala (Niemi Niem.)	38.0	109.4	73.6	120.2	55.6	189.1	46.7	53.5	139.5	13
20	M29-71-63	Simo, Simonniemi	40.3	85.5	77.3	125.8	61.0	205.5	59.0	59.4	138.9	14
21	M29-71-64	Tervola, Saares	46.5	106.0	82.4	149.8	62.6	211.0	66.9	64.6	155.6	4
22	T3-71-sv16	Hausjärvi, seed orchard No.16	48.5	112.8	83.7	155.6	70.7	259.5	-	67.6	175.9	1
Mean of experiment, %			43.3	108.2	73.4	142.2	58.7	183.9	56.0	58.1	143.0	

Table 6. Mean height, cm, in the experiments 556/1 - 556/5, assessed in 1980 and 1985.

Lot No.	Seed No.	Provenance	556/1		556/3		556/4		556/5		x̄	x̄	Rank
			1980	1985	1980	1985	1980	1985	1980	1985	1980	1985	1985
1	T3-71-SV16	Hausjärvi, seed orchard No. 16	70.9	138.6	37.1	85.3	27.4	40.7	60.3	202.6	48.9	116.8	3
2	M29-70-26	Rovaniemi, Hirvas, P6105	75.6	156.5	43.8	67.9	29.1	50.9	61.7	208.2	52.5	120.9	1
3	M29-70-32	Kittilä, Alakylä	61.7	120.3	43.7	86.4	29.8	44.3	56.3	170.8	47.9	105.4	5
4	M29-71-62	Kemi, Liedakkala, (Niemi Niem.)	52.0	109.9	28.8	59.0	21.9	27.2	51.2	168.3	38.4	91.1	7
5	M29-71-64	Tervola, Saares	64.7	146.7	36.6	87.2	28.1	44.7	53.7	188.6	45.8	116.8	3
6	M29-70-86	Kolari, Aitamännikkö	58.6	139.8	38.7	90.3	28.3	64.1	58.7	186.9	46.1	120.3	2
7	M29-71-63	Simo, Simonniemi	61.9	135.4	38.7	80.0	25.8	37.8	52.2	167.0	44.6	105.1	6
8	M29-70-92	Ylitornio, Hannukkalanniemi	58.1	109.9	38.5	68.6	24.4	26.9	-	-	40.3	68.5	8
9	M24-70-50	Kuhmo	70.3	142.9	37.2	93.9	27.4	50.3	47.9	166.8	45.7	113.5	4
Mean of experiment, cm			63.8	133.4	38.2	79.8	26.9	43.0	55.3	182.4	45.6	106.5	

As can be seen the height development is very similar in both experiments as well as in all provenances.

It might be noted, that the height of the seed orchard source in both experiments is fairly good.

If we again refer to the poster the height growth has been compared for larch and Scots pine and the mean height is in the latest measurements very much the same. Why the superiority in height of the larch at young age is now disappearing is not yet clear.

A look at the damages by climate, diseases and pests is therefore necessary.

DAMAGES DISEASES AND PESTS

Generally speaking, the Siberian larch has in Finland been free from climatic damages. Not even the spring frost, which has prevented the cultivation of this species in Central and Western Europe has damaged the vegetative growth. The generative development, on the other hand, is frequently disturbed, and damaged meiosis and frozen flowers are in many cases the cause of poor seed production.

But in recent years, when the cultivation of the Siberian larch has extended further north, reports are increasing about frost damages on the leading shoots. In this case, it is the question of early frost in the autumn or early winter. This is a sign of poor adaptation to the length of the growing period and must be further studied in all provenances. If the top shoot is repeatedly cut back by frost it is understandable that the height growth will suffer.

The diseases and pests of Siberian larch are well known (Rozhkov 1970) but very few diseases have been recorded in Finland and none of them have been serious.

Of the pests, there were in the earlier reports observation of damages by the aphid Adelges laricis Vallot and epidemics of this insect could be dangerous for the development of larch stands. In recent times, this pest seems to be increasing again in young larch plantations. A close look should therefore be kept on the situation and preventive measures taken, when necessary.

More damage has been caused by vertebrates. The elk has damaged stems and shoots in many cultures anc especially in the older days. tl plantations and sowings were damaged l reindeer.

A particular pest is the vole who : certain years can make great damage. : the winter 1978 - 79 the voles kille 96 % of the plants in the experimer 556/2 belonging to the series her discussed.

Also the hare has been found to ea young plants in the winter time.

There are up to now no observatior about possible differences between tl seed sources as far as diseases ar pests are concerned.

SILVICULTURE

It has not been made too many studie about the silvicultural aspects of larc cultivation. In the oldest day plantation as well as sowing were usec but lack of seed and the improvement c the nursery techniques have in recer years led to the almost exclusive use c planting.

In my experience the planting of 1 + or 1 + 1 + 1 stock is better than 2 + or 1 + 2, that is, the rapid developmer of the larch roots has to be checked t frequent transplantation.

When growing containerized plants car should be taken to protect the root well with snow or other means. A mentioned earlier, a severe winter col may cause damages on unprotecte seedlings.

In some cases the method of sowing migh have advantages and an experiment ha recently been laid out at the Toivonien research station as a cooperatic between Helsinki University and tł Forest Research Institute.

Plantation in the autumn has bee successful in our experiment No. 556 ar this method should perhaps be mor frequently used.

Russian experts have told me that als sowing in the late autumn might give beneficial seed stratification and good start in the spring. When mor seeds are available this should t tried.

Most of the plantations in Norther Finland have been established as pur larch stands at a fairly wide spacing It is well known that the crown of th larch is sensitive to stand density ar that larch stands should be kept light by frequent thinnings.

One might, however, consider, whether not in the north the larch could be used also in mixed cultivations, as a speculation one could think of coppice with standards together with Betula tortuosa.

Great care should be taken in selection of the right site for the Siberian larch cultures. The larch is a tree of the good slopes where aeration and water flow are suitable for its root system. It does not grow on silty soils, neither on swamps. It will not grow satisfactory on poor sites and is thus not an alternative to pine on very dry and poor soils.

For difficult soil conditions we have, perhaps, to look at other larches.

OTHER SPECIES OF LARCH

The other species of larch have been grown in the north on a very limited scale, and most of the cultures have been single trees around schools, in parks and cemeteries.

Larix decidua Mill. seems to grow fairly well where it occurs in the southern parts of the area. Big trees of unknown origin can be seen in the parks of the city of Oulu and at the Hirvas Forest School near Rovaniemi there is at least one good tree. A good young plantation, provenance Kitee, will be seen at Kivalo during the exkursion. European larch might also have been planted in the Tornio river valley but the species has not been checked, so far.

In 1912 there were planted 5 plants of European larch and 80 plants of Siberian larch as far north as at Järvenpää, north of the lake Inari (Anon. 1917). Turtiainen (1969) reported that more than 20 trees were still growing but did not specify which species.

Larix gmelini var. japonica (Maxim. ex Regel) Pilg. has also been planted as an ornamental at the forestry school at Hirvas. One tree has been recorded in the Swedish city of Haparanda on the Swedish/ Finnish border (Julin 1959). A small plantation was made in the 1950ies at Kivalo.

Recently a small seed lot was obtained from a very northern source at Magadan in the Soviet Union, Lat. 59°38' N, Long. 151°50' E. This origin which might represent the species Larix gmelinii Rupr. the true Dahurian larch, has been planted in the forest limit experiments at Utsjoki in 1980. The survival of these plants after three seasons in the field in the autumn of 1982, was 89,5 %.

The Kurilean and maybe Dahurian larches should perhaps be tried on swamp soils where they seems to occure in their natural area (see e.g. Luukkanen 1977). If northern origins from Kamchatka or from the Magadan region could be obtained it could be an alternative at least in the Oulu region and, perhaps, in southernmost Lapland where bogs of good type are common.

So far the only larch species tried on swamp soils is the tamarack, Larix laricina (Du Roi) R. Koch. Also for this species the experiences are very limited.

At the Kolari research station there is a tamarack plantation from seeds obtained from Fairbanks, Alaska which has been growing quite well and has not in the beginning been attacked by voles. In another experiment with several origins from Alaska at the same place vole damages have occurred.

In the Utsjoki trials there are two origins from Alberta and Saskatchewan which, after three years, had survived 93.8 % and 96.9 % respectively.

The tamarack plantations are too young for a judgement of the possibilities of this species but it is one of the larches for which much more trials with northern seed sources should be planted.

Larch hybrids have not at all been tried in the northern parts of Finland but have given good results in the south. It might be considered if not hybrids between Siberian and European larch should be tried in the best climate and perhaps also the hybrid between Siberian and Kurilean larch on swamp soils.

Of provenance hybrids we have no results in the north and also in the south the experiences are limited. A cross made between trees from Pinega and trees from Nishni Tagilsk did not show heterosis compared with the pure provenances. More southern provenances have not been tried yet.

CONCLUSIONS

On the basis of experiences hitherto, it may be concluded that the Siberian larch is a promising exotic for cultivation in the northern parts of Finland.

Great attention must be paid to the use of the right seed sources. Results, so far obtained, indicate that the origins from the western parts of the species' range are to be preferred. Further experiments with northern sources, e.g. Mesen, Petchora etc., should be established, could only seed samples be obtained.

Local seed sources from old plantations can be used, but the results given should be observed. Seed orchards with plus tree material from the northern cultures should be - and in fact are - established.

On the right site and with the right origin the yield of Siberian larch might be of the same magnitude or slightly better than the yield of Scots pine. Comparisons with other exotics must wait.

These conclusions are very similar to those of Edlund (1966). Future activities should concentrate on breeding Siberian larch further, on provenance trials with tamarack and on limited experiments with other larch species and hybrids in the southern parts.

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RESEARCH ON LARIX LARICINA IN SWEDEN

Milan Simak and Evert Jeansson

ABSTRACT: Seventy sources of tamarack (*Larix laricina*) from Canada and the USA were analysed in different experiments in Sweden. Seed weight increases from the western to the eastern part of the American continent. Tamarack showed very sensitive reactions to photoperiod and to intermittent light, which can be used in practice when growing seedlings in greenhouse. A series of 12 provenance trials was laid out in Sweden between lat. 55°35' and 65°05'N. In general, tamarack provenances can be planted in Sweden 7-8 degrees more towards the north than what is the latitude of its origin. The maximum survival coincides rather well with the maximum growth. Different types of damage to tamarack occurring on these experiment plots were discussed.

INTRODUCTION

Tamarack, *Larix laricina* (Du Roi) R. Koch, occurs naturally in the whole of Canada with the exception of large parts of B.C., Yucon, the southern parts of Alberta, Saskatchewan, and the northernmost parts of Canada. It also grows in the USA around the Great Lakes and in Alaska.

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This is an area roughly limited by longitudes 53°-150°W and latitudes 40°-68°N. In the western parts of its natural range, it ascends to elevations of 500 m and in the eastern part up to 1200 m. It occupies all types of soils but usually swampy lands, etc. where the competition with other tree species is not so hard. Tamarack frequently grows with one or more associates, the most common ones are black spruce, northern white-cedar, balsam fir, paper birch, quaking aspen, eastern white pine, red maple, black ash, white spruce and American elm. Associates vary geographically and according to site conditions (Rudolf, 1966).

Table 1 Seed sources used in the experiment

P no	Ex no	State	County	Lat. N °	Lat. N '	Long. W °	Long. W '	Alt. m	1000 seed weight g. Fill.	1000 seed weight g. Empty	Empt. %	Col. Y.
1	11	ALASKA	TANANA RIVER	65	00	147	30	150	1.15	.	21	71
2	118	N.W.T.		58	58	111	40	229	.	.	41	64
3	110	ALBERTA	WATERWAYS	56	39	111	14	335	1.61	0.68	30	64
4	7	B.C.	FORT ST. JOHN	56	38	120	35	732	1.87	.	2	68
5	12	SASKATCHEWAN	BUFFALO NARROWS	56	05	108	55	427	2.13	.	.	71
6	109	MANITOBA	THE PAS	53	55	101	15	260	1.55	0.79	41	64
7	13	SASKATCHEWAN	MEADOW LAKE	53	50	108	40	640	1.84	.	1	.
8	1	ALBERTA		51	00	101	00	740	1.66	.	0	69
9	117	MANITOBA	WINNIPEG	50	05	95	25	229	2.05	0.92	24	64
10	132	ONTARIO	GURNEY TWP	49	30	82	14	213	1.82	0.85	75	64
11	3	QUEBEC	CHAGEL	48	55	79	03	290	2.19	.	30	70
12	16	QUEBEC	PREISSAC	48	30	78	15	.	2.18	.	.	.
13	4	QUEBEC	ROBERVAL	48	26	72	16	336	2.47	.	30	70
14	23	QUEBEC	ROBERVAL	48	26	72	16	.	2.47	.	6	70
15	116	MICHIGAN	ISLE ROYALE	48	05	88	42	186	.	.	89	64
16	112	MINNESOTA	ST. LOUIS	48	02	91	37	397	1.89	0.94	47	64
17	5	QUEBEC	PREISSAC	48	01	78	17	321	.	.	1	70
18	20	QUEBEC	GUERIN	47	45	79	20	.	2.19	.	1	.
19	17	QUEBEC	LAKE LORTIE	47	40	74	15	.	2.28	.	5	.
20	6	QUEBEC	SEIGN D.L.MALBAIE	47	40	70	20	244	1.58	.	35	70
21	21	QUEBEC	CABANO	47	39	68	57	.	2.30	.	.	.
22	2	QUEBEC	CABANO	47	39	68	57	244	2.29	.	16	70
23	158	MINNESOTA	ITASCA	47	31	94	05	396	1.64	0.83	59	64
24	15	QUEBEC	LA MALBAIE	47	20	70	20	.	2.27	.	.	.
25	103	MINNESOTA	ITASCA	47	07	93	20	389	1.55	0.73	63	64
26	128	MICHIGAN	HOUGHTON	47	01	88	25	201	2.16	0.92	30	64
27	101	MINNESOTA	ST.LOUIS	47	00	93	00	387	1.81	0.71	27	64
28	18	QUEBEC	RADNOR	46	45	72	50	.	2.43	.	.	.
29	102	MINNESOTA	CARLTON	46	42	92	31	335	2.29	0.92	46	64
30	9	NOVA SCOTIA	CHIGNECTO	46	35	64	25	80	.	.	.	.
31	22	QUEBEC	LANGEVIN	46	21	70	22	.	2.39	.	.	.
32	120	MICHIGAN	ALGER	46	21	86	20	244	1.83	0.87	24	64
33	153	MICHIGAN	ALGER	46	20	86	20	244	2.07	0.91	59	64
34	154	MICHIGAN	ALGER	46	20	86	20	244	1.95	0.94	37	64
35	122	MICHIGAN	CHIPPEWA	46	19	84	14	183	1.95	0.94	31	64
36	160	MICHIGAN	GOGEBIC	46	15	89	10	488	1.87	0.79	59	64
37	14	QUEBEC	BERTHIER PARTAGE	46	15	73	15	.	2.18	.	.	.
38	19	QUEBEC	LAKE CHERTSEY	46	11	73	52	.	2.21	.	2	.
39	10	NOVA SCOTIA	BEDDECK	46	07	59	45	30	.	.	.	.
40	8	NEW BRUNSWICK	ACADIA FOREST	46	00	66	20	98	2.36	.	.	.
41	124	ONTARIO		46	00	77	26	146	1.99	0.87	76	64
42	151	WISCONSIN	FOREST	45	48	88	56	457	1.60	0.91	59	64
43	152	WISCONSIN	ONEIDA	45	46	89	12	366	1.40	0.95	46	64
44	127	MAINE	SOMERSET	45	38	70	16	362	2.35	0.96	35	64
45	100	MINNESOTA	ANOKA	45	10	93	05	244	2.00	0.93	76	64
46	125	VERMONT	FRANKLIN	44	57	73	05	70	2.22	0.97	86	64
47	131	NOVA SCOTIA	ANNAPOLIS	44	48	65	03	229	2.36	0.96	56	64
48	119	WISCONSIN	SHAWANO	44	38	88	27	235	2.00	0.86	83	64
49	114	VERMONT	LAMOILLE	44	30	72	37	229	2.31	1.02	29	64
50	118	MAINE	MT. DESART IS.	44	30	68	00	30	2.14	1.02	41	64
51	155	MICHIGAN	WEXFORD	44	15	85	31	393	1.36	0.87	70	64
52	156	MICHIGAN	WEXFORD	44	14	85	32	396	1.58	0.85	90	64
53	121	MICHIGAN	WEXFORD	44	13	85	30	393	2.09	1.06	23	64
54	111	WISCONSIN	TREMPEALEAU	44	09	91	28	224	1.97	0.93	68	64
55	157	WISCONSIN	LACROSSE	43	51	91	08	206	2.36	1.00	53	64
56	129	ONTARIO	OXFORD	43	13	80	35	297	2.19	0.92	51	64
57	113	MICHIGAN	LIVINSTON	42	30	83	30	274	1.73	0.80	68	64
58	145	MICHIGAN	LIVINGSTON	42	30	84	20	244	1.87	1.04	81	64
59	147	MICHIGAN	LIVINGSTON	42	29	84	20	244	1.88	0.83	62	64
60	148	MICHIGAN	LIVINGSTON	42	29	84	20	244	2.13	0.96	87	64
61	149	MICHIGAN	INGHAM	42	28	84	50	244	2.23	1.15	81	64
62	130	ILLINOIS	LAKE	42	27	88	02	244	2.38	0.89	62	64
63	146	MICHIGAN	LIVINGSTON	42	27	84	25	244	2.02	0.91	82	64
64	115	MICHIGAN	KALAMAZOO	42	23	85	22	256	1.92	0.94	64	64
65	133	CONNECTICUT	LITCHFIELD	41	51	73	16	439	1.67	1.07	96	64
66	126	PENNSYLVANIA	LACKAWANNA	41	15	75	39	598	2.58	1.16	82	64
67	105	MARYLAND	GARRETT	39	42	78	56	820	2.22	1.01	80	62
68	106	MARYLAND	GARRETT	39	42	78	56	820	1.98	0.87	77	62
69	161	B.C.	.	.	.	.	.	.	1.28	0.57	66	.

P no = Provenance number Ex no = Suppliers number

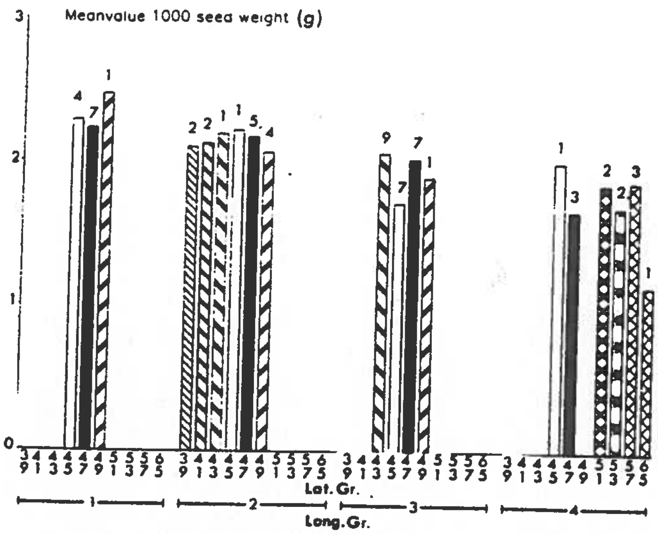

Figure 1. Weight of 1000 filled seeds for provenances of Larix laricina gathered in latitude and longitude groups. Each latitude group comprises 2 lat.degr. Longitude group 1 = 58-73; 2 = 73-83; 3 = 83-93; 4 = 93-148. Figures above the columns indicate number of sources analysed within the respective latitude group.

Tamarack was regarded for a long time as a less interesting species in American forestry. Only in recent years the foresters became more aware of this larch which on well-drained sites shows the fastest juvenile growth among the boreal Conifers growing on similar sites (Mac Gillivray 1962, Johnston 1973, Mead 1978). Several provenance experiments with tamarack have been started during the last decennia both in Canada and the USA (Pauley 1965, Sajdak 1970, Jeffers 1975, Cech, Keys & Weingartner 1977). Recently, also a breeding strategy was proposed by Park & Fowler (1982) and Simpson (1983).

In Sweden the interest in tamarack awoke in earnest about 30 years ago, principally because of its fast growth at young age and the great tolerance to growing on swampy soil types where it is difficult to grow other tree species. On these types of soils tamarack can be at least a good pioneer tree paving the way for planting other species later on. For the short rotation program of Conifers, tamarack seems to be a very good candidate both with regard to its fast growth and its good wood properties. Moreover, tamarack with its wide ecological adaptability is a suitable partner to be crossed with other better growing larch species, since the hybrids may show a better growth and survival than the parent trees (cf. Mac Gillivray 1967, 1968, Riemenschneider & Nienstaedt 1983). Especially hybrids with siberian or dahurian larch could be useful as alternative tree species for many sites in northern Sweden. These were some of the reasons why a series of different experiments was started with tamarack at the Swedish College of Forestry. Four groups of experiments are reported here: I SEED ANALYSES, II NURSERY RESEARCH, III PROVENANCE RESEARCH, and IV DAMAGE TO TAMARACK.

I SEED ANALYSES

Material and methods: Seeds to the provenance trials were supplied by different forestry organizations in Canada and the USA. Most of the seeds were received by courtesy from Prof. Pauley, Minnesota, USA (Ex. Nos. 100-161 in table 1). The same material was used in several provenance trials in the USA (Pauley 1965, Jeffers 1975). The material originates from a very wide area limited by the latitudes 39°42' N and 65°00' N and by the longitudes 59°45 W and 147°00 W. The latitudinal range of the seed sources would correspond to approximately the distance between Skellefteå (Sweden) and the southern part of Albania. Although nearly 70 seed sources were represented totally, the material does not cover satisfactorily the whole range of natural distribution of tamarack, because some areas, especially those in the northern regions, were difficult to reach for cone collection. Thus, only 5 provenances of the totally 69 originate from latitudes passing the Scandinavian peninsula. The cones were collected in autochthonous stands according to the information received from the suppliers.

Result: The technical quality of the seeds was studied at our laboratory. Some of the results of these analyses can be of interest to be presented here. This species has the smallest

Table 2 Larix laricina plots laid out 1973-1974 in Sweden

Plot No.	Locality	Long. W	Lat. N	Alt. m	Area m^2	Planted year	No. of provenances 1/ L.l.	P.s.	P.a.	B.v.	Exp. 2/ type	No. of plants/ prov.
1901	Svevekull	14°08'	55°35'	80	3600	1973	53	1	1	2	PP	30
1902	Svevekull	14°08'	55°35'	80	2451	1973	54	1	1	1	D	-
1903	Svevekull	14°08'	55°35'	80	1800	1974	20	-	-	-	LN	20
	Remningstorp											
1904	" Jonstorpsmossen	13°36'	58°28'	115	9000	1974	55	2	2	1	PP	40
1905	" Jonstorpsmossen	13°36'	58°28'	115	2500	1974	53	2	2	1	D	-
1906	" Jonstorpsmossen	13°36'	58°28'	115	2160	1974	20	-	-	-	LN	20
1907	" Storängen	13°37'	58°28'	125	4500	1974	45	2	2	1	PP	30
1908	" Storängen	13°37'	58°28'	125	2160	1974	20	-	-	-	LN	20
1909	Röskär	18°10'	59°25'	30	432	1974	20	-	-	-	LN	12
1910	Bärmyren, Håknäs	19°35'	63°32'	30	2200	1973	9	1	-	1	PP	50
1911	Bärmyren, Håknäs	19°35'	63°32'	30	1650	1973	9	1	-	1	PP	50
1912	Bärmyren, Håknäs	19°35'	63°32'	30	1452	1973	9	1	-	1	PP	33
1913	Bärmyren, Håknäs	19°35'	63°32'	30	2200	1973	9	1	-	1	PP	50
1914	Höglunda, Sörmjöle	19°57'	63°43'	50	9500	1973	10	1	1	1	PP	90
1915	Höglunda, Sörmjöle	19°57'	63°43'	50	9500	1973	10	1	1	1	PP	90
1916	Falträsk, Lycksele	18°30'	64°48'	250	5500	1973	9	1	1	1	PP	75
1917	Falträsk, Lycksele	18°30'	64°48'	250	500	1973	9	1	1	1	D	-
1918	Falträsk, Lycksele	18°30'	64°48'	250	480	1973	9	1	1	1	P	10
1919	Rökå, Malå	18°53'	65°02'	325	3360	1973	9	1	1	1	P	10
1920	Rökå, Malå	18°53'	65°02'	325	1440	1973	9	1	1	1	D	2
1924	Enafors	12°20'	63°18'	560	360	1974	20	-	-	-	LN	10
1925	Storbränna	20°45'	65°05'	205	1080	1974	20	-	-	-	LN	10
1926	Höglunda, Sörmjöle	19°57'	63°43'	65	520	1973	10	1	1	1	D	-

1/ L.l. = Larix laricina, P.s. = Pinus silvestris, P.a. = Picea abies, B.v. = Betula verrucosa
2/ PP = provenance plot, single tree parcel, LN = LN-treated plants; D = demonstration plots, rows

seeds among all larch species. The average weight of 1000 pure seeds rarely exceeds 2 grams. Filled seeds were separated from empty ones in most of the samples by the aid of x-radiography and the thousand-grain weight of each fraction and sample was determined. The average weight of 1000 filled seeds for all the investigated sources was 2 grams and it varies between 1.15 and 2.58 grams. The weight of the empty seeds constitutes about 46 % of that of filled seeds. The mean frequency of empty seeds in the samples Ex. 100-161 was 58 % (23-96 %). Not all samples were included in this analysis, since empty seeds had been removed from some of the samples by the suppliers. The average weight of filled seeds shows a tendency to increase with decreasing longitudes, i.e. from West to East of the American continent and in western America possibly also with decreasing latitudes (fig. 1). The material is too scanty to be the subject of a detailed statistical analysis in this respect. The radiographic analyses also showed some insect infestation in some of the sources. The seeds had a good anatomical development, even those from the northernmost latitudes (P 1) and from the highest latitudes (P 67-68). The radiographic image of tamarack seeds is characteristic, as the coat in the micropylar end is characteristically pointed.

Discussion: According to earlier investigations, the frequency of empty seeds in tamarack varies between 15 and 90 % (Duncan 1954, Hall 1981). The mean frequency of empty seeds in the present material is 58 %, and a removal of those improductive seeds would be necessary in rational plant production. The relatively big difference in weight between filled and empty seeds (about 2:1) makes it easy to remove empty seeds from a seed lot by aspirator or by flotation in absolute alcohol, as has been shown by x-radiographic test. Interesting is the increasing seed weight in tamarack provenances in the direction from west to east in the natural distribution range of this species.

This direction corresponds to the way that tamarack wandered over the North-American continent after coming from Asia. Larix decidua (Simak 1967) shows similar clinal increase with the altitude from about 2.5 grams (Polish larch, about 300 m a.s.l.) to about 12 grams (Western Alpine larch, about 2000 m a.s.l.). The increasing seed weight of these two larch species could be seen as an evolutionary young character that probably made it easier for the larch to occupy new territories. Subject to the limited seed material from the marginal area of distribution, the anatomically always well developed seeds of tamarack indicate that the species is generatively well adapted as pioneer tree for climatically harsh conditions. A comprehensive study on seed ecology of tamarack in interior Alaska was carried out by Brown (1983).

II NURSERY RESEARCH

Tamarack and the other larch species are known to be strictly adapted with their photoperiodic reactions to the latitudinal position of their origin. Therefore, with respect to the wide latitudinal distribution of the present provenance material (39°42' N - 65°00 N), it stands to reason that provenances from extreme northern and southern localities could suffer as to growth and survival if raised in one central nursery. Two nursery experiments have been carried out with the aim of finding out how to counteract such problems.

a) Long-night treatment (LN-treatment) in order to accelerate the maturation processes in one-year-old plants of the southern provenances.

b) Intermittent light treatment (IM-treatment) in order to break the long-night obstructive effect on the growth of the plants of the northern provenances.

Material and methods (LN-treatment): For the LN-treatment, seeds from 16 provenances (P: 1,4,5,7,8,11,12,13,17,20,22,24,30,37,39 and 40) originating from a latitudinal range between 46°and 65°N were selected. Though P 1 originated from a much more northerly latitude than the geographical location of the experimental nursery (65°resp. 59°N), it was used in the experiment, too, in order to study its reactions on LN-treatment. Seeds of each provenance were sown in rows on each of two blocks in a plastic greenhouse at Röskär (59°24'N) on April 1, 1972. Between August 13 and October 31 the plants in one of the blocks were covered by black plastic between 16^{00} and 08^{00} daily, i.e. they were kept in artificial darkness for 16 hours (in practice, the LN-treatment can be accomplished in 3-4 weeks). Plants on the other block that were not covered by plastic served as controls (C-treatment). In spring 1973 the one-year-old plants of both treatments were transplanted on the spot. In the spring of the next year the LN- and C-plants were set out on experimental plots on six different localities (plots 1903, 1906,1908, 1909, 1924 and 1925, cf. table 2).

Result (LN-treatment): The following observations were made on the plants in Röskär nursery and field (cf. fig. 2). At the end of the first growing season in the nursery the total length of the treated plants was on an average 62 % of that of the C-plants. At that time, the LN-plants had finished their growth, set buds and lignified their shoots while C-plants were still active in growth. At the end of the first winter the C-plants were damaged by frost to 59 % of their total length while the LN-plants were in a very good condition and had higher survival than the C-plants. At the end of the second growing season, the LN-plants were about twice as high as the C-plants. As the covering experiment was performed only at the end of the first growing season, from the second growing season the LN-plants run as great risk of frost damage as the C-plants. In spite of this, three years after planting in the field the LN-plants of southern provenances in most cases still

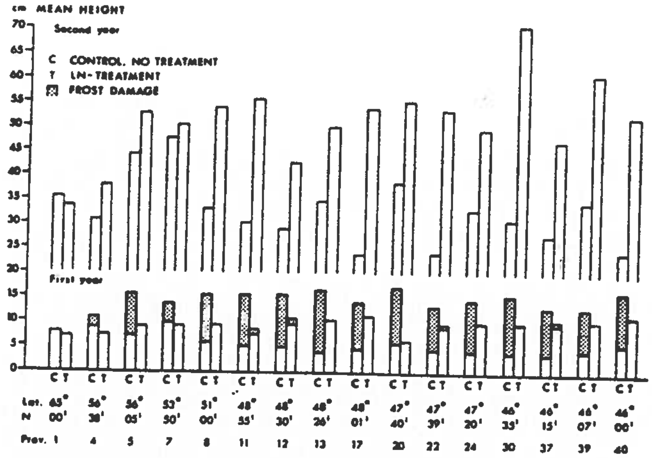

Figure 2. Comparison in mean height and frost damage between LN-treated and untreated plants of 16 provenances. LN-treatment was performed at the end of the first growing season at Röskärs nursery (Lat. 59°24'N).

showed a better development and survival than the C-plants (Simak 1974 and 1977).

The northernmost provenance (P 1) diverges from this general trend because it originates from 65°C, i.e. six degrees more northerly than the experimental nursery. C-plants of this provenance showed poor vigour, since they had to grow at a shorter day length than that in their natural habitat. Moreover, the condition of the LN-plants was still inferior to that of the C-plants because the short growing season in the nursery was additionally shortened by the covering. Northern provenances cultivated in a southern nursery require a prolonged photoperiod, otherwise they will finish their growing season too early. A prolonged photoperiod can be achieved by IM-treatment.

Tamarack plants of particular origin stop growing and start setting buds when the increasing night length in autumn exceeds the so-called "critical night length". These reactions are genetically controlled. Nights longer than the critical night length can be split up by IM into two "short nights" to which the plants will then adjust their reactions as to two separate short nights, i.e. the plants will continue to grow and bud initiation does not occur. The length

IM- lux	1000	250	110	60	40	0
Mean height, cm	5.0 ±0.3871	4.6 ±0.4456	2.0 ±0.3195	1.9 ±0.0976	1.8 ±0.1204	1.1 ±0.0484
% seedlings with term. buds	5	8	33	87	70	97

Figure 3. Height of the plants and bud setting at the end of the IM-treatment at different light intensities.

and intensity of IM vary for different species (Simak 1975, Ericsson & Simak 1977).

Material and methods (IM-treatment): The northernmost provenance, P 1 (65°N), was selected for IM experiment. Seeds were sown one by one in boxes in a plastic greenhouse at Röskär. The boxes with the plants were placed at five different distances from an artificial light source (Sylvania Grolux, VHO-WS 215 W) which was switched on automatically every night between 00.00 - 01.00 during the period July 18 - September 15. (In practice, one starts and finishes the IM-treatment at an earlier date than in this pilot study in order to get a longer growth period and well maturated plants before winter comes). Otherwise, the plants were exposed to the prevailing environmental conditions in the greenhouse. The light intensities of the IM at different distances from the light source were 1000, 250, 110, 60, 40 lux. The control plants were grown under normal night conditions. After the IM treatment, bud development and height growth were determined for each plant.

Result (IM-treatment): A light intensity of about 300 lux during IM treatment was enough to nullify the inhibitory influence of the long night on plant growth. The height of the plants in the series 250 - 1000 lux was four to five times that of the controls. The bud setting was effectively prevented by IM. Even the plants exposed to 40 lux were significantly taller than the control plants (fig. 3). More details about this experiment in which also Pinus silvestris and Picea abies were IM treated, are given by Simak (1975).

Discussion (LN- & IM-treatments): Our experiments with tamarack in the nursery showed that the untreated southernmost provenances grew late into the autumn and thus the most tardy plants within a provenance were damaged or eliminated by early frost. A new population of surviving plants with another genetic constitution than the original population was thus formed. Also the untreated northern provenance, P 1, showed very poor development in the southerly located nursery due to the less appropriate photoperiodicity. Of course, plant material raised like this is not suitable for a provenance experiment. The selection and treatment of plants during the first year in the nursery influence the plant growth and reactions during the following years and thus an interpretation of the results of the field experiments can point in the wrong direction. It is therefore desirable that a provenance test in the field is started with unbiassed plant material.

Figure 4. 1-1 plants of P 4. Left: An untreated plant; height 35 cm, Ø at the root neck = 6.1 mm, Ø at the base of the 2-year shoot = 2.4 mm. Right: An LN-treated plant; height = 74 cm, Ø at the root neck = 6.8 mm, Ø at the base of the 2-year shoot = 5.0 mm.

The nursery experiments described here showed that through LN- and IM-treatments plants of extremely southern and northern origin, respectively, can be conditioned to a level corresponding to the development they would reach if raised in their natural habitat. The LN-treated tamarack plants of southern origin, i.e. unselected and undamaged by frost, grew better than the controls, at least in the next three years after being planted in the field, thanks to their good initial condition and fast growth away from the hostile frost and competitive vegetation layer just above the ground surface (fig. 4). Similarly, the negative effect of the short photoperiod on the development of P 1-plants can be counteracted by the IM-treatment. The LN- and IM-treatments were carried out as pilot studies only on a limited material, since it was the first time in Sweden that these treatments were applied to forest tree plants under greenhouse conditions. At present both these methods are performed in Sweden by routine. Hence, the LN-method is used to produce seedlings in 2-3 turns within a growing season. The IM-method is applied in order to prevent terminal bud setting for greenhouse seedlings produced very early in the year when the still prevailing long nights outdoors would introduce dormancy to growing seedlings at cotyledon stage (Ericsson & Simak 1977). Consequently, treating all plants with LN or IM in a provenance project like this would be no problem. Of course, one could also desist from sowing seeds from sources of extreme photoperiodic reaction in a central nursery in order to avoid the described stress effects. However, raising a provenance material at different nurseries can cause other problems in this kind of experiments.

Tamarack plants are often set out in autumn, i.e. during the still progressing growing season. The success of the autumn planting is depending on many factors, particularly on the maturity of the plants. Larch provenances, even those ecologically fitted for Swedish conditions, can become sensitive to frost if taken up from the nursery bed early in autumn before they have reached full maturity. If set out in hostile field environment in the autumn such plants usually have no chance to accomplish the interrupted maturity processes before winter comes and will therefore suffer from frost. LN-treatment of plants intended for planting in the autumn would make them resistant to frost damage in the coming winter.

III PROVENANCE RESEARCH

Tamarack was occasionally planted in Sweden already at the end of the previous century (Schotte 1917). The first provenance trial was established in 1958 in southern Sweden by the National Board of Forestry in the province of Halland. The trial was discontinued at an early stage since the plants were heavily damaged by frost and noxious animals. In 1969 the same organization planted 12 provenances of tamarack at Egernahult (56°37'N) and 7 provenances at Åkulla (57°08'N). The results of both these trials were reported by Ahlberg & Johansson (1984). At the same time (1968) the Swedish College of Forestry (Department of Reforestation), Stockholm, planted as pilot study 3 plots in the vicinity of Simrishamn on different soil types (55°35'N, Alt. 80 m) and 2 plots in northern Sweden, one of them at Skallsjö (63°29'N, Alt. 465 m, Jämtland) and the other at Hedmark (64°46'N, Alt. 470 m, Västerbotten). The number of planted tamarack provenances varied between 5 and 12 on the plots. On three of the plots also provenances of other larch species were planted. Some preliminary information about the growth of the best tamarack provenance in comparison with other larch species is given by Simak (1979).

On the basis of this first series with tamarack, a second series of field experiments was laid out over the country by the College of Forestry (table 2). The purpose of these field experiments was to study mainly the growth and survival of different tamarack provenances under the ecological conditions prevailing in Sweden. This second tamarack series is presented here only outlined since the material is too comprehensive for going into detailed analyses in this limited report.

Material and methods: When studying the suitability for introduction of an exotic species in short-term experiments (15-20 years) and on a great number of provenances, as in this tamarack project, a single tree parcel design seems to be the most advantageous method. This design was used in the present provenance trials.

The provenance plots were laid out on 12 different localities between latitudes 55°35' and 65°02'N. The plots 1901,1904,1907, 1910-1916, 1918 and 1919 were planted in autumn 1973 or in spring 1974 using 1-1 stock (table 2). On the three southern plots 1901,1904 and 1907, 45-55 provenances were tested. On the remaining northern plots only 9-10 provenances were planted; 7 respectively 8 of them originating from latitudes over 50°N. To study the growth of tamarack on different sites, some of the plots with the same provenances were situated close to each other but on different soil types. In this way three groups of plots, 1904, 1907 and 1910-1913 and 1916, 1918, were laid out. Local origins of birch, Scots pine and Norway spruce, one to two provenances of each per plot, were also planted for comparison with the larch. Several inventories have been made on the plots since they were established. Here only height growth and survival of 10-year-old trees on plots 1901, 1904 and 1907 as well as that of 9 year-old trees on plots 1914-1916, 1918 and 1919, are presented.

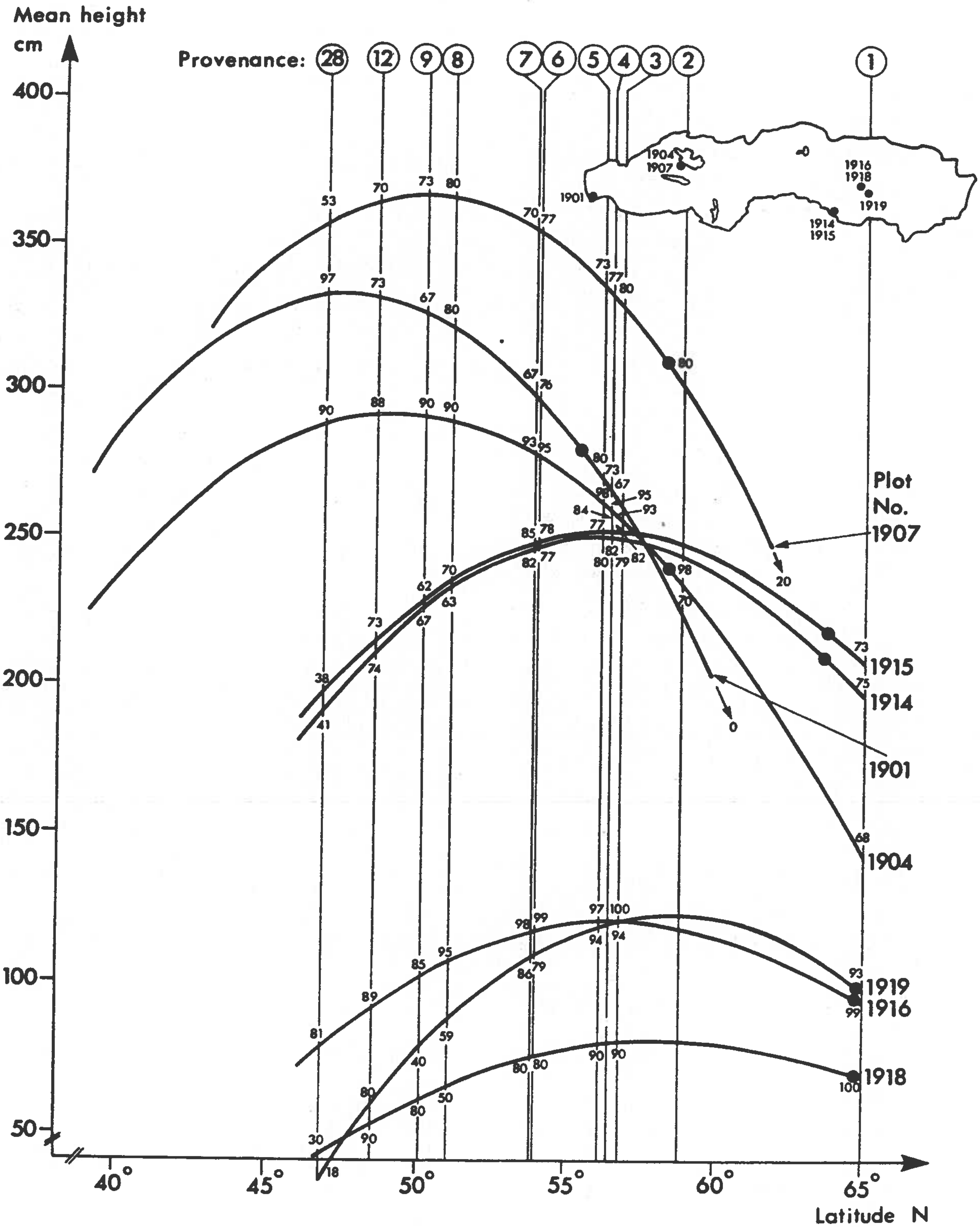

Figure 5. Mean height of 9- and 10-year old plants of different provenances in relation to

Results. The correlation between origin of the provenances (latitude) and height of the 9- respective 10-year-old trees was calculated for each plot. Hereby curves of second degree ($Y = a + bx - cx^2$) with a rather clear maximum were obtained. According to these curves the best growing tamarack provenance originates from a latitude 7-8 degrees more southerly than the latitudinal position of the particular experimental plot. Thus, on the experimental plot 1907 located at 58°28'N latitude the best growing tamarack provenances originate from a latitude of about 50°N in America (fig. 5), etc.

In the range 42° to 49°N from where most provenances originate (P 11-64) the variation in average height growth among provenances on plots 1901,1904 and 1907 is very wide. For instance, on plot 1901 the 12 provenances in the range between 46°to 47°N had an average height of 328 cm with maximum at 385 cm (P 38) and minimum at 268 cm (P 26). In contrast, the few northern provenances planted on the northern plots 1914-1916, 1918 and 1919 showed a high correlation between height and latitude of origin. The correlation coefficients are R = 0.88 to 0.96 with the exception of R = 0.69 for plot 1918.

The survival of plants in the field experiments was checked at each inventory. In table 3 the survival of the provenances on plots 1901,1904, 1907 and 1914-1916 in 1981 is presented. In general, the highest survival coincides with the best growth. Possibly, there is a slight tendency that provenances showing maximum survival originate from latitudes about 2-3 degrees more northerly than those showing maximum growth. This relation was particularly apparent on the southern plots 1901-1907.

Plots 1910-1913 planted on sites with extremely inferior soil conditions (Sphagnum swamp and peat) were discontinued in 1982 due to low survival. The other twin plots, 1904 and 1907, as well as 1915 and 1918 showed great differences in plant growth and survival depending particularly on the soil type (fig. 5).

Table 3 Average height growth (H) and survival (S) of tamarack provenances within latitudinal groups of origin in comparison with local species according to the inventory in 1981. Index at H-value indicates number of analysed provenances.

Lat. °N	1901 H cm	S	1904 H cm	S	1907 H cm	S	1914 H cm	S	1915 H cm	S	1916 H cm	S
39-42	266^{2}	48	244^{3}	84	-	-	-	-	-	-	-	-
42-44	306^{5}	54	264^{5}	75	356^{2}	58	-	-	-	-	-	-
44-46	338^{11}	69	254^{8}	83	327^{8}	61	-	-	-	-	-	-
46-48	331^{19}	71	285^{21}	88	362^{19}	72	188^{1}	41	191^{1}	38	75^{1}	81
48-50	318^{6}	71	292^{8}	90	347^{6}	73	204^{1}	74	223^{1}	73	98^{1}	89
50-52	326^{2}	73	326^{2}	90	393^{2}	77	233^{2}	66	229^{2}	66	101^{2}	90
52-54	292^{2}	72	289^{2}	94	341^{2}	73	251^{2}	80	251^{2}	82	116^{2}	98
54-56												
56-58	268^{3}	73	266^{3}	95	334^{3}	77	245^{3}	81	249^{3}	81	121^{2}	99
58-60	236^{1}	70	245^{1}	98	354^{1}	80	-	-	-	-	-	-
64-66	$-^{1}$	0	110^{1}	68	157^{1}	20	198^{1}	75	208^{1}	73	93^{1}	99
Local species												
Birch	190^{2}	13	341^{1}	78	415^{1}	63	176^{1}	52	158^{1}	53	149^{1}	71
N. spruce	124^{2}	83	70^{2}	28	148^{2}	83	100^{1}	38	97^{1}	50	50^{1}	96
S.pine	111^{2}	35	128^{2}	74	174^{2}	53	103^{1}	13	103^{1}	12	79^{1}	88
Plot Lat.°N	55°35'		58°28'		58°28'		63°43'		63°43'		64°48'	

Birch had grown best on three of the plots. Growth of spruce and pine was on all plots comparable to that of the most badly growing provenances of tamarack (table 3). All the three native species had suffered from moose damage and frost.

Discussion: Provenances of more southern origin than 46°N were not planted on the northern plots 1910-1916 and 1918,1919 since they would not prosper at these latitudes according to our earlier experience from pilot studies with tamarack. Also the curves in figure 5 confirm that it would be meaningless to plant southern provenances like P 28 so far to the north. All the curves in this figure show that a certain tamarack provenance grows and survives best in Sweden if planted 7-8 degrees more northerly than the latitude of its origin. Ahlberg & Johansson (1984) came to similar conclusions when evaluating the 15-year-old tamarack plots in southern Sweden and found that provenances originating from southern sources (45-47° N) were more successful in growth. In Sweden the climate is particularly influenced by the Gulf

Stream, a circumstance that makes this transfer towards the north possible. Maybe, that transfer of tamarack should be modified with regard to the altitude of the locality of the origin. Unfortunately, the present material is not sufficient for such studies, inter alia because in many cases the altitudinal data for the origin of the provenances are missing.

Cech et al. analysing 16 provenances of 7-year-old tamaracks on a plot situated on the latitude about 40^{0} N in the USA, i.e. on the southernmost border of tamarack's natural distribution, found a negative linear correlation between growth and latitude of the origin. Similar results were reported by Sajdak (1970). This pattern, showing a lower growth of provenances of northern origin with regard to the geographical position of the experimental plot, agrees well with the results obtained on all of the plots in Sweden (cf. fig. 5 and Ahlberg & Johansson 1984).

The high correlation between the latitude of origin and height of the trees on plots 1914--1916, 1918 and 1919 makes it easier to choose tamarack seed sources suitable for transfer to northern Sweden. However, on plots 1901, 1904 and 1907 the great variation in growth among provenances originating from an area south of about 47^{0}N latitude makes such choice tricky. Also Ahlberg & Johansson (1984) observed great differences in growth among southern seed sources originating from the same provenance region. The reasons for this variation are unknown, so far, but it is highly desirable to identify them in order to improve the criteria for introduction of tamarack to southern Sweden.

The good growth of tamarack in comparison with pine, spruce and even birch on most experimental plots is a consequence of the vigorous growth of this larch at an early age. Maybe, that in later stages the growth of the tamarack will cease and therefore it is too early to make definite conclusions about tamarack's growth in comparison with other species. In any case, on southern plots in Sweden the best tamarack provenances grew as well as the best ones on the experimental plots in the USA (cf. Jeffers 1975 and Cech et al., 1977). A factor that has not been considered in this report is the shape of the trees. Tamarack is rather scrubby at early age but the shape can be improved with age and therefore its evaluation will be made on a later occasion.

Plant survival depends on the interference of the abiotical and biotical environmental factors as well as on the inherited ability of the plants to stand out against these factors. In case the plants possess the appropriate resistance, they can counteract the external perils, e.g. frost, diseases, otherwise when the internal defense is lacking they can be injured or killed, e.g. by voles and moose.

In the present material, the mortality of the plants depends mainly on the factors that are causing most injuries on the respective plot, i.e. frost, moose and insects (table 4). In general, the survival is good, especially for the provenances with the best growth (table 3). The direct relation between growth and survival of a provenance can be understood in principle as a better growth being the consequence of better plant vigour. Plants with better vigour grow faster away from the stages at which a certain type of damage frequently occurs. However, this occurrence of damage at a certain stage of tree development, i.e. at certain height, diameter, etc., can cause unexpected differences in survival and growth among provenances with different patterns of development (cf. damage on plots 1914 and 1915 in table 4). The 10-year observations show that "survival" is hardly a crucial factor for introduction of tamarack into Sweden.

The growth of tamarack varied considerably on different sites within a geographic area. This appears clearly when comparing the two plots 1904 and 1907 situated next to each other at Remningstorp. The ten-year-old tamarack trees were on average 68 cm longer on the highly fertile site of 1907 than on the poor peat of 1904.

The parallell course of the two curves for average tree height plotted against latitude of origin (fig. 5) indicates the difference in the effects of the ecological factors of the two site types without changing the latitudinal position of the maximum growth. Similar relations were also found on the twin plots 1916 and 1918 at Falträsk. The discontinued plots 1910-1913 can serve as an example that even if the tamarack has a high capacity to encounter poor soil types, its potential in this respect has limitations. The rather sterile peat moss and waterlogged Sphagnum swamp were limiting factors for the survival of the tamarack on these plots. However, in rare cases tamarack can grow even at open Sphagnum and other barren sites and therefore it would be desirable to make pedological studies of different soil types to clarify the minimum factors for the growth and development of the tamarack.

IV DAMAGE TO TAMARACK

Besides the genetic adaptability of a species to a new habitat there are some ecological factors that are more decisive than others for the growth and survival of a species introduced into a new habitat. Experience from these 9- to 10-year-old test plots shows that frost and especially noxious animals seem to be the most decisive factors for the growth of tamarack in Sweden. However, it is to be expected that when the planted tamarack trees grow older, other types of damage will also occur.

Material and methods: By revision of the field experiments the cause and degree of damage to the plants/trees were registered. In case of several injuries, e.g. frost and insect damage, only the most serious damage was noted. In this report the most frequent types of damage and the degree of damage per plot are presented summarily as well as the effect of this damage on plant growth. Only the damage on plots 1901,1904,1907 and 1914-1916 registered in 1981 is discussed (table 4). Plots 1901,1904 and 1907 were protected by fence that, however, could not prevent efficiently the moose from entering.

Results: From table 4 it is evident that the frequency of damaged plants varies very much for the different plots. Thus, on plot 1914, 88 % dead and damaged plants were registered, while the corresponding value on plot 1904 was only 11 %. Also the intensity of the damage varied among the plots. In general, the performance of the tamarack trees was considerably reduced by the damage. Of the about 20 various types of damage registered the main types were injuries caused by frost, moose (incl. roe-deer) or insects. These three types of damage have also been evaluated separately for each plot. Table 4 shows that each plot had its own specific spectrum of damage.

Discussion: It is evident that the occurrence and degree of various types of damage on a plot depend on the geographic position and topographic situation of the plots, on the soil and vegetation types, etc, i.e. on the biotope in which the plot is located. A damage-doer usually prefers a certain biotope. Thus, the two plots 1904 and 1907 are located next to each other but in different biotopes. Plot 1904 was planted on drained peat soil without undergrowth except for a dominating Calluna cover. Here the frost was the main factor causing damage to the plants. In contrast, plot 1907 was planted on a fertile, humid alder bog surrounded by mixed spruce and hardwood forest. The seedlings were planted in a vegetation of Filipendula ulmaria that was over one metre high. In the beginning the meadow-sweet was removed yearly around each plant. To some extent, this vegetation protected the young tamarack plants from frost. The plot was frequently visited and damaged by moose (table 4). Similarly, plots 1914 and 1916 can be compared since they are planted on about the same latitude though located far from each other. Plot 1914 was planted on a surged moraine with abundantly growing bushes of birch, aspen, sallow and young pine trees. The site was an El Dorado for moose and insects. Much damage was caused by the larvae of Pristiphora spp. that had defoliated the trees, many times completely, in the last few years. Moose damage up to 1981 was slight since the plants were too small and there were other shrubs and trees on the plots tempting the moose more. However, in recent years when the tamarack became taller, the moose damage increased. Plot 1916 is situated on a well drained slope facing a lake. Tamarack grows well on this site. With the exception of slight but frequent frost damage, no other serious damage was observed on the plot.

The effect of the damage has been reflected in the growth development. The height of the trees decreased with increasing degree of damage (table 4) except for on plots 1914 and 1915. The explanation of this reversal situation on the two plots may be that the tallest plants were more exposed to larvae than the smaller plants which were better protected by the surrounding vegetation.

The frequency of damage to each provenance has not been presented separately due to the fact that the actual damage with the exception of frost injuries was not provenance-specific. The external damage can seriously influence the growth of tamarack and can eventually be an obstacle to cultivating this larch. One can reduce the damage by cultivating the tamarack in biotope where the damage-doers occur rarely or not at all. The varying spectrum of damage in table 4 supports this assumption.

Table 4 Damage situation on six experimental plots according to the inventory in 1981 (only tamarack considered).

Plot	1901	1904	1907	1914	1915	1916
Survival % 1981	67	87	69	73	70	94
	Per cent of damaged trees					
No damage	87	89	81	12	16	59
Slight d.	1	2	11	28	13	32
Moderate d.	11	9	6	48	41	9
Heavy d.	1	+	2	12	30	0
	Mean height of the trees (cm)					
No damage	331	284	366	191	149	118
Slight d.	238	226	307	233	227	92
Moderate d.	236	190	268	240	239	69
Heavy d.	289	132	201	236	244	
	Type of damage (%)					
Frost	44	72	6	0	0	72
Moose	32	1	42	1	+	+
Insect	1	4	3	96	98	18
Others	23	23	49	3	2	10

SUMMARY

In this report, information is given about experiments carried out with tamarack (Larix laricina) in Sweden during the last 20 years. Seeds for the experiments have been supplied from 69 autochthonous stands in Canada and the USA.

The nursery experiments showed that the growth of tamarack is extraordinarily sensitive to photoperiodic conditions. This has been demonstrated in some experiments in plastic greenhouse in which the effects of long night and intermittent light were tested on different tamarack provenances. The experiments were continued also in the field. Depending on the reaction to the photoperiod, suitable methods for raising tamarack seedlings from photoperiodically widely separated provenances in a central nursery are discussed.

The reaction of a tamarack provenance to a certain night length is genetically determined. This must be considered when introducing the species into Sweden. Fortunately, the maritime-influenced climate in Sweden modifies the latitudinal transfer of tamarack from America to Sweden in such a way that tamarack provenances can be planted in Sweden 7-8 degrees more towards the north than what is the latitude of its origin. This relation was confirmed on 12 provenance plots in Sweden planted between latitudes 55°35'N and 65°02'N. The tamarack has grown much better than the local Norway spruce and Scots pine during the first 10 years. The survival was high within the limits proposed for

transfer. The shape of the young trees was not quite satisfactory. Damage to the trees was mostly caused by frost, moose and insects. These injuries can be reduced by planting tamarack in biotopes where the damage-doers are less abundant or can be controlled.

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THE DISTRIBUTION AND REGENERATION OF LARIX FORESTS IN NORTHEAST CHINA

Chou Yi-Liang & Wu Hong-qi

INTRODUCTION

Northeast China includes Heilongjiang, Jili, Liaoning Prov. and the east part of Inner Mongolia Autonomous Region situated between 38°43' and 53°40'N latitude, 115° 40' and 135°3'E longitude in extreme eastern part of Eurasia near the Sea of Japan and affected by the southeastern monsoon. Forests are distributed over the eastern half part of Northeast China where is a major base for timber-production in China. Larix forest is one of the principal forest types in the area.

The Larix forests in Northeast China are consisted of 1 species, 2 varieties and 1 form: L. gmelini and f. hsinganica, L. olgensis var. changpaiensis and var. heilingensis which are edificator or dominant tree species and have similar ecological habits. They are very intolerant and cold-resistant trees, and can grow in dry, infertile or swamped soil even on the permanent frozen ground. But they are best adapted to grow in drained, moist and sandy soil. Therefore, they can be discussed together in "Larix forests". But they have different distributions (fig. 1) in Northeast China. They are endemic species in Northeast China except L. gmelini extending from East Siberia, which are discussed respectively as follows.

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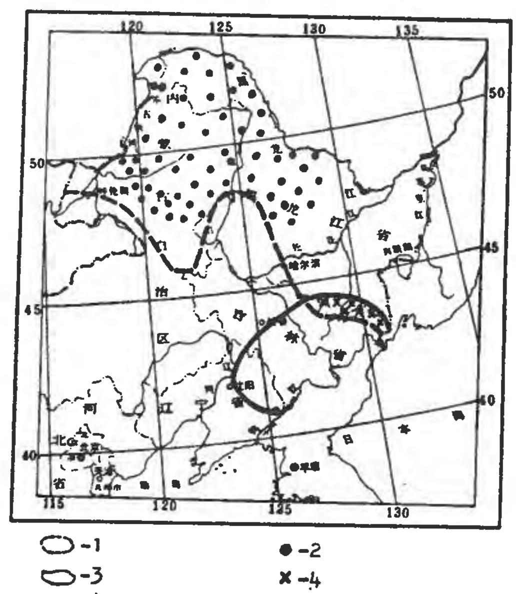

Figure 1. The distribution of the principal Larix of Larix forests in Northeast China: 1. L. gmelini; 2. L. gmelini f. hsinganica; 3. Larix olgensis var. changpaiensis; 4. Larix olgensis var. heiligensis.

Larix olgensis var. changpaiensis Yang et Y. L. Chou in Act. Phytotax. Sinica 9(2): 169. fab. 16-17. 1964---L. olgensis auct. non Herry: auct Fl. Chinae Bor-Or. (Mansh.) (fig. 2).

The variety is distinguished from the type by annual shoot with scattered hairs, generally, a pecies separately on both lateral sides of pulvini at apex, easily deciduous, usually, without hairs except the bases of the shoots; wider leaves about 1 mm. wide; surface of scales with sparse glandular verruca or hairs.

Larix olgensis var. heilingensis (Yang et Y. L. Chou) Y. L. Chou, Ligneous Fl. Heilongjiang. 40. fab.3: 6-8. 1986---L. heilingensis Yang et Y. L. Chou in Act. Phytotax. Sinica 9(2): 173. fab. 19. 1964---L. dahurica Turcz. var. heilingensis (Yang et Y. L. Chou) Kitag. Neo-Lineam. Fl. Mansh. 47. 1979. (fig. 2).

The distribution of the variety is between L. olgensis var. changpaiensis and L. gmelini (fig. 1). Somewhat intermediate in morphology between them. But it is easy to distinguish and the comparison is following in detail (tab. 1).

The ecological habit, timber quality and uses of the variety are same with the type and L. gmelini. But L. olgensis var. heilingensis grows faster than the type and L. gmelini, which is fast growing tree adapted better in Northeast China.

Larix gmelini f. hsinganica (Yang et Y. L. Chou) Y. L. Chou, Ligneous Fl. Heilongjiang 36. 1986---L. gmelini var. hsinganica Yang et Y. L. Chou in Act. Phytotax. Sinica 9(2):177. fab. 21. 1964 (fig. 2).

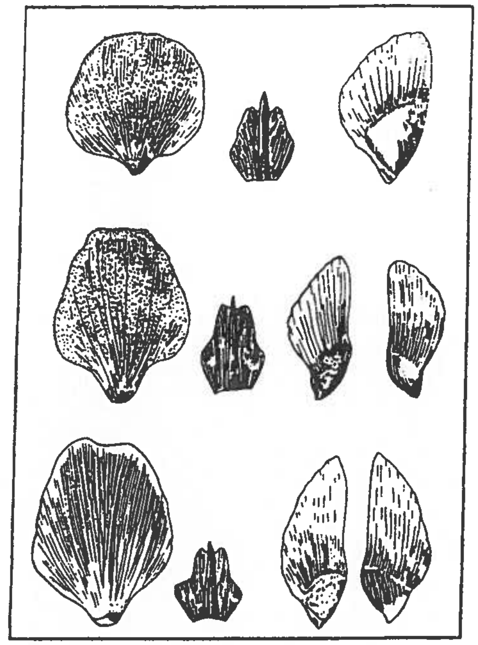

Figure 2. The morphology of scale, bract, seed: upper--Larix olgensis var. changpaiensis; middle--Larix olgensis var. heiligensis; lower--Larix gmelini.

Table 1 The comparison of morphological characteristics of Larix

Characteristics	Species	L. olgensis var. changpaiensis	L. olgensis var. heilingensis	L. gmelini
Annual shoots	Colour	pale reddish-brown	pale brown	pale yellow brown
	White powder	a little	✓ 1	no
Leaves	Length	shorter, 0.8-2(2.5) cm	✓	longer 1.5-3.5 cm
	Numbers of stomatic lines	3(4)	(3)4-5	2-3
Scales	Shape	round-obovate, broadly ovate or roundish	pentagonoid ovate	pentagonal ovate
	Glandular varruca or hair	yes	✓	no, glossy
Size of bract		$\frac{1}{3}-\frac{1}{2}$ scale	about $\frac{1}{2}$ scale	about $\frac{1}{3}$ scale
Shape of wing		obtriangular	broadly sickle-shaped	sickle-shaped

1/ [✓] uniform characteristics

Differ from the type by pubescent shoots. It sprouts earlier than the type about 7-8 days in spring and its growing period is longer.

The vegetation in Northeast China is divided into 3 forest regions and 1 grassland region. Larix forests are distributed in the two largest forest regions, e.g., Cold-temperate Coniferous Forest Region, and Temperate Coniferous and Broad-leaved Mixed Forest Region. The specific composition, distribution and natural regeneration of Larix forests are quite different in the two region.

LARIX FORESTS IN THE COLD-TEMPERATE CONIFEROUS FOREST REGION

The region including the north of the Greater Khingan Mts. situated from 46°26'N latitude (nearby Aershan, Inner Mongolia) to Amur river about a span of 8° latitude is extreme northern forest region in China. The climate is different in the area. Two portions are divided by 49°20'N latitude (Yakeshi, Inner Mongolia). The north lies in cold-temperate zone in which the zonal vegetation is the cold-temperate coniferous forest (boreal forest); south is located in temperate zone in which the zonal vegetation is temperate steppe and the cold-temperate coniferous forest extends southwards along the range of the Greater Khingan Mts. forming montane vegetation joining with the cold-temperate coniferous forest.

The ridges of the Greater Khingan Mts. are generally 700-1000 metres altitude in the forest region. The mountain tops are round, and most of their gradients are gentle below 20 degrees. The higher peaks are about 1400 metres above the sea level and the highest peak in north---the 1530 metres Mt. Aokeliduishan and in south---the 1720 metres Mt. Taipingling.

Annual mean temperature is from -2°C to -5.6°C in the area. Because it is far from ocean, the continental climate is marked. The frost-free period lasts from May to September about 90 to 110 days. Mean annual precipitation is from 360 to 500 mm., but the evaporation exceeds the raifall by 250 %.

The forest region is arid from May to June when it is cloudless and fogless, humidity of the air is very low and solar radiation is high. This makes the flammability high and forest fire occur frequently. Forest fire becomes a important factor affecting the forests in the area.

Affected by the climate, most of plants are eurytopic and fire-resistant in the forest region. Particularly, the composition of tree species is simple. Larix is almost single dominant species forming Larix forest which is the extention of the Larix forest in the Eastern Siberia, and similar in the specific composition and physiognomy. Larix gmelini is principal tree mixed with f. hsinganica.

Owing to the influence of southeastern monsoon more or less, some broad-leaved trees in the temperate coniferous and broad-leaved mixed forest region appear in the Larix forests. The horizontal forest---cold-temperate coniferous forest is boreao-nemoral forest in the forest region. With increasing elevation, the specific composition of Larix forest is changing markedly showing the vertical distributions of the Larix forests in the forest region (fig. 3):

A. Larix forest with broad-leaved trees;
B. Larix forest;
C. Larix forest with spruces;
D. Open Larix forest.

The Specific Composition and Distribution of the Larix Forests

Larix forest with broad-leaved trees: It is horizontal forest in the forest region distributed in the area at low elevations. With the increasing latitude, the upper limit of the Larix forest is descending gradually (fig. 3). Because the elevations of the mountainous area generally exceed the upper limit, the Larix forest with broad-leaved trees is not distributed widely in the forest region. The zonal soil is brown forest soil.

Mixed with temperate broad-leaved trees is the important characteristics of the specific composition in Larix forest affected by the temperate coniferous and broad-leaved mixed forest region. Dryresistant trees, Quercus mongolica and Betula dahurica are principal broad-leaved trees. In addition there are Populls davidiana, Tilia amurensis, Fraxinus mandshurica, Phellodendron amurense, etc. They grow not well and usually from secondary tree layer in which the numbers of the individual trees are also fewer. The Larix forest is similar to the temperate Larix forest.

Larix forest: It is distributed widely in the forest region because the distribution is uniform with the elevations of the area. With increasing latitude, the vertical distribution of the Larix forest descendens gradually (fig. 3). Soil is typical brown forest soil which is shallow and better in water permeability. The Larix forest is similar to the "South taiga" in Eastern Siberia in physiognomy and specific composition in which the simple specific composion is a major characteristic.

Larix forest with spruces: It appears in upper area of the mountains distributed not widely at higher elevation (fig. 3) in the forest region. The climate becomes humid in the vertical belt and the soil is podzolized brown forest soil.

Larix forest with spruces is similar to "Middle taiga" in specific composition and physiognomy, the characteristics of dark boreal forest (spruce-fir forest) consisting of single dominant tree---Larix and accompanied by Picea koraiensis and P. jezoensis. Sorbus amurensis and Betula ermanii often appear in the Larix forest, which are the accompanying broad-leaved trees in the dark boreal forest (spruce-fir forest). Due to the influence of forest fire, there are only some seedlings found occasionally in the Larix forest. Because of the temperate inversion, the Larix forest also occurs in the wet and cold local areas at lower elevations as azonal forest.

Open Larix forest: It is scattered to occur on some higher peaks. The elevations of its distribution are increasing from north to south, e.g., 1200-1350 metres altitude Mt. Aokeliduishan (51°50'N lat., 122°08'E long.) in the north and 1450-1720 metres altitude Mt. Taipingling (fig. 3).

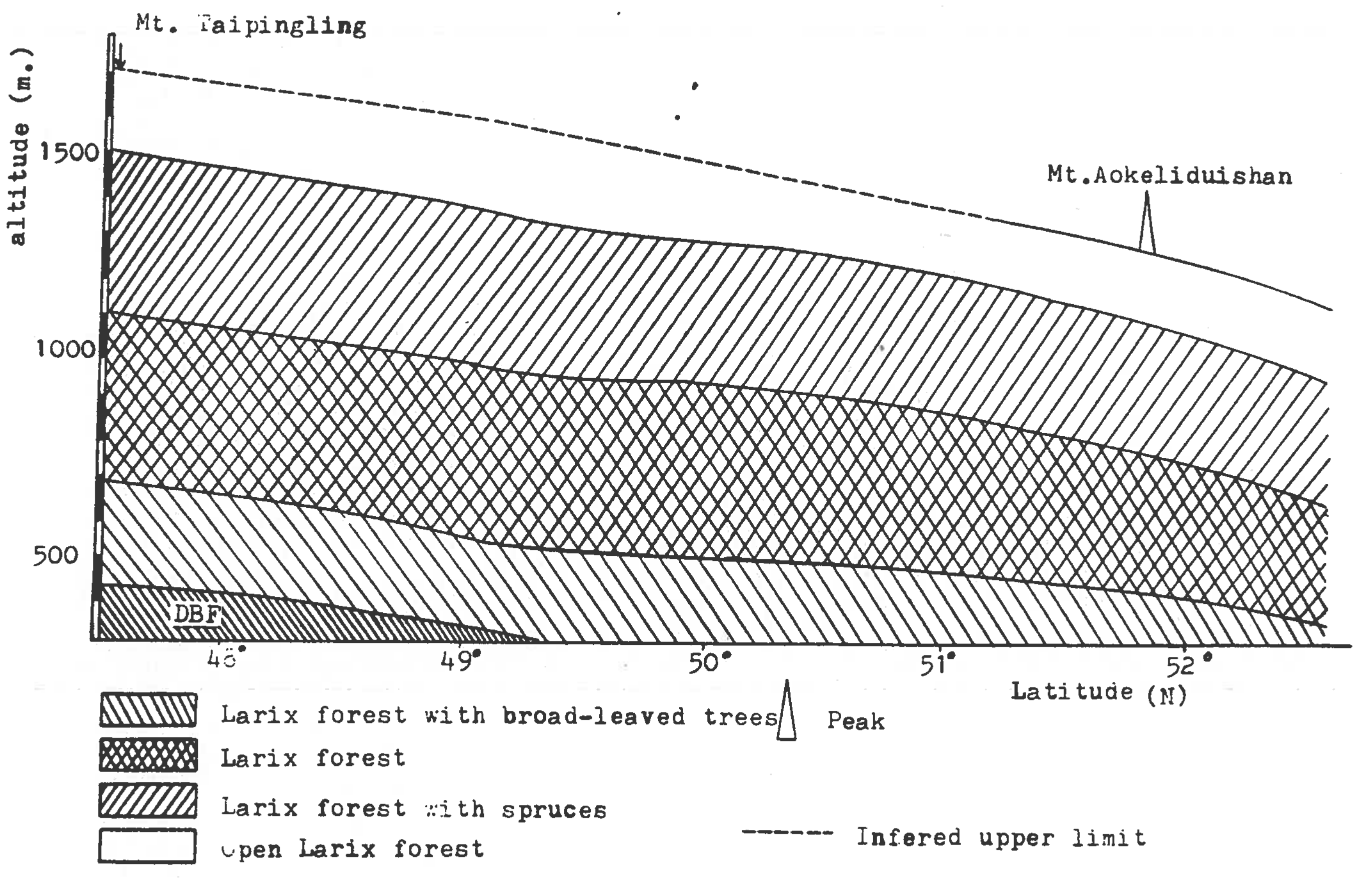

Figure 3. The vertical distribution of the various Larix forests in the coldtemperate coniferous forest region: DBF--Deciduous broad-leaved forest.

The soil in which the Larix forest grows is rocky soil. The soil layer is shallow and with bare rock. The climate is very cold and wind is very strong in the areas. Other trees could not grow in the areas. Larix grows barely forming open Larix forest as zonal vegetation on the vertical belt which is the upper forest limit in the forest region. Open Larix forest is similar to "North taiga" in Eastern Siberia in specific composition and physiognomy. The canopy density is below 0.3-0.4 and the growth of Larix is very poor. Larix is single dominant tree species forming pure Larix forest or mixed with a few numbers of Betula ermanii.

The Growth and Regeneration of the Larix Forests

The vertical distribution, specific composition and physiognomy of the various Larix forests are quite different in the forest region mentioned above. Also there are much differences of the growth and regeneration among them.

For convenience, the various Larix forests are respectively represented by the following symbols in text and figures:

Type A---Larix forest with broad-leaved trees;
Type B---Larix forest;
Type C---Larix forest with spruces;
Type D---Open Larix forest.

Growth.--The growth of height, D.B.H. and volume: The growth curves of height, D.B.H. and volume (fig. 4, 5 and 6) show that Larix grows most rapidly in type A, more rapidly in type D, and slowly in type C and B in the primary stage of growth, which is close related to the structure of the overstory canopy and the characteristics of the regeneration. This indicates that the overstory trees in type A and D are approximatly even-aged and the regeneration of Larix in the understory is very poor. The overstory trees occured in open. There is no suppressed period in the young stage of Larix in type A and D. But the natural regeneration of Larix is better and the overstory trees occured in the understory which have a marked suppressed period in the sapling stage in type B and C. When they are free from the overstory, they grow rapidly and exceed the growth of trees in type D. Larix grows always rapidly in type A because of the better site. At last the total growth increment of the various Larix forest increases in order of descending altitude.

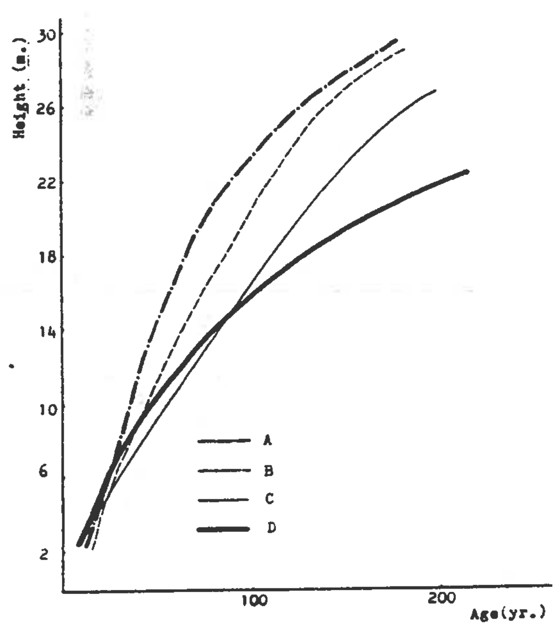

Figure 4. Height growth of the various Larix forests in the cold-temperate coniferous forest region: A. Larix forest with broad-leaved trees; B. Larix forest; C. Larix forest with spruces; D. Open Larix forest.

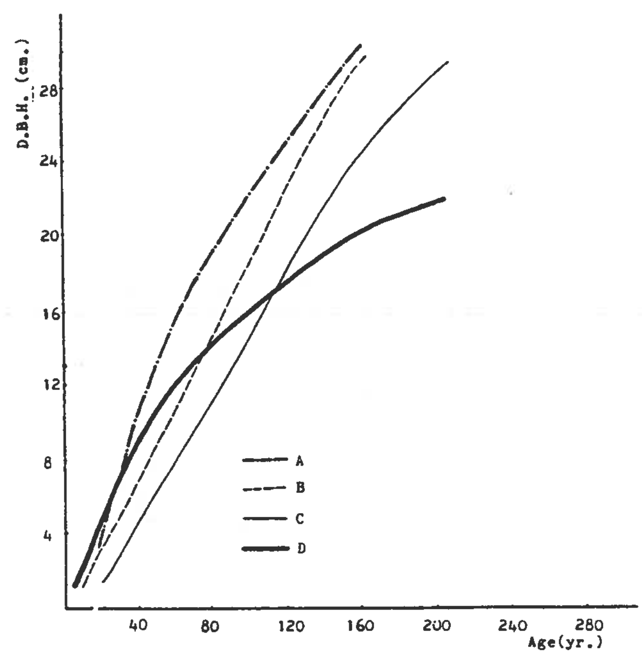

Figure 5. D.B.H. growth of the various Larix forests in the cold-temperate coniferous forest region: A. Larix forest with broad-leaved trees; B. Larix forest; C. Larix forest with spruces; D. Open Larix forest.

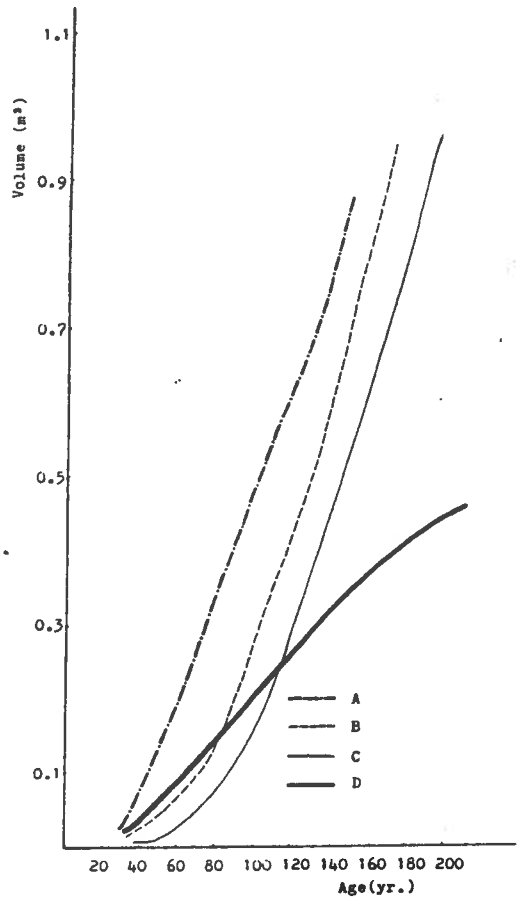

Figure 6. Volume growth of the various Larix forests in the cold-temperate coniferous forest region: A. Larix forest with broadleaved trees; B. Larix forest; C. Larix forest with spruce; D. Open Larix forest.

The mean increment and annual increment of volume: Mean increment indicates the mean increment of tree each year and the annual increment is the actual increment each year. The annual increment increases gradually and reaches at maximum. Then it begins to reduce. During the reduction of annual increment, the mean increment reaches at maximum. At this time the both growth curves are intersected. The age at the intersecting point is called quantitative mature age which is a major basis for determining the age of final felling. The stem analysis (fig. 7) reveals the differences of the quantitative mature age and stem volume at the age among the various Larix forests. The quantitative mature age comes most early in type D and puts off with the descending altitude. From figure 6, the volume of Larix is lowest at the quantitative mature age in type D (The same result is gotten according to the annual increment and mean increment curves of height and D.B.H.) and increases with descending elevation reaching maximum in type A (the horizontal forest in the forest region) in which large timber can be gotten.

Regeneration.--The natural regeneration is quite different among the various Larix forests in the forest region (fig. 8). The regeneration is best in type B and poor in others. It is better in type A than C and very poor in type D. The proportions of the seedlings above 30 cm high and below 30 cm high are approximately uniform, which reveals that there are always differences of regeneration among the various Larix forests in the regeneration process of Larix seedlings not caused by the difference of mortality under competition after a large number of seedlings occur among the various Larix forests. After the Larix forests, particularly, type C and B are disturbed, Betula platyphylla often occurs. Betula platyphylla is light-demanding tree adapted to grow in the site like Larix except the swamp. Betula can occupy the open in Larix forest and clear lands with the luxuriant mosses and herbs in which Larix is difficult to occur because of its relatively poor competitive ability with weeds. Betula platyphylla produces large quantities of seed each year (in Larix, good cone and seed crops occur at 3- to 5-year intervals in the forest region) and has more widespread small seed dispersal. Therefore it often occupy the better sites forming birch forest even though the sites are also suitable for Larix. But Betula platyphylla will be replaced by Larix at last because its relatively short lifespan about 70 to 100 years.

Although Larix is light-demanding tree, the luxuriant moss and herb layers are more important than the shading affecting the natural regeneration of Larix. Thick ground cover makes the rooting of Larix difficult. The natural regeneration of Larix is still poor even though the overstory is open after clear-cutting. In contrary, the regeneration is very excellent in the bare soil and fire slash. This shows that the cause inhibiting the regeneration of Larix is the luxuriant moss and herb layers. Therefore, the ground cover must be removed so that the regeneration condition of Larix is improved.

Besides Betula platyphylla, other broadleaved trees, e.g., Quercus mongolica, Betula dahuria, Populus davidiana, etc. appear forming mixed forests after disturbance, which causes the regeneration of Larix more difficult.

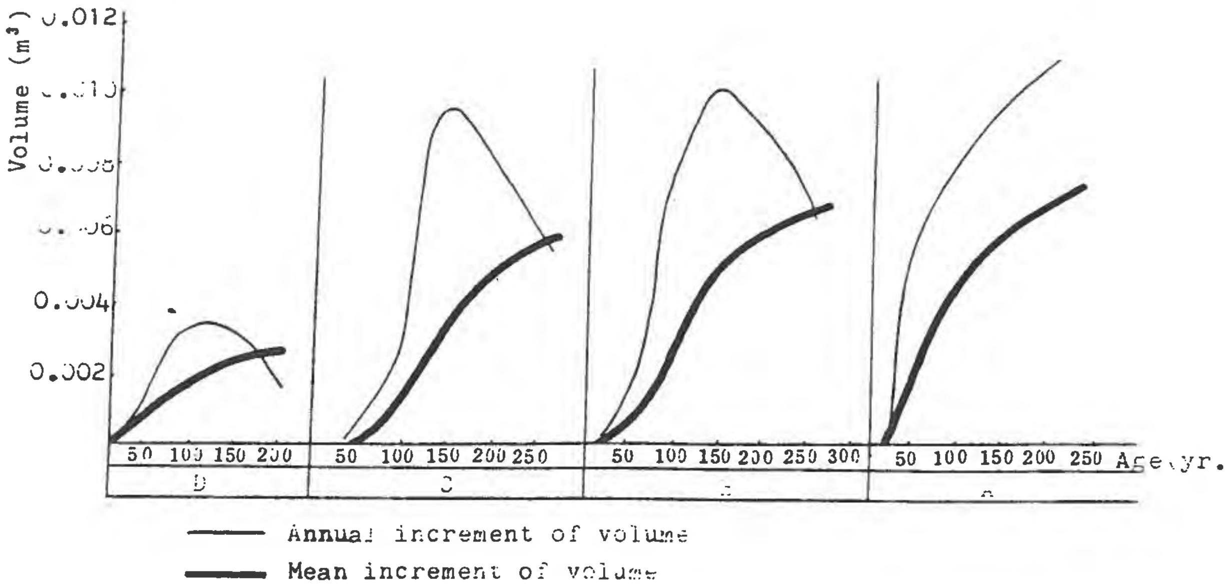

Figure 7. Mean increment and annual increment of volume of Larix in the cold-temperate coniferous forest region: A. Larix forest with broad-leaved trees; B. Larix forest; C. Larix forest with spruces; D. Open Larix forest.

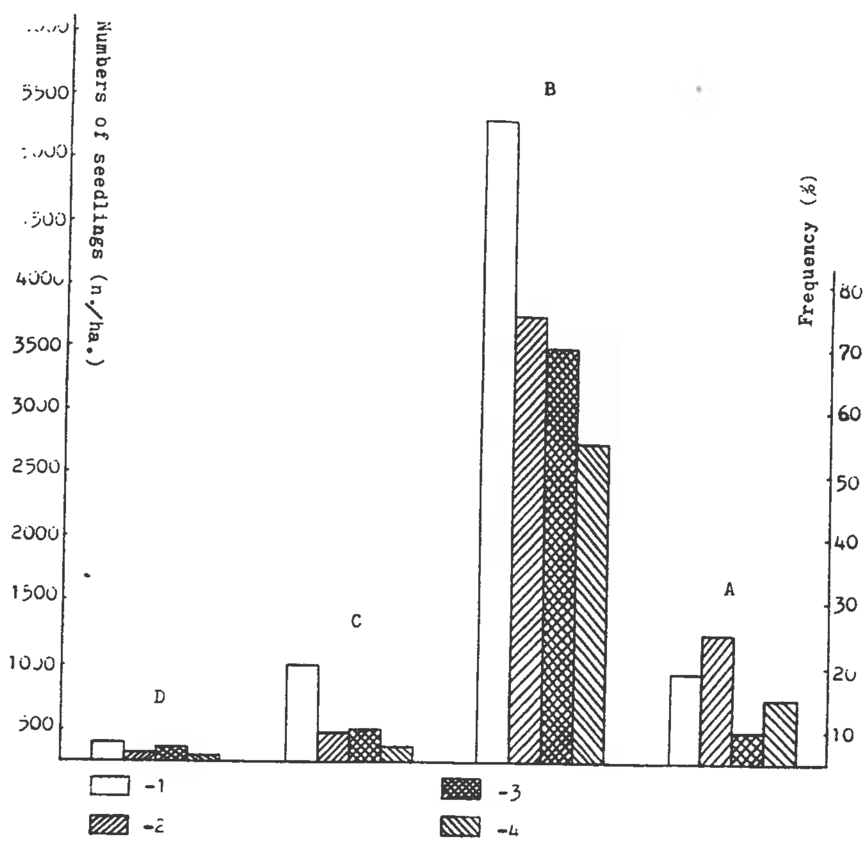

Figure 8. The regeneration in the various Larix forests in the cold-temperate coniferous forest region: 1. total numbers of Larix seedlings per hectare; 2. frequency of Larix seedlings; 3. numbers of Larix seedlings (height >30 cm) per hectare; 4. frequency of Larix seedlings (height >30 cm). A. Larix forest with broad-leaved trees; B. Larix forest; C. Larix forest with spruces; D. Open Larix forest.

The quantity and growth of Larix seedlings are quite different in the various Larix forests. The growth of the seedlings in type D is very poor beyond compare with in the others. The growth of seedlings in type A, B and C is only discussed as follows. The height growth of seedlings is slower in type C (curve C, fig. 9), which is maybe related to the thicker moss layer inhibiting the rooting in soil causing the lack of nutrients and shading of overstory. The seedlings grow rapidly in type A (curve A, fig. 9). This shows that the site in type A is not suitable for the regeneration of Larix, but for the growth of Larix seedlings. Therefore, the artificial regeneration is the major method in type A. Although the growth of seedlings in type B is slower than in type A, faster than in type C. In addition, there are large numbers of seedlings in type B. The typical Larix forest belt is the best area of the natural regeneration of Larix, where the major regeneration method should be natural regeneration with artificial improvement.

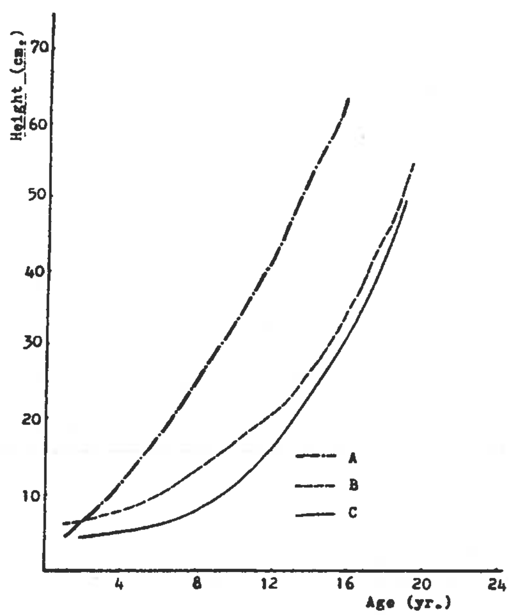

Figure 9. Height growth of seedlings of Larix in the various Larix forests in the cold-temperate coniferous forest region: A. Larix forest with broad-leaved trees; B. Larix forest; C. Larix forest with spruces.

Owing to the differences of the regeneration and growth of Larix in the various Larix forests, the different ways should be adopted in silviculture and management which are concluded following:

Larix forest with broad-leaved trees, which is not widespread in distribution, occurs at low altitudes in the forest region and denotes deeper, fertile soil, higher quantity of heat in site. The area of primary forest has been very small due to the human activity. The silviculture and management of secondary forest is major task. The growth of artificial Larix stands is very fast on the vertical belt. But the natural regeneration is poor. Therefore, artificial regeneration is major method.

Typical Larix forest distributed most widely is a major portion of the Larix forests in the forest region becoming the base of timber production. The natural regeneration is best in the belt and should be the main way in silviculture and management of the Larix forest. By Rational final felling, the better natural regeneration condition should be provided.

Larix forest with spruce, which is mainly distributed in the upper reaches of small streams, has a cold and wet site in which the moss layer is developed in the understory. It is more significant for water and soil conservation and should be managed as protection forest. Timber production is secondary purpuse.

Open larix forest which is valueless for the management of timber production only appears on some scattered higher peaks and should be determined as protection forests.

LARIX FORESTS IN THE TEMPERATE CONIFEROUS AND BROAD-LEAVED MIXED FOREST REGION

The forest region including the eastern mountainous area in Northeast China is situated at 45°15′-52°20′N latitude, 126°-135°30′E longitude just like a new moon. Main mountains are the Lesser Khingan Mts., Wandashan Mts., Zhangguang-chailing Mts., Laoyeling Mts. and Changpai Mts. forming undulating hills and complex mountainous topography. Most of the mountains are not over 1300 metres above the see level and the highest peak is the 2691 metres altitude Mt. Baiyunfeng in Changpai Mts., which is also the highest peak in Northeast China.

The forest region is located at the extreme east of Eurasia near the Sea of Japan, which has marine (moist) temperate monsoon climate affected deeply by the Pacific Ocean. The precipitation is from 500 mm to 800 mm concentrated within a few summer months (June, July and August) about 70 % to 80 % of the annual rainfall. The forest region has higher temperature in summer and the July mean temperature is from 20°C to 26°C or more. The maximum temperature may achieve 39°C. This is suitable climate condition for the growth of plants in the forest region where luxuriant forests thrive as one of the major bases for timber production in China. The forest region, far east of USSR and north of Korea belong same natural zone called "flora of Manchuria" commonly.

The horizontal forest is temperate coniferous and broad-leaved mixed forest. Pinus koraiensis is principal tree accompanied by many temperate deciduous broad-leaved trees more ten species and cold-temperate conifers, e.g., Picea jezoensis, P. jezoensis var komarovii, P. koraiensis and Abies nephrolepis. With increasing elevation, the coniferous forest consisted of spruce and fir gradually appears transition to montane cold-temperate coniferous forest (spruce-fir forest) in vertical distribution in the forest region.

Larix is abundant in the forest region. Larix gmelini and f. hsinganica are distributed in the north of the area, L. olgensis var. changpaiensis in the south and L. olgensis var. heilingensis in the crossed area between the distribution of L. gmelini and L. olgensis var. changpaiensis (fig. 2). Most of Larix forests are secondary forests in the forest region where there is only a large and continuous area of Larix forest in the Changpai Mts. formed by the affecting of volcanic activity (the last volcanic eruption is in 1702). But the typical Larix forest is restricted in swamp, in which other trees are not adapted to live, because of the relatively poor competitive ability of Larix forming swamp-inhabiting Larix forest which appears discontinuously but in widespread distribution in the forest region. According to the specific composition, distribution, the occurence and development of Larix forests, three main types of Larix forests are clasified in the forest region:

A. Montane cold-temperate Larix forest;
B: Temperate Larix forest;
C. Swamp-inhabiting Larix forest.

The Specific Composition and Ditribution of the Various Larix Forests

Montane cold-temperate Larix forest: derived from the montane cold-temperate spruce-fir forest is distributed at higher elevations (fig. 10). It is concentrated to appear in the Changpai Mts. and has marked characteristics of dark boreal forest (spruce-fir forest) in the gradually replaced state. The overstory is almost consisted of Larix accompanied by Abies nephrolepis, Picea jezoensis var. komarovii, P. jezoensis and P. koraiensis in the understory forming the compound storied forest.

Because of shading in Larix forest, the regeneration of Larix is very poor. There are large numbers of seedlings of fir and spruce or a few seedlings of Pinus koraiensis which is endemic tree in the forest region and annual or biennial slender seedlings of Larix in the understory. According to the investigation in a sample plot, there are about 4000 seedlings of fir per hectare, 1000 seedlings of spruce per hectare, 200 seedlings of pine per hectare and 700 seedlings of Larix per hectare in the understory of the Larix forest. Because of the luxuriantly overgrowing mosses, the regeneration of various trees is difficult. Generally, most of seedlings occur on the fallen trees on which the moss layer is thin. For example, 95 % of seedlings occurs on fallen trees in a sample plot. One seeling which did not occur on fallen tree, at age of 14 yr., 30 cm high is covered 12 cm high by mosses and its lower lateral shoots covered up by mosses has withered without leaves. The seedlings about 1 to 3 yr. old, 3 to 12 cm high, grow very poorly and are difficult to grow up in the understory. The individuals of Abies nephrolepis at age of 4 - 48 yr., 6 - 163 cm high and Picea jezoensis var. komarovii at age of 9 - 31 yr., 14 - 104 cm high, grow better in the Larix forest, which will form dense understory causing dark and wet in Larix forest. The trend of development of the Larix forest is forming spruce-fir forest. In the process of succession, a series of transitional types is realized, which include: Picea koraiensis-Larix forest, Picea jezoensis var. komarovii-Larix forest, Abies nephrolepis-Larix forest, etc., according to the investigation on the west slopes of the Changpai Mts.

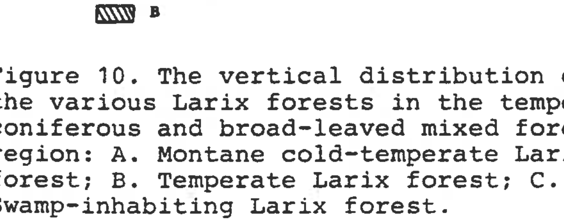

Figure 10. The vertical distribution of the various Larix forests in the temperate coniferous and broad-leaved mixed forest region: A. Montane cold-temperate Larix forest; B. Temperate Larix forest; C. Swamp-inhabiting Larix forest.

Temperate larix forest: It is derived from the temperate coniferous and broad-leaved mixed forest--the horizontal forest in the forest region distributed at low elevations (fig. 10). Although the temperate Larix forest is not ditributed widely, it is unique type in Northeast China, which has the characteristics of the temperate coniferous and broad-leaved mixed forest. It is consisted of Larix, Pinus koraiensis, Tilia amurensis, Ulmus japonica, Fraxinus mandshurica, Acer mono and Quercus mongolica, etc.. Larix is dominant tree in the overstory, the broad-leaved trees grow beneath the overstory and Pinus koraiensis often occurs in the understory, which forms compound mixed forest.

After disturbance, the grasses will be luxuriant in the site inhibiting the natural regeneration of Larix. But the broad-leaved trees and Pinus koraiensis can occur in the site. Fraxinus mandshurica, Tilia amurensis, Ulmus japonica, Quercus mongolica and Phellodendron amurense, etc. are principal regeneration trees in the understory of Larix forest in which the numbers of seedlings can reach at 10000 per hectare. The specific composition of regeneration trees is similar to the one of the broad-leaved trees in the horizontal forest. After Larix is replaced by broad-leaved trees, the horizontal forest--temperate Pinus koraiensis and broad-leaved mixed forest will gradually restore.

Swamp-inhabiting Larix forest: It appears in widespread distribution in the forest region and is the primary forest restricted in the low and humid valleys or undrained soil in which there is permanent stagnate water. The soil is bog soil or swamped meadow soil and has the different level of the peat accumulation in which other trees are difficult to live, but Larix can grow forming the Larix forest. Generally, Larix is single dominant tree or there are a few number of Abies nephrolepis, Picea koraiensis, Betula costata and the indicative small tree Alnus hisuta, etc. mixed in the Larix forest. Fraxinus mandshurica and other broad-leaved trees occur in slightly drained soil forming the transitional types to the temperate Larix forest. The most marked characteristic of the specific composition is that most of plants in the understory are the typical helophytes in the swamp-inhabiting Larix forest. They have xeromorphism. Sphagnum spp. are principal mosses and there are also insectivorous plants. They indicate the moist soil, physiological drought and lack of mineral nutrients in site. Though Larix can survive, it grows poorly in the inhibiting state, which shows that Larix is not better adapted to grow in the ecological condition. Particularly, in heavy swamp, high level of peat accumulation, the growth of Larix is very poor, low tree height, small crown, shorter leaves, small cones, and at the age of 115 to 125 yr., only 6.5 to 8 m high, 9 to 11 cm in girth, called "small old tree". The density of stand is very low, 0.3 - 0.4 in closure and the life span is shorter. The stand is consisted of living, dying and died trees replaced by each other, about 30 to 40 percent of died trees. Because of the luxuriant sphagnum mosses and permanent stagnate water in undrained soil, the humidity of air is higher in the forest so that there are large numbers of mosses, e.g., Leudocon pendula, and lichens, e.g., Usnea longissima, U. diffracta, attached to the stems and branches forming peculiar landscape which is almost valueless for forest management.

Growth and Regeneration of the Various Larix Forests

Growth.--There are the difference not only in specific composition but also in the growth among the various Larix forests in the forest region, which results from the differences of water, heat and soil conditions. See figure 11 and 12. The growth of height and D.B.H. of Larix in temperate Larix forest is better than in the montane cold-temperate Larix forest and is very poor in the swamp-inhabiting Larix forest. Temperate Larix forest distributed at low elevations has dark brown forest soil, better water and heat condition, in which the process of biological small cycle containing much more mineral materials is faster so that the nutrient elements reverting to soil are more. Comparing with the brown forest soil (taiga soil) in montane cold-temperate Larix forest, dark brown forest soil is more fertile which is more suitable for the growth of trees. Therefore, Larix grows best in temperate Larix forest. In contrary the bog soil, permanent stagnate water, poor aeration and lack of mineral nutrients, is infertile. The growth of trees is extreme poor in ihibiting state called "small old tree".

Regeneration.--The Larix forests except swamp-inhabiting Larix forest in the forest region are secondary forest respectively derived from montane cold-temperate coniferous forest (spruce-fir forest) and the horizontal forest---temperate coniferous and broad-leaved mixed forest, and also provide the better regeneration condition for the primary forests. The specific composition in the Larix forests is similar to it in the primary forests except the upper story consisted of Larix. With the gradual changing of site gradient, there are the transitional types of the Larix forests among the three main Larix forest types, which belong to the corresponding Larix forest depending on the specific composition.

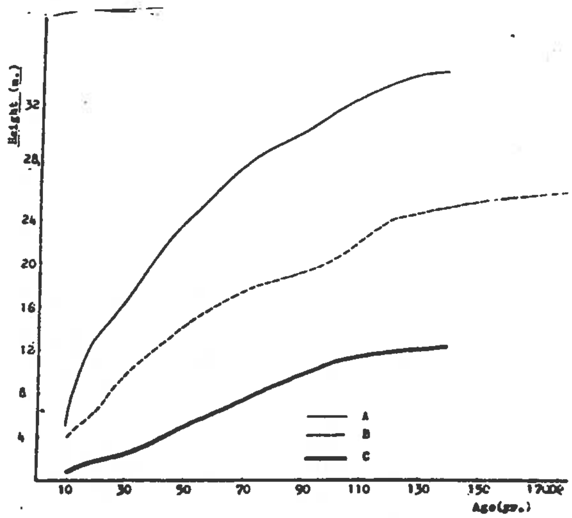

Figure 11. Height growth of the various Larix forest in the temperate coniferous and broad-leaved mixed forest region: A. Temperate Larix forest; B. Montane cold-temperate Larix forest; C. Swamp-inhabiting Larix forest.

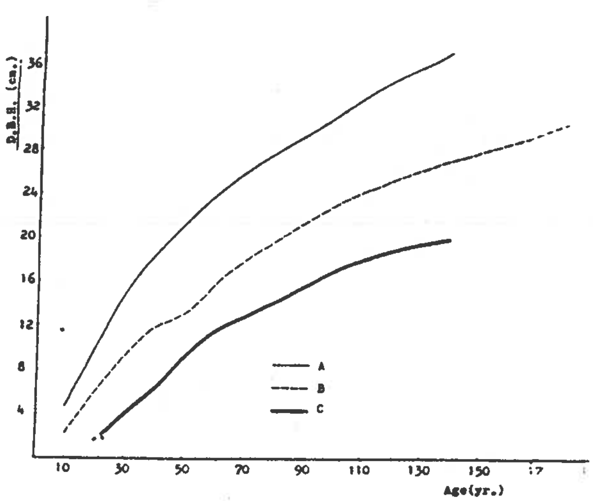

Figure 12. D.B.H. growth of the various Larix forests in the temperate coniferous and broad-leaved mixed forest region: A. Temperate Larix forest; B. Montane cold-temperate Larix forest; C. Swamp-inhabiting Larix forest.

The natural regeneration of Larix is govened not only by the shading but also by the much thicker moss and herb layers inhibiting the rooting of Larix. Generally the natural regeneration of Larix is poor even in open cutting slash, but better in fire slash because Larix occurs greatly in the bare soil. The ground cover must be removed ensuring the natural regeneration of Larix. The open area in Larix forest or the felling slash, Betula platyphylla often appears forming birch forest or mixed forest with Larix. Their regeneration and development have been mentioned above. In the case of lacking the seed sources of Larix and Betula platyphylla, the disturbance causes the invatation of intolerant herbs (e.g., Deueuxia angustifolia, Osmunda cinnamomea and Sorbaria forbifolia, etc.) and shrubs, which makes the soil swamp out and the regeneration of Larix and Betula platyphylla more difficult. There are a few numbers of Larix seedlings, which are 9 to 10 yr. at age, 35 to 50 cm high, growing on the fallen trees. The regeneration under clear-cutting should be adopted in the silviculture and management of Larix forest in the forest region according to the biological characteristics of Larix. But the seed source of Larix and the luxuriant mosses and herbs are both important affecting the regeneration of Larix. Therefore, seed trees must be reserved and the ground cover should be removed. That Betula platyphylla is mixed rationally in Larix forest is a better way in the silviculture and management of Larix because it is better tree in improvement of soil increasing the soil fertility and has many uses and high value.

LARIX IN THE USSR

A.I. Iroshnikov

ABSTRACT: Genus Larix Mill with comparatively small number of species is widely spread in the boreal regions of North America and Eurasia. It particularly dominates in the forests of continental regions of East Siberia, Central Asia and Far East, occupying up to 70-90 per cent of their territory.

Larch forests occupy about 279 mln ha, that is 40,5 per cent, of forest covered territory of the USSR (Drozhalov M. M., 1984). Moreover, three polymorphic species - Larix sibirica Ldb., L. dahurica (gmelinii) Turcz.et Trautv. and L. Kajanderi Mayr. are absolutely prevailing. Larix Sukaczewii Djilis, L. kurilensis Mayr and L. Gzekanovskii Szaf. have comparatively small area and Larix olgensis Henry, L. Lubarskii Sukacz., L. polonica Racib., L. decidua Mill and L. moritima Sukacz. occupy isolated plots.

USSR's Larix gene pool is studied with different completeness but available information about form diversity of the most valuable Larix species is sufficient base for systematic utilization of their genotypic potential.

Description of intraspecific differentiation and egologobiologic properties of the main Larix spesies, growing in the USSR, is given in the report.

Key words: Larix (larch), area, gene pool, intraspecific differentiation, biological and ecological properties, hybridization.

INTRODUCTION

In the study process of Larix genus individual species have been revised repeatedly. At the same time Larix species nomenclature is rather disputable

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up to nowadays because of different notions of the botanists about species distinguishing criteria, their genetics relations and evolution. Debatableness of many taxons is also depend on insufficient genus gene pool study and natural hybridization (its distribution and the role in Larix species formation).

Total number of Larix species recognized by some systematists varies from 6 to 29 and species, growing in the USSR territory - from 3 to 15. Such considerable fluctuation in genus Larix taxonomic differentiation related with the fact that some botanists together with "good" species distinguish in the same range climatic ecotypes or hybrid forms, appearing in the area contact zone and obtained after artificial crossing. Others don't admit species status of many geographically isolated populations which are distinctly differ by the morphological features complex.

At the first stage of Larix investigation in Russia evaluation of its individual properties was carried out in botanical gardens and parks where its different species, forms and spontaneous hybrids were represented. But the decisive significance in gaining wide popularity by the Larix had its cultures, established at the second half of the XVIII and in the XIX century in some regions by Fokel (Greshner, 1843), Ch.Mayer (1850), I.N. Shatilov (1885), K.F. Turmer (1891), P.I. Levitsky (1903) and others.

It is significant that hybrid forms (Keppen, 1885; Shreder, 1899) and works in Larix artifisial crossing (Kurdiani, 1912, 1932; Piatnitsky, 1933; Albensky, 1939, 1959; Jablokov, 1962; Kudasheva, 1964; Kruklis, 1968; Avrov, 1974; Kniazeva, 1978) revealed in Russian botanical gardens were arranged mainly for the zone where Larix is introduced. Only from 40-50 years of the XX century Larix natural populations became the subject of more systematic study. At the same time increased the interest towards its natural hybridization processed in the individual species area contact zones (Kolesnikov, 1946; Dylis, 1947, 1959, 1961; Bobrov, 1961, 1972, 1978; Koropachinsky, Milutin 1964; Kruklis, Milutin, 1977; Konovalov, Pugach, 1978 et al.) which earlier were interpreted only fragmentary (Middendorf, 1867; Sukachev, 1912, 1931; Sukachev, Poplavskaya, 1914).

Larch forests occupy about 279 mln ha - 40,5 per cent of forest covered territory of the USSR (Drozhalov, 1984). Moreover, three species - Larix sibirica Ldb., L. dahyrica Turcz. et Trautv. and L. Kajanderi Mayr. are absolutely prevailing. Other species have rather small area (Larix Sukaczewii Djilis, L. kurilensis Mayr. and L. Czekanovskii Szaf.) or occupy extremely limited isolated plots (Larix olgensis Henry, L. Lubarskii Sukacz., L. decidua Mill., L. polonica Racib. and L. maritima Sukacz). Such species as Larix leptolepis (Sib. et Zuc) Endl., L. occidentalis Mutt., L. principis-ruprechtii (Mayr) Pilger, L. Laricina (Du Roi) K. Koch and L. potanini Batalin are represented only by artificial stands or by separate trees in botanical gardens and parks. Larix lyallii Parl., L. griffithii Hooker and L. masteriana Rehder et Wilson are practically haven't been introduced in the USSR up to nowadays.

Larix Sukaczewi Dyl.

This species occupies certain rather

limited ecological niches in the European North-East and Trans Ural - the regions with temperate continental climate. Larix Sukaczewi area is attributed by A.P. Iljinsky (1929) to the reductioning net (or regressive. area perforata) type. By the number of morphological characteristics and biological properties it clearly differs from the nearest "neighbours" - Larix polonica in the South-West and L. sibirica - in the west. Larix Sukaczewi contacts with L. sibirica only at the North-Western part of the area in the lower reaches of the Ob river. In this region the two species introgressive zone, compared with the middle and South taiga and partially-wooded steppe districts of the vast Western Siberia lowland, where they are fragmentary embedded among dark-coniferous, pine, aspen and birch forests, more clearly expressed. Moreover, Larix Sukaczewi is arranged for the more "warm" places, than L. sibirica.

As a result of anthropogenic factors influence Larix Sukaczewi representation is reduced in several times in the western part of the area. Although it disappeared in some regions already in historic time, L. Sukaczewi in the postglacial period hadn't significant contact with L. polonica.

Originally Larix Sukaczewi was characterised as comparatively monomorph species with weak intra- and interspecific variation (Dylis, 1947). More detailed study of its natural populations) E.A. Pugach, 1964, 1970; N.V. Kuprianov, 1968; V.N. Nikontsuk, 1970, 1972) displayed genotypical composition specific features of larch forests of Gorky region, situated on the left bank of the Volga, the Upper Kama, Northern middle and Southern Ural districts. Certain genetics links of the Udmurtian and Gorky district stands with middle Ural northern part population were revealed.

Together with regional race singling out by the morphological characteristcs complex, species differentiation on a number of climatic ecotypes: zone-provincial in the European North-East and zonebelt in the Ural was shown. Larix Sukaczewi climatic (physiological) races were found out in the result of some populations' progeny trail in the geographical cultures established at different time in Moscow, Voronezh, Leningrad, Briansk, Sverdlovsk districts and in Bashkirian and Udmurtian autonomous republics. The same experiments became the base of the Larix Sukaczewi forest seed-zoning elaboration. According to the investigations, its most valuable gene pool is concentrated in the Soviet Union European part of mixed and Southern taiga forest zone. Its utilization also gives high effect in partially-wooded steppe districts of Western Siberia, Northern Kazakhstan and European part. In the warmer and more moist regions Larix Sukaczewi is not just as good as Larix decidua and L. polonica in productivity.

For Larix Sukaczewi populations (A.S. Jablokov, 1962; A.I. Iroshnikov, 1970, 1977; N.V. Kuprianov, 1968) absolute domination of green cone forms through the whole area is typical. Trees with red cone and transitional in ripe female cone colour are represented in populations individually as a rule.

In mircostrobile colour during flowering period the following forms are distinguished: pale green, whitish, pink and violet crimson.

Through the whole area two forms well distinguished in cone seed scales are found (Dylis, 1947). One of them have rounded, at the tip - well rounded scales. Another form - with broad avoid, at the tip - obtuse triangular scales. Between these forms in all populations there are a number of fine and gradual transitions.

In the middle and Southern Ural and also in Udmurthia very rare in populations one may come accross the form with turned outwards scales and small cones, similar with Larix leptolepis cones. In Larix Sukaczewi cultures was found out by B.V. Grozdov (1960) large-cone form. As was shown by V.N. Nikontchuk (1970) in the stands there are forms with low (3 %) and high (up to 17 %) seed yield. According to the ripening time early and late ripening forms are distingished. According to the degree of sexual dimorphism display in all populations specimen of the 3 types are represented: strobiles (more than 80 %), male (macrostrobiles are poorely represented) and female (with macrostrobiles primary development).

According to the growth character, crown form, folliage colour, form and the time of needle fall the following Larix Sukaczewi forms are distinguished: with narrow piramid-shapped or columnar crown; with saged ("weeping") branches, dense crown with small branches; with bend top, often not separated from the upper horisontal lateral branches; spruce-like; with blue-greyish foliage; with very long needles; with fine branches; with rough branches; little and very barrel-butted, with early and late needle fall in the autumn.

By the bark form in the Ural (E.A. Pugach, 1970) trees with finely and deeply fissured bark were distinguished. But they have transitional types. V.N. Nokonchuk (1972) indicates only 4 forms without transitional types: hard barked, thick barked, with bark craked into square plates and bark with deep fissures. Because of the absence of clear bounds between numerous form distinguished by bark form, he considers that it is reasonable to use type classification of its variability. All bark distinctions are brought together to the two main groups of its formation type: A. Ridged bark (broad ridged and narrow ridged types, thick barked, coarse barked, deeply fissured and craked into plates forms); B. Flaked bark (broad flaked type with alder-like thick barked and pine-like plate subtypes and narrow flaked type).

Investigations in the middle and Southern Ural found out that according to productivity, growth rate, physico-mechanic characteristics and seed quality finely fissured form trees have higher characteristics (Konovalov, Pugach, 1978 et al.). But in cultures established in the central partially wooded steppe (V.I. Birukov) higher growth rate, bole quality and insect resistance had deeply fissured, crimson barked soft barked and green cone forms (the author classified the Larix under study to the Larix Sibirica, but this needs verification).

V.N. Nikonchuk (1970) points out the following morphologic characteristics' complex, inherent to the Larix Sukaczewi trees (in Smolensk region cultures) characterized by fast growth rate and good bole quality: dense spreading crown with thick branches pointed horisontally or slightly upwards and thick barrel-butted bole, covered with thick coarse bark. The colour of the bark in the cut is crimson or red-greyish-brown.

Larix Sukaczewi with L. leptolepis and L. decidua interspecific hybridization high efficiency have been shown in many trails (Albensky, 1951, 1959; Jablokov, 1962; Kudasheva, 1964 et al.). But problems of population provenance selection, which ensure maximal heterosis under interspecific and separate intraspecific crossing aren't worked out. Selection intensity among hybrid progeny and principles of individual selection with long-term heterosis effect enlightened unsufficiently.

Larix polonica Racib.

In the USSR territory natural populations of this species are represented obly by several small plots in Ukranian Garpathians. All of them are situated in the upper mountain zone with temperate cold climate. Larix polonica area (A.P. Iljinsky, 1929) is belong to the fragmental (disjunctive) type. Its quick reduction is connected with human activity.

In spite of extremely limited forest areas with Larix polonica, the latter for a long time already is represented in West Ukranian, Kaliningrad region and Lithuanian republic's cultures. In all cases it is necessary to identify its stands.

Larix polonica is represented by two geographical (climatic) races, distinguished by the complex of morphological characteristics and growth conditions: typical (var. Typica Sz.), growing in Poland central and North-Western regions (and in the Western USSR regions in the past) and mountain (var. pienina Sz.), growing in Carpathisna, Tatra Mountains and Pienine. It differs from Larix decidua and Larix sibirica by the smaller micro- and macrosrtobiles. At the same time green cone form domination and construction of seed scales testifies L. polonica (expecially its typical race) genetics connection with L. Sukaczewi. It is possible, that at the South-Eastern border of its distribution it (mountain race) hybridizes with L. decidua. But we haven't enough grounds to classify L. polonica as hybrid larch (L. decidua x sibirica), as E.G. Bobrov (1972, 1978) does. Its populations (especially near Visla) are rather monomorph and don't have intermediate or supposed parent forms. Moreover, Larix polonica individuals are essentially differ from available L. decidua and L. Sukaczewi hybrids. History and phylogeny of L. polonica need further study with wider natural and introduced populations' hybrodological analysis.

Larix decidua Mill.

In the USSR it grows in Garpathians. In artificial stands in Western and number of Central USSR's European part districts it, like L. polonica often exceeds in productivity L. Sukaczewi and L. sibirica cultures (sometimes worse in wood quality).

Since Larix decidua area is arranged mainly for different Alps and Tatra Mountains zones, its populations are very unequal. Mother stand altitude and its gene pool differentiation by separate geographical provinces, different in their history and introduction perspectives influence on the Larix decidua progeny growth and resistance first of all.

Larix sibirica Ldb.

The greater part of the species area is arranged to the low moisture region in the continental mountainous districts of Southern Siberia. Larix sibirica occupies more cold places in comparison with L. Sukaczewi. At the same time it is less cold resistant than L. gmelinii.

The border with the latter coincides with the permafrost soil distribution limit. In the Larix sibirica and L. gmelinii areas boundary zone hybridogene populations of these two species are concentrated, they are called Larix Czekanovskii.

In the result of the herbarium collections study, Szafer (1913) singled out Larix sibirica altai form. Subsequent investigations (V.N. Sukachev, 1924, 1934, 1938; N.V. Dylis, 1947) differentiated L. sibirica on Altai, upper Enisei (Saian), upper Lena and subarctic geographical races. At different time these races were considered as varieties, climatic (geographical) ecotypes or subspecies.

Larix sibirica significant polymorphism was proved by its gene pool detailed study in natural populations and in geographical cultures. Silviculturists' special attention was attracted by Larix sibirica populations pronounced unequality in the different mountain altitude zones of Southern Siberia.

Detailed study of Larix sibirica variation in natural populations and geographical cultures established in the different Siberian zones allows to varify its intraspecific differentiation and to use its gene pool more effectively (Iroshnikov, 1981, 1985).

Altai race comprises middle mountainous and high mountainous populations of Saura, Central, Southern and Mongolian Altai. It characterises by comparatively weak polymorphism (green cone form with elastic pointed and oval scales are absolutely prevailing).

Enisei race is the most large and heterogene. It includes populations of North-Eastern Altai, Kuznetsk Alatau, Western and Eastern Saian, Tannu-01, Khamar-Daban, Khangai, Khetenei and near Angara river. Moreover, Selenga, upper Enisei and especially upper Ob populations experience strong gene migration pressure from the Altai race population. This fact causes its high polymorphism. Populations of the Eastern Saian, Khetenei are more uniform, they are remarkable for absolute domination of red-cone forms with hard broad oval seed scales. 'In the Eastern Khetenei spurs this race crosses with Larix gmelini.

Subarctic race is represented by forest tundra and Northern taiga subzone populations; from the Nadim basin in the West up to the Norilka basin in the East. In the lower Ob Larix sibirica and L. Sukaczewi introgressive hybridization zone is pronounced. The latter is arranged for less cold locations than Larix sibirica.

Baikal and Lena races in the North-Western part of its area exercise Larix gmelinii pressure and in the South-Eastern part - Enisei race population pressure. These races are close to the latter. Rare isolated populations of the Western Siberia lowland central part and also hybridogene populations in the Larix sibirica and L. Sukaczewi contact zone need supplementary study.

Pointed out Larix sibirica race division reflects species location history at the post glacial period. In the process of migration, mutation, crossing and tolerant genotypes selection further race differentiation in connection with latitude and altitude took place. The most valuable Larix sibirica gene pool is concentrated in its optimum area: in the Southern Siberia plain, premountainous and low mountainous populations. Cultures, established from seeds of those populations in the Siberian partially-wooded steppe and Southern taiga regions are characterized by the highest growth and resistant properties (Table 1). Progenies from the Northern taiga high mountainous populations have extremely low productivity.

Cultures, established from seeds of the middle mountainous and middle taiga subzone populations are characterised by intermediate properties. Larix sibirica from forest tundra and from its upper growth limit in the Altai-Saian mountainous country (1800 - 2200 m) practically eliminates by 10-15 years during its cultivation in low mountain and partially wooded steppe regions. The reason of that populations progeny failure is shoot destruction by frost because of its growth process rythm destruction in new locations.

Table 1. Average height and total yield of the 17-years old Larix sibirica Ldb. cultures in Krasnoyarsk partially-wooded steppe.

Seed origin			Height		Total yield	
Region, Autonomous Republig	Forest district	Subzone altitude, m	sm	% from the control	m^3/ha	% from the control
Khakasia	Sonsk	700-900	744±12	100	87	100
Krasnoyarsk	Aban	Southern taiga	785±15	105	112	128
Irkutsk	Irkutsk	500-900	733±50	99	95	109
Krasnoyarsk	Ust-Angarsk	middle taiga South	730± 8	98	80	92
Tuvinskaya	Kaa-Khem	900-1200	642±20	86	61	70
Mountain-Altai	Chemal	900-1500	574±16	77	50	57
Mountain-Altai	Ust-Kansk	1000-1600	524±18	70	44	51
Tuvinskaya	Turansk	900-1500	552±18	74	36	41
Mountain-Altai	Verkhnekatun	1100-2000	482±26	65	24	28
Eastern Kazakhstan	Marakol	1450-2000	170±24	23	3	2
Eastern Kazakhstan	Kurchum	1500-2200	50± 6	7	0	-
Krasnoyarsk	Turukhansk	forest tundra	30- 3	4	0	-

Larix sibirica subarctic race (as well as its Larix gmelinii and L. Kajanderi corresponding races) present special attention the investigation of the forest and arctic tundra relations, possibility of the Northern forest zone limit artificial displacement and establishment of protection stands in tundra and study of woody species vital functions in the North limit of its location, subarctic conditions adaptation mechanisms and forest growth in tundra limiting or proventing factors.

Larches, growing in the Siberian Far North and characterized by short vegetation period; vegetation beginning and passing at low air and soil temperatures; fast reaction on temperature change; good development of assimilation mechanisms; brachyblast primary fromation (in comparison with aucsiblast); protection substances and highly energetic metabolism significant accumulation; long prhotoperiod; vital forms and mutants (stunted, bush-like, dwarfish) high lability; low reproduction, compensated by rather high life length; high inbreeding and polyembriony frequency (Iroshnikov A.I., 1983; Iroshnikov A.I., Fiodorova A.I., 1974).

Dendroflora adaptation to the Far North conditions is long evolution product, which is characterized by northern populations' genotypic composition quality change. The less adaptive to the extreeme Northern conditions are reproductive systems of the majority coniferous species and larch among them. Vary rare seed years, bad pollen regime, flowering, fertilization and seed ripening unfavourable conditions cause its deficiency or even complete sterility and that is one of the main reasons of many woody species low competebility in the Northern part of its area. In that sense contemporary northern continuous and isolated forest growth boundary is climatic as far as termic regime here determine the efficiency of woody species sexual reproduction.

Larix sibirica mountainous populations (altitude more that 900 m) should satisfy only seed requirements of high-altitude zones corresponding in natural division into districs. Breach of these requirements leads to quick reduction of productivity and resistance in artificial stands.

In Larix sibirica populations occur the same forms as in L. Sukaczewi but some regions in its area essentially differ by its representation. Certain shifts in the genotypic composition result from latitude and altitude change (for example, in representation of forms with narrow-oval or pointed seed scales). Increase of thick-barked form frequency in populations occurs in more continental climate. Representation of some forms in different area parts allows to reveal its adaptive significance and larch migration ways in the post glacial period (see figure). But breeding significance of some Larix sibirica forms is poorely studied; its available values (for example, green - and red-cone froms) are rather contradictory.

Larix gmelinii Rupr.

The species occupies a large part of the middle Siberian plateau, Western Trans-Baikal, Northern China and Western part of the Mongolian People's Republic, which are characterized by continental climate and long or permafrost soil distribution. On the South-Western boarder it hybridize with Larix sibirica, on the North. Eastern - with L. Kajanderi and on the South-Western - with the Far Eastern species (mainly with Larix kurilensis). It clearly differs from L. Kajanderi by more rounded form and less angle seed scales deflection from cone axis, by oval form and more dense cone consistency.

For the species populations geographical and individual variations are typical. In the Larix gmelinii populations there are small and large-cone forms, green and red cones and also intermediate in cone colour forms, bush-like and others. In the Larix gmelinii South-Western area part may be observed green-cone form domination. But its representation decreases in central and especially North Yakutia regions

During the introduction from low-mountainous populations of the South-Eastern area part to the more temperature climate regions it characterizes by very good growth during the first 15-25 years. But later it appears to be unresistant or slow down its growth. That is why it is necessary to select fast growing forms in the optimum zone for introduction and hybridization.

Larix gmelinii Northern populations (as L. sibirica) are absolutely unresistant during its introduction to the Western or Southern regions. In the whole climate races of the species are not studied yet.

Larix Kajanderi Mayr.

Many botanists don't appove its status of the species. V.L. Komarov (1934), for example, considers it to be Northern, more continental Larix gmelinii race. Its species area to a great extent coincides with the steady Yakutsk anticyclone and the lowest in the Northern hemisphere winter air temperature region.

In the contact zone with Larix gmelinii A.P. Abramov and I.U. Koropachinsky (1984) recorded hybridogene populations of these species. On the South Western border of its distribution Larix Kajanderi crosses with L. kurilensis. Larch, growing on the central Kamchatka regions, was classified by E.G. Bobrov as L. Kajanderi. But N.V. Dylis (1961) singled it out (and larch from the Okhotsk coast and Northern Sakhalin) as Northern, Okhotsk-Kamchatsk race of Larix kurilensis.

In Larix Kajanderi a number of form was singled out by the colour, size and cone and seed scales type. In the whole geographical and intraspecific variability of the species is poorely studies. Progeny trails of some L. Kajanderi populations above its area testify the species unpromising introduction. In the less continental climate its cultures are characterized by weak resistance and bad growth.

Larix kurilensis Mayr.

Besides above mentioned Northern race N.V. Dylis (1961) singled out Southern, island, race which is spread in the Southern Kuril Islands (Shikotan and Inturup) and in the large part of Sakhalin. Larix kurilensis is typically maritime form. Besides two geographical races it has several types by the cone form.

The species was widely tested in cultures only in Baltic Republics where it demonstrated good growth. Larix kurilensis x L. decidua hybrid in Leningrad demonstrated especially high growth characteristics (Dylis, 1961). But they were poorely frost resistant there. Similar hybrid in FRG (Bavaria) had total height growth of 15 m in the age of 17 years. These experiments testify that in more warm and moist USSR's regions Larix kurilensis can be used during the fast growing larch forms breeding.

Larix olgensis Henry

The species has very limited area - area solitaria (it is located in one very limited point), occupying cost from the Valentine bay up to Vladimir Bay. Some authors say about its distribution in Korea and China North-Eastern regions. But V.L. Komarov's (1934) collections didn't prove it.

I.K. Shishkin (1933) and B.P. Kolesnikov (1946) singled out a number of morphological forms and ecotypes. But it isn't yet clear whether it connected with species' polymorphism or with Larix olgensis natural hybridization with other Far Eastern Larix species.

G.V. Gukov (1976) considers that Larix olgensis is more warm loving than other Sikhote-Aline Larix species. In his opinion it is poorely resistant form (because of slow growth rate, bad seed quality, etc.)

Larix olgensis during its crossing with Larix sibirica gives fast growing in the first years hybrid progeny. One can believe that species gene pool became poor in the result of intensive exploitation during 150 years and intermittent fire. That is why through protection of available plots and fast-growing resistant forms selection are needed. Wide progeny and hybrid trails in the regions with warm and moist climate are also necessary.

Larix maritima Sukacz.

One of the least studied USSR's larches. Its species status is rather disputable. E.G. Bobrov (1972, 1978) considers Larix maritima as a natural Larix Kajanderi x L. kurilensis hybrid. Its area according to G.V. Gukov's data, is rather limited: in the river Koppy and Botchy basisns flown into Tatar strait. In cultures Larix maritima is studied unsufficiently and its growth rate data are contradictory. G.V. Gukov considers that Larix maritima is one of the most fast growing species of the Far East. It is almost absolutely resistant to fungus diseases.

Natural hybridization processes on the species area boundary have been mentioned already. Some systematists consider hybridogene populations as independent species, others - as hybrid larches. On the USSR's territory N.V. Dylis (1961) singled out 4 hybrid groups: Larix Gzekanovskii, L. ochotensis, L. amurensis, L. Lubarskii. Besides he pointed out larches hybridization in the contact area of L. sibirica and L. Sukaczewi.

E.G. Bobrov (1972, 1978) singled out 5 larches formed in the introgression hybridiration process: Larix Czekanovskii, L. maritima, L. Lubarskii, L. polonica and L. Kajanderi x kamtshatica hybrid.

Among hybridogene species only Larix Czekanovskii is the most fully studied (Kruklis, Milutin, 1977). For that species introgression specific peculiarities in the parent species populations were shown in the result of isolation mechanisms (ecological barriers in the first place) and character of peculiarities combination and splitting in hybridogene populations. It was established that this natural hybrid doesn't have specific kariotype. Increased hybridogene Larix Czekanovskii variability level is distinctive only for quality characteristics. Hybridogene species regardless of occupied territory are interesting for breeding of individuals with heterosis effect.

SUMMARY

Rapid growth rate, high wood quality, practically unlimited possibility of distant crossing (with hybrid progeny significant heterosis effect), high polymorphism, adaptation to extreeme environmental conditions, wide introduction perspectives beyond area boundaries of many Larix species attracted attention of silviculturists, botanists and plant-breeders. Some of the species, races and populations form forest boundary on the Northern limit of dendroflora distribution and its upper boundary in the mountains. Within Eurasia, with the increase of the continental climate, the following species change is observed: Larix Sukaczewi Dyl. - L. sibirica Ldb. - L. Czekanowskii Sz. - L. gmelinii Rupr. - L. Kajanderi Mayr. Subpolar populations of the mentioned species are convenient object for the study of the woody species adaptation mechanisms to the extreme environmental conditions.

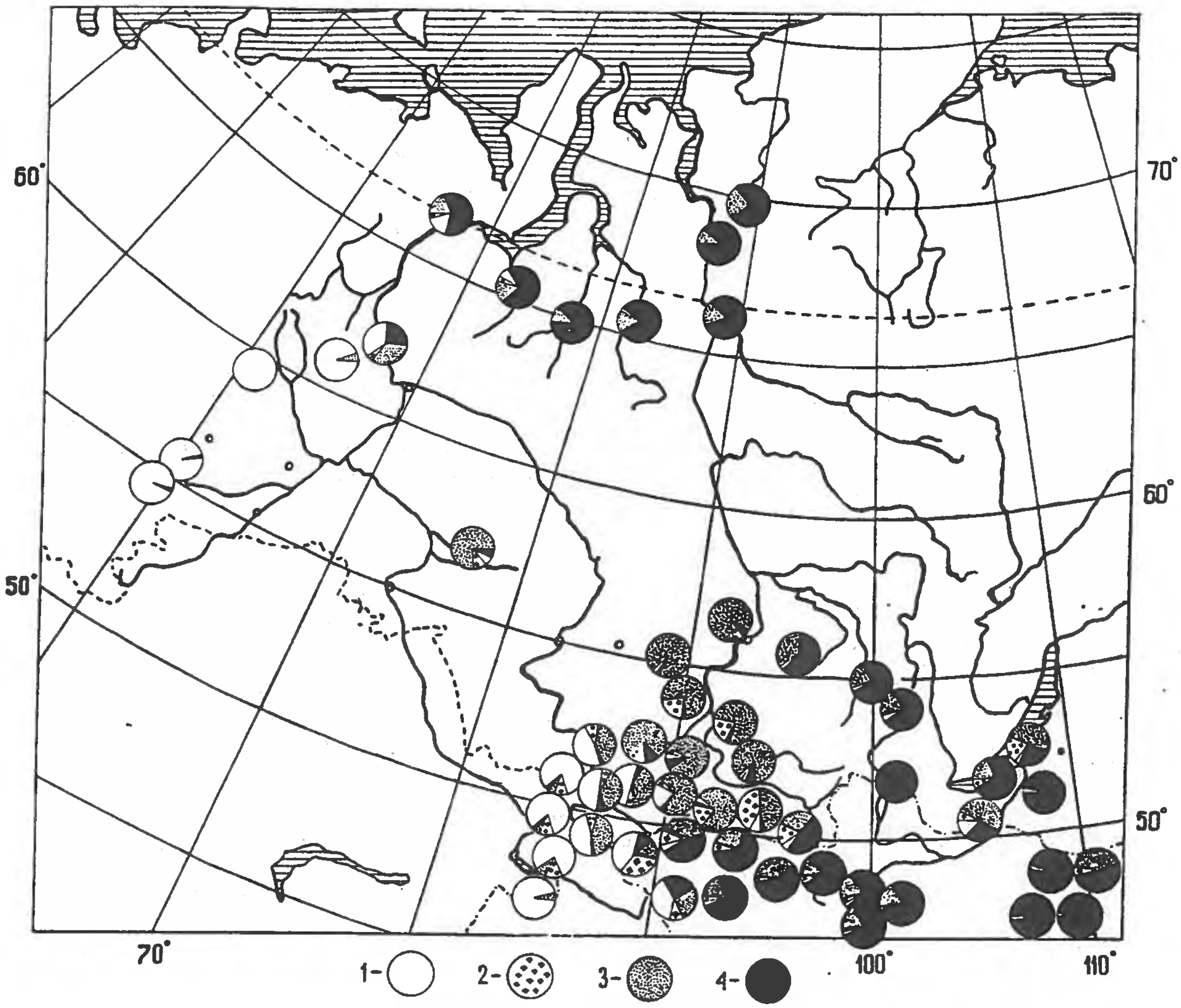

Figure 1. Structure of the Larix sibirica Ldb. populations within the species area and Larix Sukaczewi Dyl. populations in the South-Eastern part of the area according to female cone colour: 1. green cone, 2-3 intermediate forms (2. green cone with narrow red edgeof seed scales; 3. red cone with small green spots in the lower part of seed scales), 4. red cone.

LARCH IN NORTH AMERICA

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ABSTRACT

Three species of Larix are native to North America: L. laricina is a transcontinental component of the Boreal Forest Zone; L. lyallii is a scattered component of the upper Subalpine Zone of the Rocky Mountains and Cascade Mountains of the northern United States and southern Canada; and L. occidentalis is a component of the lower elevation, Montane Zone, of the same mountainous region. The silvics, emphasizing range, productivity, habitat, and reproduction characteristics of the two species most suited to northern regions is reviewed.

INTRODUCTION

Three species of Larix, L. laricina (Du Roi) K. Koch, L. lyallii Parl., and L. occidentalis Nutt. are native to North America. Within L. laricina is placed L. alaskensis W.F. Wight which has been shown to be neither a separate species nor a subspecies (Ostenfeld and Larsen 1930) although some botanists give it varietal status (Fowells 1965).

L. laricina has the broadest range of the three species (Figure 1). It is transcontinental, ranging from the Atlantic shore of Newfoundland nearly to the shore of Norton Sound of the Bering Sea in Alaska (Fowells 1965; Viereck and Little 1972). Its east-west range covers approximately 107 degrees of longitude. It reaches its southern limit in the eastern United States in the Appalachian Mountains of West Virginia at approximately 39° N. Latitude and its northern limit, on the delta of the Mackenzie River in the Northwest Territories of Canada, is about 68.5° N. Latitude. East of the Mackenzie River, it is commonly a tree line species whereas to the west it commonly does not reach as far north as Picea glauca (Moench) Voss. The north-south range covers approximately 30 degrees of latitude; the northern most portion of its range is in the west, particularly in the Mackenzie River drainage. It grows from sea level to 520 m in the western portion of its range and to 1,220 m in the east.

Inspection of the range maps (Fowells 1965; Viereck and Little 1972; Dobbs et al. 1976) for L. laricina indicate three distinct populations: 1) Mackenzie River drainage and eastward, 2) Alaska, and 3) the Prince George-Quesnel area of the Fraser River drainage in British Columbia. Within the Yukon Territory, the gap is not as pronounced as suggested by the range maps; the status of the gap in Alaska has not been adequately defined.

L. lyallii and L. occidentalis are much more limited in their range. Both are confined to the Rocky Mountains and Cascade Mountains and particularly, but not exclusively, to the drainages of the Columbia River and Fraser River systems. L. occidentalis is confined to drainages west of the Continental Divide in Montana, Idaho, Oregon, Washington, and British Columbia. The latitudinal range is approximately 7.5 degrees, from approximately 44° to 51.5° N. Latitude and the longitudinal range is nearly 9 degrees, between 112.5° to 122° W. Longitude. It typically occurs at elevations between 500 and 2,100 m.

L. lyallii is a subalpine species with two distinct populations: 1) Cascade Mountains of Washington and British Columbia between 47.5° and 49.5° N. Latitude and 2) Rocky Mountains of Idaho, Montana, British Columbia, and Alberta between 45.5° and 51.5° N. Latitude (Arno and Habeck 1972; Dobbs et al. 1976). In the Cascades it occupies a longitudinal range of nearly one degree and in the Rocky Mountains, a longitudinal range of nearly five degrees. In the Rocky Mountains it occurs primarily west of the Continental Divide especially in British Columbia; however it crosses the Divide in numerous places. The absolute elevational limits of L. lyallii are about 1,520 and 3,010 m (Arno and Habeck 1972); however, it typically occurs at elevations from 1,800 m to alpine tree line (Arno and Habeck 1972; Krajina 1969). The Cascade Mountains' populations are at lower elevations than the Rocky Mountains populations; this reflects regional differences in the elevational limits of the Subalpine Zone. The range is relatively discontinuous; populations are confined to the higher mountains and separated by the lowlands. The range is much more restricted than that suggested by Ostenfeld and Larsen (1930).

From the range data, it is obvious that there is little likelihood of natural hybridizing between L. laricina and L. occidentalis or L. lyallii. Generally, L. lyallii and L. occidentalis are separated from each other by at least 150 m of elevation; occasionally the two species do mix and hybridize (Carlson 1965; Little 1979). Dobbs et al. (1976) state that the two species may naturally hybridize where their ranges approach or overlap one another.

In addition to the native Larix, species native to Europe and Asia and hybrids have been planted quite extensively in North America. Species include: L. decidua Mill., L. gmelini (Rupr.) Lit. (L. dahurica Turcz.), L. kaempferi (Lam.) Carr., and L. sibirica Ledeb.

L. occidentalis reaches the greatest size of all the Larix species. Franklin and Dyrness (1973) suggest typical ages in excess of 700 years and diameters of 140 cm and heights of 50 m in the Pacific Northwest. Fowells (1965) reports a record, maximum age of 915 years and diameters greater than 200 cm. On the best sites, trees can be 70 to 80 m tall (Hitchcock et al. 1969). However, it has limited potential in the northern forest since it is unique as the only Larix species "definitely not a tree of arctic or alpine timberlines" (Arno and Habeck 1972) and is generally associated with a moderately long vegetative season.

L. lyallii, although a species of the subalpine timberline, reaches relatively large sizes. Arno and Habeck (1972) report trees up to 160 cm in diameter and 26 m tall in the Bitterroot Mountains of Montana; the largest tree found was in the Cascades and has a diameter of 190 cm. They report an average life span for the species of 500 years with many individuals reaching ages of 700 years and the oldest being nearly 1,000 years. L. lyallii occupies sites having rigorous climates; temperatures are below freezing for more than one-half the year and recorded mimima are less than -55°C (Arno and Habeck 1972; Krajina 1969). Hence, L. lyallii may have some potential in the northern forest, especially at lower latitudes.

L. laricina, primarily a species of the Northern Forest, does extend southward to intermingle with the Grasslands in the west and the North American Deciduous Forest in the east. It reaches neither the great age nor the size of its North American relatives. Fowells (1965) gives a maximum reported age of 335 years but notes that typically the maximum age is 150 to 180 years and Harlow and Harrar (1958) state that maturity is reached in 100 to 200 years. Brown (1983) reports trees 130 years old from a bog in Alaska. Tree diameters are typically under 60 cm; Harlow and Harrar (1958) report a maximum diameter of 91.5 cm and Fowells (1965) citing reports in the literature states that a few reach 91 to 101 cm. The U.S. Forest Service (1908) states that it rarely attains a diameter greater than 76 cm. The largest tree in Alaska is reportedly 33 cm in diameter; however, there are reports of trees slightly larger. In northeastern British Columbia, on a wet hydrothermal site at Liard River Hot Springs (Latitude 59.4° North) several large trees occur in one grove, the largest is greater than 50 cm in diameter. L. laricina trees occasionally may exceed 25 m in height (Harlow and Harrar 1958). The U.S. Forest Service (1908) states maximum heights rarely exceed 30 m.

Hence, two species of North American Larix, L. lyallii and L. laricina, have potential for management in the Northern Forest. These two species, especially the latter will be emphasized in further discussions. There is, however, little published information concerning L. lyallii.

PRODUCTIVITY

Only Krajina (1969) provides comparative site index (base age = 100) information for the three North American species of Larix (Table 1). However, he provides no height-over-age curves.

Table 1. Growth classes and associated site indices (base age = 100) for the North American species of Larix (from Krajina 1969).

Growth class	Site Index in metres		
	Lala	Laly	Laoc
Ia	24	15	39-42
Ib	22.5	13.5	36
IIa	21	12	33
IIb	19.5	10.5	30
IIIa	18	9	27
IIIb	16.5	7.5	24
IVa	15	6	21
IVb	12	4.5	18
Va	9	3	15
Vb	6	1.5	12
Vc	<5	<0.75	<9

Note: For species codes see Appendix I.

Gevorkiantz (1957) published anamorphic site index curves (base age 50 years, total age) for L. laricina (Figure 2); these curves must be questioned. Heffernan (1987) located eight sites in Alaska with L. laricina having a breast height age equal to or greater than 50 years. Free hand curves of her data are presented in Figure 2 for comparison. Bolghari and Bertrand (1984) developed site index curves for plantation grown L. laricina in Quebec province; they used total age = 25 years for the index age. Their curves are also presented in Figure 2. It is apparent that existing site index curves for Larix laricina require considerable refinement.

No site index curves exist for L. lyallii.

The growth and productivity of Larix laricina, despite the species' wide range, has not been seriously studied until quite recently. Kellogg (1907) reports on one small plantation (less than 0.05 hectare) in Bureau County, Illinois, which is south of the species' natural range; at 45 years, trees within this plantation having an initial spacing of 1.5 x 1.8 m averaged 18.5 cm dbh and 17.4 m in height. These trees averaged 0.21 cm of radial increment per year and 0.5 m of height growth. Beeftink (1951) reports similar height growth for natural stands in Alberta.

Stiell (1986) provides some of the most detailed growth information available on its early growth. His data are for a 1970 levels-of-growing-stock plantation in which the first measurements were obtained in the autumn of 1978; a portion (three of the six spacings) of his data are presented in Table 2. For the six year period, 1979 through 1984 growing seasons inclusive, mean annual radial growth at breast height ranged from 0.25 to 0.55 cm and was positively correlated with spacing; mean annual height growth ranged between 0.6 and 0.7 m and was not correlated with stand density. Stand mean annual basal area growth ranged from 0.7 to 2.0 m^2/ha and was inversely related to the number of stems per hectare.

Table 2. Average stand characteristics for 15-year-old L. laricina plantations of various spacings on an upland site at the Petawawa National Forestry Institute, Ontario, Canada (from Stiell 1986).

	Year	Nominal planted spacing, m		
		1.75	3.00	4.25
Trees/ha	1978	2,488	1,058	550
	1984	2,262	1,043	532
Mean dbh, cm	1978	3.7	4.2	4.6
	1984	8.0	10.0	11.3
Mean height, m	1978	4.4	4.6	4.6
	1984	8.4	8.7	8.5
Dominant height, m	1978	5.8	5.8	5.9
	1984	10.0	9.6	9.8
Basal area, m^2/ha	1978	2.6	1.5	0.9
	1984	11.0	8.2	5.4
Total volume, m^3/ha	1984	46.1	35.1	21.4

Hall (1983) compared early height growth of L. laricina with that of other native and exotic conifers in Newfoundland (Tables 3 and 4). His data show that height growth of plantation grown L. laricina exceeds that of the other native conifers and may equal, exceed, or be less than non-native Larix species. With respect to the non-native species of Larix, the relationship depends upon species and/or provenance. The height growth relationships among the species of Larix is certainly unclear. Reimeschneider and Nienstaedt (1983) present five and eight year old height growth data for various species and hybrids of Larix planted in Oneida County, Wisconsin; their data are presented in Table 5. Note how the ranking of the various species and hybrids changed over a three year period.

Table 3. Average total height of planted 15-year-old Larix laricina and other conifers on four sites in Newfoundland (from Hall 1983).

Species/Provenance	---Location---			
	Bottom Brook	North Pond	Windsor Lake	Avondale Heathland
	(height, m)			
Lala/Nova Scotia	4.58	4.68	2.90	4.12
Lade/Central Europe	4.72	2.16	1.88	
Lade/Germany Region 6	4.52	1.86	2.27	
Laka/Germany Region 7	4.97	3.03	2.52	
Laka/Germany Region 7	4.79	3.64	3.15	
Laka/Honshu Japan	5.31	2.45	2.87	
Pigl/Nova Scotia				1.21
Pima/New Brunswick	3.13	1.48	1.68	
Pima/Newfoundland				1.20
Piba/New Brunswick				3.28
Pisy/Scotland, Morayshire				2.73

Table 4. Average total height of 8 year old L. laricina and exotic species of Larix planted on a productive forest site in western Newfoundland (from Hall 1983).

Species/Provenance	Height m	Statistical relationship
Lala/Petawawa, Ontario	1.21	b
Lasi/Krasnojarsk, USSR	.92	d
Lasi/Krasnojarsk, USSR	.62	e
Laka/High Meadow Forest, England	1.32	b,c
Laeu/Newton Seed Orchard, Scotland	1.56	a
Laeu/Mabie Seed Orchard, Scotland	1.49	a,c

(Note: Statistical relationship: means with the same letter are not significantly different from each other at 0.99 probability.)

Table 5. Mean heights at five and eight years for various species and hybrids of Larix at one site in northern Wisconsin (from Reimenschneider and Nienstaedt 1983).

Species	Number of Seedlots	5-year Height m	Rank	8-year Height m	Rank
Lasi	1	1.83	8	4.31	3
Lade	9	1.85	6	4.19	4
Laka	4	1.85	7	3.70	8
Lade X Laka	3	2.16	1	4.69	1
Laka X Lade	1	2.09	2	4.48	2
Laka X (Laka X Lade)	5	1.90	5	3.94	6
Lade x (Laka X Lade)	10	1.93	3	4.17	5
Lala (Ont)	4	1.93	3	3.80	7

Vallee and Stipanic (1983) provide height growth data for a Larix provenance trial at the Lotbinière, Quebec arboretum. After 10 years, thirteen provenances of L. laricina had a range in mean height of 4.9 to 6.0 m; the average height of all provenances was 5.4 m. The range of mean height for four provenances of L. decidua was 4.8 to 5.8 m and the average of the four was 5.3 m. The range for two provenances of L. kaempferi was 5.5 to 5.8 m and the average was 5.6 m; one of these seed sources was from the Honshu seed orchard. Thus on the basis of these early results, certain provenances of L. laricina appear to have height growth comparable with that of non-native Larix species.

Bolghari and Bertrand (1982) cited by Vallee and Stipanic (1983) sampled a large number of conifer stands in southern Quebec and found the Larix species to be the fastest growing.

Their height data (from Vallee and Stipanic 1983) at 25 years are presented in Table 6. Note that on the better sites, the exotic Larix had better heights than L. laricina and off-site, the poorer sites, the situation is reversed. Bolghari and Bertrand (1984) later produced yield tables for the 118 L. laricina plantations. Site index (index age = total age of 25 years) ranged from 8 to 18 m.

Table 6. Mean, minimum, and maximum height (site index) of various coniferous species' plantations in southern Quebec, Canada (from Bolghari and Bertrand 1982 as cited by Vallee and Stipanic 1983).

Species	Number of plots	Height at 25 years, m Mean	Minimum	Maximum
Pire	289	11.8	6.0	18.1
Pist	59	9.4	5.8	12.7
Pisy	149	10.3	5.8	14.4
Pigl	249	8.9	4.4	15.1
Piab	120	9.9	6.6	15.7
Lala	118	14.3	9.3	18.2
Lade/Laka	70	16.2	8.4	23.7

Jeffers (1975) compared the height growth of nine-year-old planted L. laricina provenances on good upland sites at two locations in northern Wisconsin. At the Forest County site, the range of heights for six provenances was 2.6 to 3.2 m with a mean of 2.8 m; at the Onieda County site, the range of heights for four of the same provenances was 2.1 to 3.2 m with a mean of 2.4 m. He also reported on the growth of eight-year-old plantings. At the Forest County site, the range of heights of 18 provenances was 1.3 to 2.3 m with a mean of 1.95 m. At this location, five provenances, three from Wisconsin, one from Minnesota, and one from Maine, exhibited the best height growth with means above 2.1 m; two Michigan and the Alberta sources had the poorest height growth with means below 1.8 m. It is noteworthy that the Alberta source (Latitude 56.6° N and Longitude 111.2° W) only reached a height of 1.3 m at this site (Latitude 46.0° N and approximate Longitude 89° W). At the Oneida County site, 16 provenances (the Alberta source was not included) had a range in heights of 1.4 to 2.0 m with a mean of 1.7 m. The five best provenances, including two (Wisconsin and Maine) from the five best at the Forest County site, had mean heights in excess of 1.9 m.; the other provenances were from the upper peninsula of Michigan, southern Ontario, and Nova Scotia. The three poorest seed sources, with height growth less than 1.5 m, were from Minnesota and Michigan. One of these poor sources, the Minnesota (Anoka County) near the southwestern edge of the range, ranked second among the top five at the Forest County site.

The above growth rates for young plantations could be considerably greater than that suggested for natural stands.

On a variety of sites in Alaska, Heffernan (1987) compared the competitive ability of L. laricina and its associates. She determined the time necessary for natural, established seedlings (15 cm tall), seedlings or hardwood sprouts, to reach breast height (1.4 m). L. laricina typically reached breast height sooner than Picea glauca (Moench) Voss and P. mariana (Mill.) B.S.P.; its height growth was only slightly less to slightly better than that of its hardwood associates, Betula papyrifera Marsh., Populus balsamifera L., and P. tremuloides Michx. She found on many sites that it took established seedlings three to seven years to reach breast height; however, on poor sites, the time to reach breast height was often greater than ten years. She also developed height-over-age curves for trees 25 years and older and found typical heights ranging from 6.2 to 12.2 m at 25 years of age. Best growth was on the drier sites having a thin organic horizon and/or where there was a high component of broadleaf trees, Salix spp., and/or Alnus spp. Poorest growth was on wet soils with permafrost and a thick organic horizon and/or where L. laricina, Picea mariana, and Ledum groenlandicum Oeder were dominant. Thus, for apparently free-growing trees in natural stands, she found height growth rates to be similar to that reported for plantations.

Cooley (1904) states that the height of the average L. laricina in Hancock County, Maine at 15 years of age is 4.9 m, at 30 years it is 13.4 m, and at 45 years it is more than 18 m. She also refers to old trees in Wisconsin often being 30 m tall.

Information on diameter growth is limited. For Hancock County, Maine, Cooley (1904) reports the following diameters, the mean of many measurements:

- 2.5 cm at 8 years
- 6.4 cm at 11 years
- 19.0 cm at 20 years
- 21.6 cm at 25 years
- 45.7 cm at 45 years.

Thus over a period of 45 years, the mean annual radial growth is 0.51 cm. In northern Indiana she refers to trees 14 to 15 m tall being nearly 14.5 cm in diameter and trees between 18 and 21 m tall being 55.9 to 66.0 cm in diameter.

Data from Carpenter (1983) from four "representative natural" L. laricina stands in northeastern Minnesota suggest mean annual radial growth rates of less than 0.30 cm for trees 50 to 75 years old. Data from northern Alberta (Wang et al. 1985), albeit the growth representing the mixed condition of before and after drainage, suggest relatively slower rates of radial growth; trees with a stump (50 cm above the ground surface) age of less than 35 years had mean annual radial growth rates of 0.17 to 0.25 cm. Our data from better sites in Alaska suggest mean annual radial growth rates of 0.20 to 0.25 cm for trees 30 to 40 years old.

As stated previously, Stiell (1986) reported that diameter growth of plantation L. laricina begins to be strongly affected by spacing between 10 and 15 years of age. His data indicate mean annual radial growth rates of 0.22 to 0.38 cm over the 15 year life of the plantations at Petawawa, Ontario. During the five year, initial period of competitive expression, mean annual radial growth ranged from a low of 0.25 cm on the high stocking plots to 0.50 cm on the low stocking plots.

Bolghari and Bertrand (1984) provide yield information for plantation grown L. laricina in southern Quebec province. Table 7 summarizes that yield data. Note that for wide spacing, 2.75 x 2.75 m, diameters range from 9.8 cm on poor sites to 24.3 cm on the better sites; the mean radial growth per year averages 0.14 to 0.35 cm, respectively.

Wang et al. (1985) demonstrated that drainage has an effect similar to release on L. laricina. Hence, the data of Bolghari and Bertrand (1984), Stiell (1986), and Wang (1985) demonstrate that management activities can greatly influence radial growth of L. laricina and must be considered in any effort to utilize the species successfully.

Arno and Habeck (1972) provide limited information concerning the growth rate of L. lyallii. They found stands with trees in excess of 25 m tall. In the Bitterroot Mountains of Montana-Idaho they found trees up to 26 m and they found trees near Harts Pass in the North Cascades of Washington 24 to 27.5 m tall. Often times, however, trees are stunted; trees several hundred years old may be only two to three metres tall. Individuals on the most favorable sites maintain growth rates of one centimetre radially per 8-10 years for at least 200 centuries. Individual trees can reach breast height diameters of 25 or more centimetres in 120 to 150 years and occasionally diameters greater than 60 cm by 200 years of age. Under harsh environmental conditions or strong competition, growth may be as little as one centimetre per 80 years for centuries; one tree found on a dry site with strong competition from Pinus albicaulis Engelm. grew radially only six millimetres in 115 years! The limited data on the growth rate of L. lyallii in its natural habitat does not suggest the species for fibre production; however Franklin and Dyrness (1973) note that its ameliorating influence on the site allows typical, lower elevation subalpine species (understory plants and trees) to ascend to higher elevations than would be otherwise possible. Hence, in spite of its slow growth, it may find an important role in the establishment of protection forests.

HABITAT

The North American species of Larix are extremely shade intolerant. Fowells (1965) reports that although L. laricina can tolerate some shade during the first three or four years, once established, it must maintain an overstory position to survive. Armson (1983) states that as long as it is in the upper canopy of mixed stands, it can compete favorably with its associates. Because of its high shade intolerance, natural stands are largely restricted to wetlands (Spurr and Barnes 1980). Arno and Habeck (1972) report that L. lyallii is less tolerant than any of its associates which include Pinus albicaulis Engelm. and P. contorta Dougl. ex. Loud.

Both species tolerate extreme temperatures. Lowest recorded temperatures for L. laricina range from -29° to -62°C; maximum temperatures range from 29° to 44°C (Fowells 1965). Mean annual temperatures range from -9°C to more than 7°C (Rowe 1972). The average frost free period ranges from less than 75 days in Alaska and northern Canada to 180 days in the southern part of its range. Arno and Habeck (1972) report the lowest recorded temperatures within the range of L. lyallii are from the Rocky Mountains with the minima being -51° to -57°C. Temperatures in the Cascade Mountains are not as severe

Table 7. Yield information for 35-year-old L. laricina in southern Quebec province, Canada (from Bolghari and Bertrand 1984).

Site index m	Spacing m	Dominant Height m	Mean Diameter cm	Basal Area m^2/ha	Volume Total m^3/ha	Volume Merchantable m^3/ha
8	1.50	10.1	9.8	19.75	86.76	60.58
	2.75	10.1	12.4	14.45	67.06	43.09
10	1.50	11.9	11.1	23.63	114.98	86.28
	2.75	11.9	14.8	18.57	90.56	64.01
12	1.50	13.7	12.4	28.51	145.62	114.59
	2.75	13.7	17.2	22.70	116.11	87.32
14	1.50	15.5	13.7	33.38	178.68	145.36
	2.75	15.5	19.5	26.82	143.71	112.81
16	1.50	17.2	15.0	38.26	214.17	178.53
	2.75	17.2	21.9	30.94	173.35	140.39
18	1.50	19.0	16.3	43.14	252.09	214.05
	2.75	19.0	24.3	35.06	205.05	169.99

because of the maritime influence. Mean annual temperatures range from a low of at least -3°C in the Rocky Mountains of Alberta to 4°C in the Cascades of Washington. The average frost free period is extremely short; often every month has temperatures below freezing.

Krajina (1969) considers both L. laricina and L. lyallii to be calciphiles. Unfortunately, he does not present supporting data. Jeglum (1971) investigated the correlation between plant species and pH and water level in peatlands near Candle Lake, Saskatchewan. He used pH to assign each stand to one of five fertility classes. Based on abundance and presence, he placed L. laricina in the eutrophic class. Unless one considers the presence of L. laricina across the peatland landscape, this could be easily misinterpreted to mean that the species is nutrient demanding. Table 8 presents Jeglum's (1971) information regarding Larix. One interpretation of the data is that seedbeds characterized by a pH range of 5.0 to 6.9 are more conducive to the germination of seed and the early survival of L. laricina; this could be due to species' interaction/competition. Also, the percentage of stands in which Larix is present appears to decline with increasing pH.

Fowells (1965) states that L. laricina tolerates high acidity. Curtis (1959), in describing the typical northern wet forest community found on Histosols in Wisconsin and in which L. laricina is a dominant, provides a community summary which suggests a typical pH of 4.7 and a calcium content of 755 ppm. On upland Spodosols and Inceptisols of the Boreal Forest where L. laricina is a minor species, the suggested pH is 5.7 and the calcium content is 2,780 ppm. On the rich Histsols of the northern wet-mesic forest, where Larix is also a minor species, the typical pH is listed as 5.5 and the calcium content as 3,780 ppm. This suggests that L. laricina, at least in the Great Lakes portion of its range, tolerates a considerable range of available calcium.

Tilton (1978) investigated the relationship of habitat to growth and foliar elemental concentrations. He found that L. laricina on northern peatlands and forested bogs with Sphagnum species present had lower foliar concentrations of N, P, Ca, and Mg and lower site index values than on fens with Carex species dominant and without Sphagnum species. However site indices were higher on sandy mineral soils where N and K concentrations were similar to that of the fens and the Ca and Mg concentrations were less!

Marie-Fortin (1927) reports that L. laricina is rare in the extensive lime stone areas of eastern Quebec.

Based on a sample of 127 stands throughout the range of L. lyallii, Arno and Habeck (1972) found L. lyallii sites often to be calcium poor. In their search of the literature, they found only the statement of Krajina (1969) that this timberline species is associated with calcium-rich sites. In Montana, they found the species largely absent from limestone substrates. In Alberta where there is an abundance of limestone and dolomite, it was found mostly on quartzite, sandstone, and shales--the same type of substrate as in Montana. They conclude, it "seems to prosper on acidic substrates, generally low in calcium carbonate, throughout its distribution. Preliminary indications are that its development may be retarded or possibly even inhibited on basic calcareous soils." Mineral soil pH for the 127 plots ranged from 3.9 to 5.7 except for the Grave Peak site in Idaho which had a pH of 6.2.

With reference to L. laricina, it appears to grow on nearly every forest site within the northern forest zone (Fowells 1965). Cooley (1904) comments on finding it on deep mineral soils as well as shallow soils overlying bed-rock in Maine. Mineral soil texture does not appear to be limiting since it is found on heavy clays to coarse sand (U. S. Forest Service 1908). Fowells (1965) reports its occurrence on woody peat and sphagnum peat. It can tolerate a wide range of soil moisture conditions. Best growth is on well-drained, but moist soils (Wile 1981; Fowells 1965). Seedlings and saplings are susceptible to flooding and droughts (Duncan 1954; Armson 1983). Fowells (1965) comments that short periods of flooding do not seriously impact it; however, prolonged flooding will kill it.

Table 8. Distribution of Larix laricina near Candle Lake, Saskatchewan by pH class based on mean values of abundance/percentage presence (from Jeglum 1971).

pH range	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9
Fertility class	Very Oligotrophic	Oligotrophic	Mesotrophic	Eutrophic	Very Eutrophic
Number of stands	5	10	19	59	15
Size, cm dbh					
Trees, ≥10	67/40	7/10	14/11	67/19	6/7
Saplings, 2.5-10	50/20	18/40	41/21	485/17	11/7
Seedlings, <2.5	306/60	286/30	1420/21	1248/15	76/7

REPRODUCTION

Cone and seed yield information are provided in Tables 9 and 10. Duncan (1954) studied the natural regeneration of L. laricina in Minnesota; much of what is known about its regeneration is still based on his work. He recognized it as the pioneer tree species on many sites. He identified four factors as affecting the success of natural regeneration: 1) the extreme shade intolerance of the species; 2) the need for a relatively constant water level and that both flooding and drought cause seedling mortality; 3) a satisfactory seed source (seed trees no more than one to two times their height from the site); and 4) rodent populations.

Table 9. Cone characteristics of North American species of Larix (from Schopmeyer 1974; Dobbs et al. 1976).

Species	Cone bearing age begins Years	Cone length mm	Period between collectable cone crops Years	Weight of hectolitre of cones kg	Seeds per hectolitre of cones kg
Lala					
US/LS	20-40	13-19	3-6	25	0.92
BC	40	10-15	5-6		0.17
ONT					0.68
Laly					
US	30-100	30-51	1-10		
BC	30	40-50			
Laoc					
US/MT-ID	25	25-40	1-10	31	0.62
BC	25	30-40	5-6		0.60

Table 10. Approximate number of clean seed per kilogram for North American species of Larix (from Schopmeyer 1974; Dobbs et al. 1976).

Species	Average	Range
Lala		
US	703,000	464,000-928,000
BC	629,000	595,000-694,000
ONT	557,000	495,000-725,000
Laly		
US	314,000	232,000-360,000
Laoc		
US	303,000	217,000-435,000
BC	289,000	178,000-343,000

Good cone crops occur every three to six years (Cooley 1904; Duncan 1954) with trees less than 12 years old occasionally producing some cones. However, Armson (1983) points out that good crops on individual trees only begin to occur after 40 years of age. Both germinative energy and germinative capacity are low, 33 and 47 percent, respectively (Schopmeyer 1974), compared to most species of Pinus and Picea. Compared to other species of Larix, these values are not that low (Schopmeyer 1974). Farmer and Reinholt (1986) evaluated the influence of stratification, light, temperature, and genotype on L. laricina germination. They noted substantial variation in the germination response of individual families to the experimental conditions which suggests genetic control. They also commented on the high percentage of unsound seed due to failed embryos, 9 to 79 percent, and speculate that it also may have a genetic basis.

In Alberta, Beeftink (1951) noted that L. laricina seed germinates in clumps of sphagnum moss. In Alaska we note that seedlings occur on recently exposed river alluvium high in calcium and magnesium salts (especially sulfate and carbonate with pH's in excess of 7) as well as the lower pH sites consisting of silty loess materials and/or organic materials; permafrost with an active zone less than one metre deep apparently is not a deterrent. Across its range, burned sites provide suitable seedbeds (Armson 1983; Johnston 1973, 1975). Although slash hinders reproduction, burning can have a negative affect on regeneration because it encourages the establishment and growth of competitive species.

Arno and Habeck (1972) report some L. lyallii seed is produced every year. They note that cones were not found on trees "less than about 100 years old" and that the species does not generally produce abundant crops until trees are more than 200 years old. They are of the opinion that successful regeneration occurs only at irregular intervals and then apparently under nearly ideal conditions as evidenced by the high recruitment. Shearer (1971) states that L. lyallii seed germinates very poorly or not at all without treatment to overcome seed dormancy. He found that soaking seed for 24 hours in a three percent solution of hydrogen peroxide increased germination from 0 to 5 to 28 percent; however, variation was great. Based on the limited data of Shearer's work, Schopmeyer (1974) gives the germinative energy as 9 percent and the germinative capacity as 14 percent.

CAUTIONS

It would be easy to say, "Both species hold promise and they are worth extensive trials." We really know very little about L. lyallii, but how much did we know about Pinus radiata D. Don) when New Zealand and Australian foresters began planting it in earnest at the turn of the century? I caution that the extreme paucity of information concerning L. lyallii must be recognized.

L. laricina, on the other hand, is known to have some problems--insects and disease. Cooley (1904) refers to the paucity of trees cver 45 years of age in a large portion of Maine. She attributed this to a disease. It is interesting to note that in Alaska, more than three-quarters of a century later, we found a paucity of trees over 45 years-of-age. Howse (1983) states that native Larix was virtually eradicated from large parts of eastern North America in the late 1800's or early 1900's.

Pristiphora erichsonii Htg. (larch sawfly) has been suggested as the probably causal agent. Fowells (1965) states that it periodically becomes epidemic over large areas for several successive years with great reductions in growth and severe mortality. This is the most serious defoliator of *L. laricina* in eastern North America (Howse 1983).

Coleophora laricella Hbn. (larch easebearer), an insect introduced from Europe in the 1800's, is considered to be the second most serious defoliator of *L. laricina* in eastern North America (Howse 1983). Severe defoliation reduces growth and repeated defoliation results in mortality (Fowells 1965).

Dendroctonus simplex Lec. (eastern larch beetle) has caused serious damage and extensive mortality in the maritime provinces of eastern Canada and interior Alaska. It is commonly present in weakened stands but appears to be able to attack apparently healthy trees.

The majority of North American pathogens attacking *L. laricina* are of little consequence. The greatest concern is *Lachnellula willkommii* Hartig (European larch canker) which has been found in Nova Scotia, New Brunswick, and adjacent Maine; oldest cankers date from the mid-1970's. Howse (1983) reports, "In areas where the disease was found, from 3 to 100% of the trees were affected and in 45% of the infected stands examined the incidence exceeded 80%." The disease causes mortality, reduced growth, and reduced wood quality.

In summary, *L. lyallii* has some potential for afforestation and reforestation and should be considered for trial plantings in spite of the extreme paucity of information about it.

L. laricina, although it has some known, serious insect and disease problems shows great potential for fibre production in the northern forest. Much more information is needed concerning its silvics and silviculture for its successful management on a wide variety of sites.

AKNOWLEDGEMENT

This report is based on data collected as part of a larger program, "Predicting the Growth and Yield of Forest Stands in Interior Alaska" which is supported jointly by funds from the Agricultural and Forestry Experiment Station of the University of Alaska and a McIntire-Stennis Act contract.

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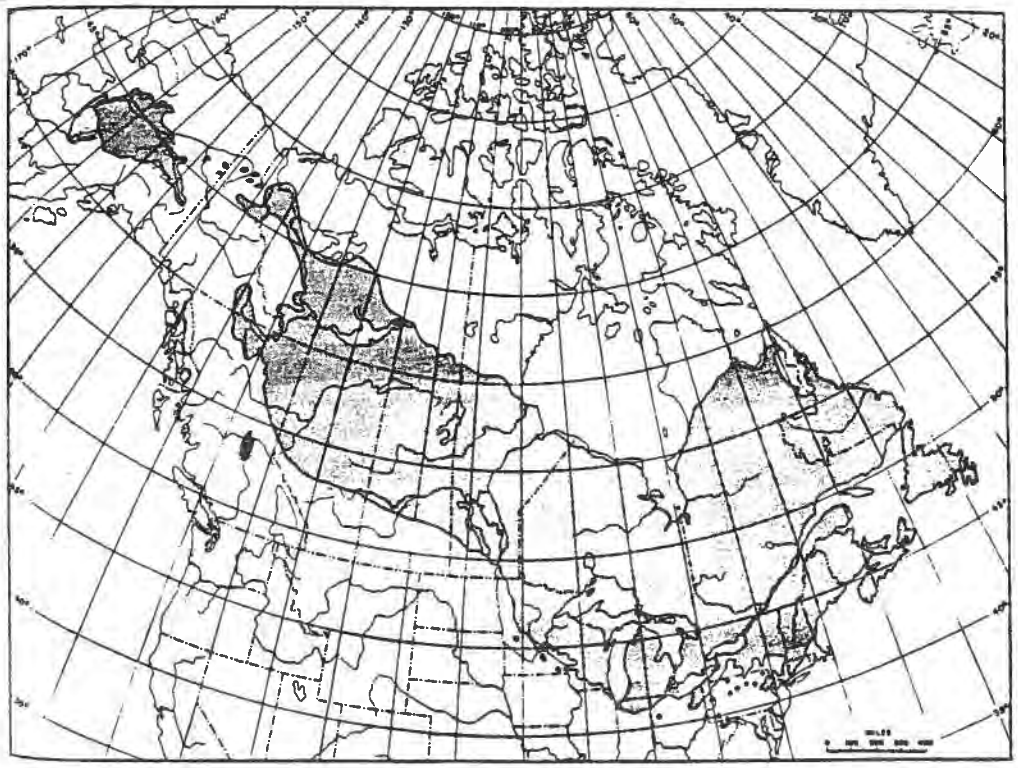
APPENDIX I

Species Codes and Names

Lade = Larix decidua Mill.
Laeu = Larix eurolepis Henry.
Laka = Larix kaempferi (Lam.) Carr
Lala = Larix laricina (DuRoi) K. Koch
Laly = Larix lyallii Parl.
Laoc = Larix occidentalis Nutt.
Lasi = Larix sibirica Ledeb.

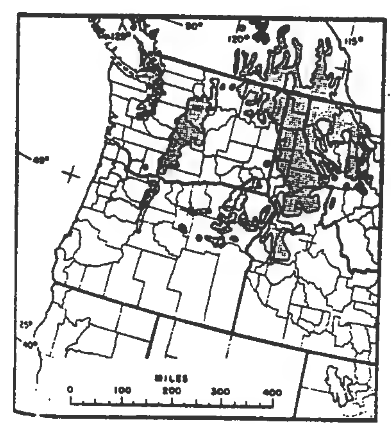
Piab = Picea abies (L.) Karst.
Pigl = Picea glauca (Moench) Voss
Pima = Picea mariana (Mill.) B.S.P.

Piba = Pinus banksiana Lamb.
Pire = Pinus resinosa Ait.
Pist = Pinus strobus L.
Pisy = Pinus sylvestris L.



Larix laricina

Larix
lyallii



Larix
occidentalis

Figure 1. The natural ranges of North American speices of *Larix* (*Larix larcinia* modified from Fowells 1965; *Larix lyallii* from Arno and Habeck 1972; *Larix occidentalis* from Fowells 1965).

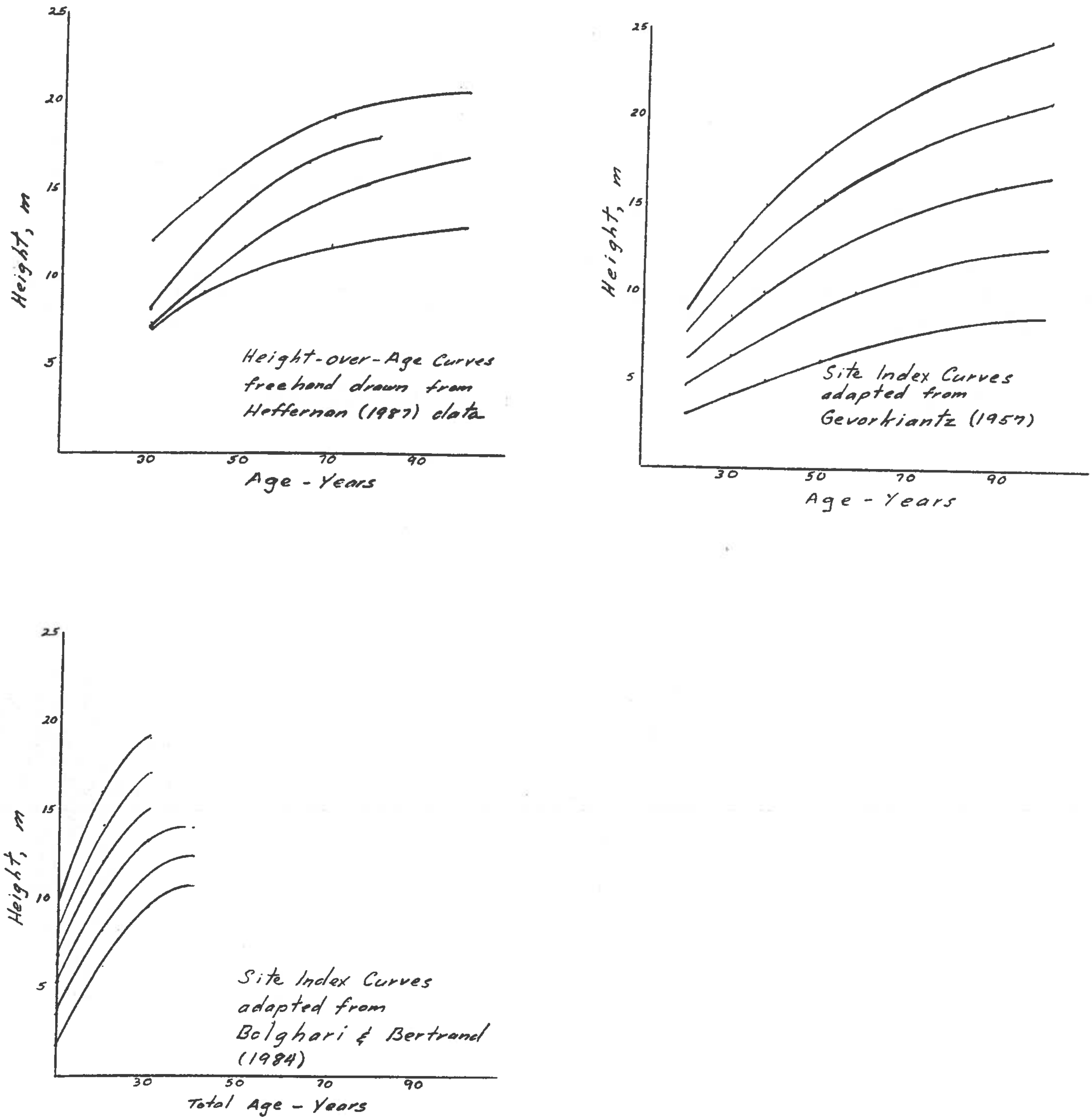


Figure 2. Comparison of site index and height-over-age curves.

STRUCTURE AND DYNAMICS OF NATURAL CONIFER FORESTS NEAR THE UPPER FOREST LIMIT

Helmut Schmidt-Vogt

ABSTRACT: The structure of natural conifer forests near the upper forest limit is characterized by low height of trees, low tree densities, low h/d values and a thus high tree and stand stability. Tree islands occur with increasing frequency in the immediate proximity of the upper tree limit. The dynamics of natural boreal conifer forests is modified by fire through raw humus decomposition and successions, mostly of broadleaved pioneer species. If fire is eliminated, nutrient flow has to be kept in motion by periodic soil preparation.

INTRODUCTION

Silviculture in Central Europe is laying increasing emphasis on the thorough knowledge of natural life processes in the forest as the pre-condition of rational silviculture. Leibundgut (1982) is pointing out, that our present silvicultural knowledge is still to a large extent based upon practical experience and research results, which were obtained from semi-natural and artificial commercial forests or from trial plots with similar conditions. Over the last decades, this opinion has stimulated an increasing number of studies in natural forests and remnant patches of virgin forest. Since only small remnants of former virgin forest are left in Europe, we carried out investigations primarily in the northern part of North America. They were concentrated on the genus spruce (Picea).

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STRUCTURE OF BOREAL CONIFER FORESTS NEAR THE UPPER FOREST LIMIT IN COMPARISON TO CONIFER FORESTS ON SITES WITH HIGH GROWTH PERFORMANCE.

The life cycle of a virgin forest can be divided into a sequence of different formation phases, which are characterized by a specific stand structure (Leibundgut 1978, 1982). In studies which were carried out in Central Europe, the following phases are generally distinguished: Juvenile phase: very high stem number, small diameter, basal area and volume strongly increasing
Optimum phase: closed, +/- one-storied stands with high stem number, basal area and volume increasing until maximum
Age phase: decreasing stem number, decreasing basal area, large timber prevails
Disintegration phase: low stem number, significant decrease of basal area and volume
Regeneration phase: disintegrating old growth stands with openings and rich young growth
Selection phase: all-aged stands, similar in structure to selection forest
The optimum phase in a virgin forest corresponds most closely to a commercial forest stand having reached maturity.

Using a number of forest transects, we will, in the following, compare the structure of stands on sites with high productivity with the structure of stands near the upper forest limit. Natural spruce forests on good sites are characterized by high tree density. In the Austrian Alps, Mayer (1966) studied a 100 year old spruce-larch forest (Picea abies - Larix decidua) which had become established after forest fire. The number of trees with a d.b.h. over 8 cm is 4300, the number of trees over 10 m height, with a maximum height at 30 m, is approx. 1500, basal area is 95 m^2 and volume 1000 m^2. High tree density in conjunction with a relatively great tree height are the cause of high h/d-values (fig. 1) and of the development of small uneven crowns. This accounts for the relative lability of single trees and of the whole stand, particularly with respect to snow pressure and wind. Increasing development towards a one-storied structure and elimination of larch are concomitant phenomena of a marked tendency towards rapid disintegration and large-scale collapse.

We compare this spruce forest with a spruce virgin forest in the north of the boreal conifer zone. Figure 2 presents a transect in the Ormtjernkampen National Park / Norway at 900 m elevation. Height growth is reduced, the tallest trees attain 20 m at the most. The stands are open, the number of trees with a height over 5 m is 350-400 spruce trees and 30-50 birch trees. Basal area in the optimum phase is around 25 m^2. The spruce crowns reach down almost to the ground, h/d-values are as low as 50-60. High stability of single trees condition stability of the whole stand.

Rowe (1977) designates the subalpine forest in the Canadian Rocky Mountains as the Mountain Counterpart of the boreal forest. Two transects from Jasper National Park provide data for the change in stand structure, as we are approaching the upper forest limit.

The first transect represents a spruce-fir virgin forest in 1650 m altitude (probably Picea engelmannii x P. glauca, Abies lasiocarpa). The number of trees over 10 m height is about 800, with a maximum height up to 35 m. In this transect, optimum phases alternate with disintegration phases over a small area, the stand has a very differentiated age structure and accordingly a complex vertical structure. H/d-values of dominant spruce trees: (100) 85-63.

The next transect is located near the upper forest limit at 2100 m elevation (fig. 3) in a pure spruce virgin forest (Picea engelmannii), aged (at 1.3 m) over 350 years. A few Abies lasiocarpa trees grow outside the transect. Tree height is somewhat reduced, but trees still attain a height up to 25 m. The number of living trees with a height over 10 m is about 310. The h/d-values of dominant spruce trees are between 60 and 33. Tree islands consisting of spruce and subalpine fir develop in typical disintegration phases. As a result of very low h/d-values, the isolated spruce trees are very stable.

A long period without fire may be infered from the great age of the tallest trees. Thus, high stability of dominant trees concurs with small-scale disintegration and regeneration phases of a mosaic-type structure.

Tree height and stem number are reduced in the same way near polar tree limit. Viereck, Van Cleve and Dyrness (1986) describe a Picea glauca - P. mariana-Alnus crispa - Betula glandulosa community type on a treeline site at 747 m elevation in interior Alaska. The nature stand is very open with a tree density of 262 trees/ha and a canopy cover of 8 %. Most of the trees are white spruce. Height averages 5 m, tree diameters average 8.4 cm d.b.h., some of the larger white spruce are up to 21.5 cm in d.b.h. and 10 m in height. Basal area of the stand is only 1.3 m^2/ha. Tree ages range from 110 years to about 150 years.

Relatively low tree height and low stand densities are important characteristics of the stand structure of conifer forests near the upper forest limit. Relatively high chest height diameter due to the large growing space of trees, and accordingly low h/d-values and high tree and stand stability. The natural forests are thus well adapted to the rigorous environmental conditions.

TREE ISLANDS

Tree islands appear the more frequently, the closer one approaches to the upper forest limit. They have been described repeatedly in the literature. In the case of spruce they originate frequently through layering of branches that are pressed to the ground. They also originate from small-scale seeding on small elevations around old stumps or trees. In comparison to single plants, the tree island is obviously better equipped to deal with snow, wind and possibly frost drought. The endowment of some tree species with the ability to regenerate through vegetative reproduction can also be seen as a measure adopted by nature to support tree - growth near timberline, under conditions detrimental to generative reproduction.

DYNAMICS

At the northern limit of the boreal conifer forest in North America and the USSR, fire plays an essential role. Fire-induced rotation cycles fluctuate generally between 50 and 200 years.

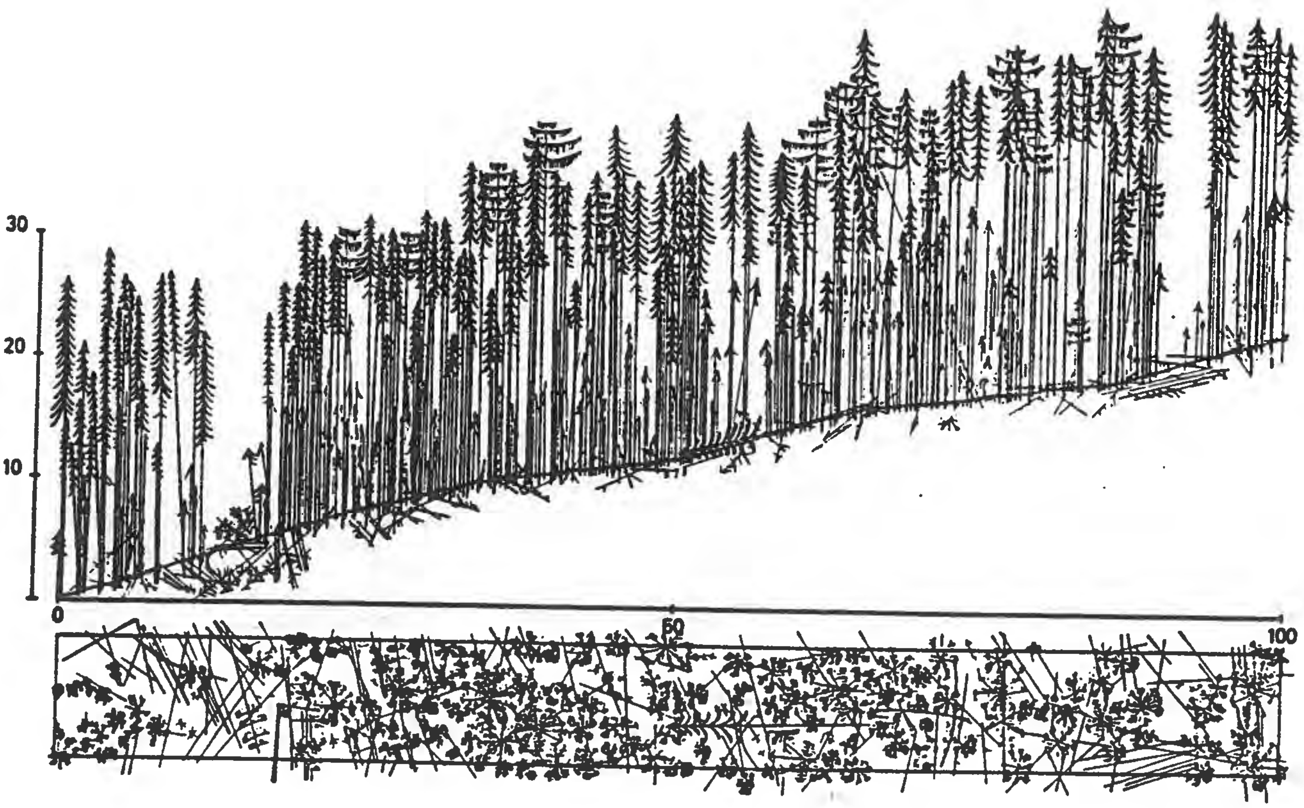

Figure 1: -- Natural larch-spruce forest within the subalpine maximum of conifer trees in the Austrian Alps with very high tree density, high h/d-values and limited tree and stand stability (Mayer 1966).

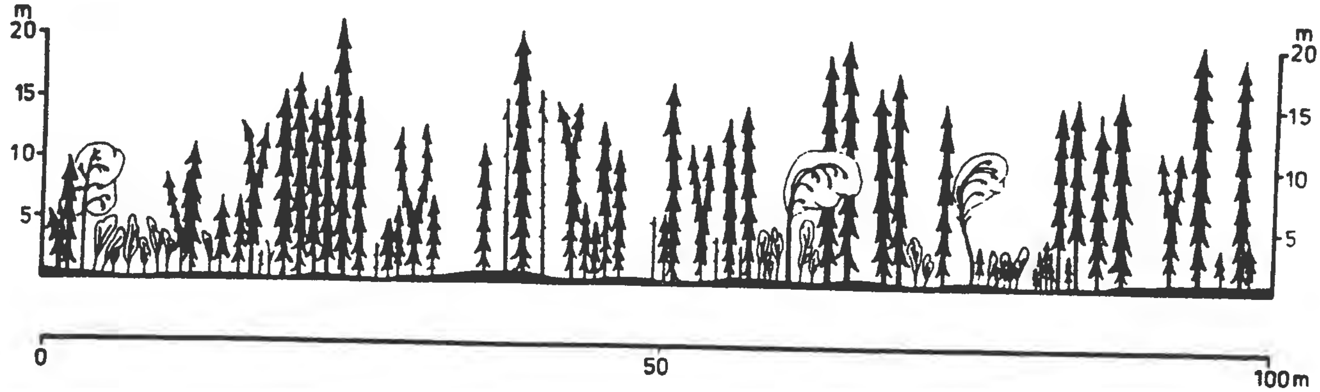

Figure 2: -- Natural spruce -birch forest in the Ormtjernkampen National Park / Norway near timberline with low tree density, low h/d-values and high tree and stand stability.

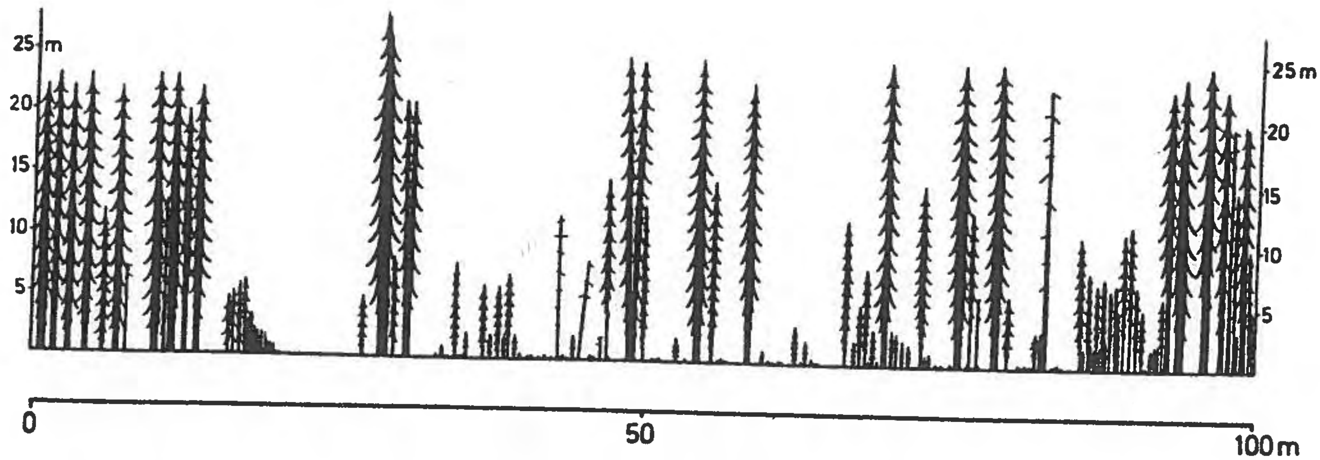

Figure 3: -- Natural spruce forest in Jasper National Park / Canada near tree line. Low tree density, very low h/d-values, regeneration in disintegration patches in the form of tree islands.

Heinselmann (1981) regards the fire regime as an integrated component of boreal ecosystems. Since in the boreal zone, on cold sites, decomposition of organic matter in the ground does not keep pace with the accumulation of humus and moss, fire plays an important part in the periodic reduction of organic layers. Nutrients, which had been fixed by the formation of moss and raw humus in closed conifer stands, through fire, return again into the nutrient cycle. Upon fire follows in most cases a pioneer forest of birch, poplar and other broadleaved pioneer species, which, by leafshedding, also act favourably upon the soil.

Through a periodically renewed sequence of forest stages, from pioneer forest to mature conifer forest, the energy flow is always set in motion anew, and a permanent fixation of nutrients in raw humus is prevented. What we actually have here, is a cyclical stability of conifer-ecosystems.

From our investigations in the Ormtjernkampen National Park / Norway followed, that in the disintegration phase of spruce virgin forest on this mountainous site, already relatively small surface units are sufficient to bring about alternation of associations. In an opening of 0.03 ha, the regeneration will be 80 % birch (Hanisch 1983). The pioneer stage with conditions favourable to the decomposition of raw humus will thus materialize on small surface units (micro-succession).

In the dynamics of conifer forest we distinguish two cycles: the small cycle with alternation of formation phases - optimum - disintegration - regeneration phases but with no alternation of tree species, and the great cycle, after disintegration or catastrophe, with successional stages and alternation of tree species until a mature conifer forest has again become established.

CONCLUSIONS FOR MANAGEMENT OF CONIFER FORESTS NEAR THE UPPER FOREST LIMIT

The stands should be established and tended in such a manner that the trees will attain low h/d-values (spruce less than 80) while commanding sufficient growing space. Wide planting space permits natural seeding of broadleaved pioneer species (birch, aspen). In the immediate proximity to timberline, forest structures with tree islands become increasingly important. Tree island afforestation should be done on suitable micro-sites.

When fire is excluded by man, nutrient flow must be kept in motion by periodic soil preparation.

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MONITORING TIMBERLINE DYNAMICS AT THE KEVO SUBARCTIC RESEARCH INSTITUTE IN NORTHERN FINLAND

Paavo Kallio

INTRODUCTION

The environment in the northern latitudes is determined by the position of the earth in space and its movement round the sun. The energy yield from the sun at different latitudes is determined by the orbit of the earth around the sun and the angle of the earth's axis. Dayly and seasonal rhythms are controlled by the same mechanism (Kallio, 1984, p. 53).

Energy means energy for life, which is the same as irradiation of the sun. This is also seen in the temperature. Light and temperature account about 94 % of the pohotosynthetic capacity and light alone some 90 % (Hari et al., 1981, p. 186). Low soil temperature has also been to be typical factor lowering growth and photosynthesis (Larcher, 1983, p. 83). The destroiing of bacteria takes place slowly as already Cajander (1933), the man who started his Metsänhoidon perusteet already very early in the page 307 says. Low soil temperatures are common everywhere in subarctic and arctic soils, e.g. at Kevo Station. Owing to low soil temperature water can not be easily absorbed by plants. There is, however, some adaptation towards the north so that colder climates plants have roots with greater water permeability at low soil temperatures than plants native to warm climates. The net assimilation rate in the northern latitudes can have values 0.1-0.3 $dm^{-2}vk^{-1}$ (Warren Wilson, 1960).

The northern plants, however, able to use even midnight sun was known as early as 1930 (Kostytschew et al., 1930; Warren Wilson 1960). In spite of the continuous daylight, however, there are differences in different seasons. Hence two maxima are observed in osmotic pressure in several plants (Lewis et al., 1920).

Light conditions in the northern latitudes differ, both in average intencity as well in rhythm. The difference in light intensity is reflected in the fact that the owernight sunshine causes the total hours of sunshine to be higher than in the south. Hence the photosynthetic intensity, which is mostly dependent on light, at Murmansk at the latitude of 69°N is some 0.51 g $dm^{-2}wk^{-1}$ while in Leningrad at 60°N it is 0.33 g $dm^{-2}wk^{-1}$ and at 43°N only 0.25 $dm^{-2}wk^{-1}$ (Warren Wilson, 1960). This is, however, a possibility for northern plants only and it is based on long adaptability of evolution. It is also seen in alpine vegetation zones, which in each site of the mountains can be different (Fonda & Bliss, 1969). The same is also seen in the different number of schrubs.

Hardening for winter is a proberty which is normal for all plants in the arctic and subarctic zones. The hardening is of two different kinds. Some of plants are always hardened. That means that even in summer they can tolerate frost, as do lichens and mosses (Kallio & Heinonen, 1971, 1973, 1975; Lange, 1965; Karunen & Kallio, 1976; Skreel & Oechel, 1981; Larcher, 1980; Pohle, 1917). The hardening needs certain particular climatic conditions, e.g. some light and temperature requirements (Tumanov, 1967; Kallio & Valanne, 1975; Martin, Mårtensson & Öquist, 1978). Lipid acid and lipids are also components of hardening. In winter it is important; linolenic and linolic acid contents are raised while in summer these contents are normally lower (Michaelis, 1934; Jönsson & Olin, 1898). The saturatity and unsaturation are most important in winter conditions (Karunen & Kallio, 1976; Levitt, 1980, 1956). Thereafter when all the prerequisites are fullfilled southern plants are southern plants able to tolerate chilling (Drake & Raschke, 1974; Taylor et al., 1974), or they are able to tolerate many degrees C° of frost (Sakai, 1962, 1966; Öquist et al., 1980; Cloutier & Andrews, 1984; Martin, Mårtensson & Öquist, 1978; Sakai & Otsuka, 1970). In general the most suitable conditions for hardening are a short day and temperature about 0 °C. In these conditions Chl-bleaching also take place and chlorophyll-protein complexes are destroyed (Öquist et al., 1980, p. 530). There are many destructive events, but usually a northern plant is able to adapt and exploit them. Hence, plants are able to translocate the stored reserve energy to a part of the plant can use it, e.g. in new shoots (Kozlowski, 1971; Ericsson, 1978). Even in defoliated trees it was possible, due to reserve energy, to get new shoots to grow (Junttila & Heide, 1981; Ericsson, 1978). Desiccation is also very important for hardening (Scholander et al., 1953). There is an example in p. 6. When the moisture content in a buttercup (*Ranunculus asiaticus*?) has decreased to 9.6 %, the plant can survive 18 days at the temperature of liquid nitrogen (-190 °C). Low temperature and high light intensity typical of northern latitudes can in some circumstances cause solarization and photosynthesis inhibition at high latitudes (Taylor & Rowley, 1971, p. 717).

Other litht conditions distinguishing northern latitudes from the southern ones are the light intensity rhythms. The rhythm is of two different kinds: the annual and dayly variation. Ecologically the dayly rhythm is more important. There are some good ecological examples of unicellular algae reaction to continuous illumination (Kallio, 1957). Continuous illumination is usually destructive in mosses and lichens (Pearson, 1970; Valanne, 1977; Kallio & Valanne, 1975; Kallio & Kallio, 1975; Kallio & Heinonen, 1975; Aro & Valanne, 1979). In lichens the recover their ability to photozynthetize very rapidly overall (Lange 1965; Kallio & Kallio, 1975; Heide, 1985; Lechowicz, 1981, 1978; Kallio & Kärenlampi, 1975; Savile, 1961).

Mosses and lichens are able to recover their ability to photosynthetize very rapidly after a period of intence cold (Kallio & Heinonen, 1971, 1975).

When it comes to the low concentration of soil nutrients, which is typical of the north, there are two different ways for life to adapt to these particular conditions (Sørensen, 1941), One of these is possibilities described by McCown (1978). McCown has studied the adaptation to low nutrient contents in soil. Plants adapted to northern conditions are able to increase production in tundra conditions if they are able to get new fertilization. Non-adapted (southern plants) can only do so when the soil temperature rises. Another way to adapt to changed environmental features compared with the south, is the use of mycorrhizal fungi. Hence the mycorrhiza problem is a northern form of adaptation (Marks & Kozlowski, 1973; Moser, 1958, 1967; Kallio, 1982; Miller & Laursen, 1978; Kobayasi, 1982; Linkins & Antibus, 1982; Savile 1981). (From the Antarctic has been described already as early as 1847 by Berkeley).

In the North there are even more possibilities to animal demands for plants than in more southern latitudes. This is due to the high selectivity, which has led to many monospecies ecosystems, e.g. *Betula*-stands at northern latitudes in Fenno-Scandia, Iceland and Greenland. In this case it is possible that small insects such as *Epirrita autumnalis* can destroy an area of 5000 km², as occurred mid-60's this centure (Kallio & Lehtonen, 1973, 1975). This has led to some kind of defence mechanism in the north. Good examples have been described by Haukioja (1980, 1982). It is possible to explain the rhythmic occurrence of these defoliations of the birch (Haukioja et al., 1983). The birch has many difficulties with the herbivores (Haukioja et al., 1981; Neuvonen, 1987 a,b). In addition, there are many other animals, e.g. among herbivores, which have the same effect on plants, e.g. microtines (Laine & Henttonen, 1983; Batzli, 1983).

The treeline is dependent on many different ecological features (Hustich, 1966, 1973). In the last Hustich has brought a new concept to northern forest line ecology. Hustich has spoken a long time of a that he has termed the "climatic hazard coefficient", which increases towards the north. This means that climatic changes are greater towards the north. The significance in northern latitudes is more dependent on climatic influences. We have a good example: in the Kevo area in northernmost Finland the pine can form germinable seeds even at a temperature, where the thermal sum is

600 dd, but to get such a situation that half of the seeds are germinable it needs about 950 dd as the thermal sum (Pohtila, 1980). How are the plants able to adapt in these conditions? They have only one possibility: to collect reserve energy. But there is a question of whether northern plants are able store energy more than southern ones. Have these, especially been able to collect more than only one year? This can be determinated e.g. in ^{14}C-method. Perhaps even by mycorrhizal activity. These show, however, not to be likely.

Some plants are able to place oneself to the warmest layer of the thermal layering, i.e. to the lowest layer close to the surface. This is the case with Betula pubescens war. apressa (Kallio & Mäkinen, 1978; Salisbury et al., 1968). It grows only a few cm above the surface of the soil, only so that a small layer of snow covers it totally providing excellent insulation. Consequently the plant is as well protected against cold in winter time as in summer.

Genetic differences in plants at northern and southern latitudes

The mountain birch problem

In Southern Finland and in Central Europe all the birch species, Betula pubescens, B. pendula and B. nana, have their own evolution (Hagman, 1971). In Lapland, however, all these birches cross and quite a new genotype has arisen (Kallio et al., 1983; Sulkinoja, 1981; Sulkinoja, Inki & Valanne, 1981; Inki & Valanne, 1979; Vaarama & Valanne, 1973; Raulo, 1977). The same feature is circumpolar. In Alaska is found a plant which in all probability is a hybrid between Betula papyrifera and B. glandulosa, called Betula eastwoodiae (Viereck & Little, 1972). The far Eastthere is a birch, Betula middendorffii which the Russian authors think is a hybrid with two different birch species.

Other plants

Even other plants hybrize easier in the North than in the South. Examples are Nymphaes and Nuphars (Mäkinen et al., in print). These plants are able to survive in hybrids. These plants are able to live vegetatively. Another genus is Sparganium , which are making many hybrids. Even some Ericacae are able to make hybrids. See the publication of (Mäkinen et al., in print). Even many mosses and lichens are able to form hybrids, but its form and nature have not been analyzed in more detail. They are, however, forming new once by vegetatively only (cf. Kallio & Saarnio, 1986).

Productivity is lower in North than in the tropics

Biomasses in the Kevo area have been measured during the IBP-period between the years 1967-1972. We have inchided three different types of forest in our measurements: birch forest, pine forest and low alpine heath. In pine forest total production was 38650 kg/ha, in birch forest on northern slopes it was 12075 kg/ha and in low alpine heath, even including cryptogams value was 270 kg/ha. In the tropics biomass and production are some one hundred times higher than in tundra area and perhaps even more in arctic desert areas where the plants grow only very sparcely at great distances from each other (Rodin & Bazillevich, 1964; Rodin & Bazillevich, 1965). There are still some observations in a latitude effect in nitrogen fixation per area. In the tropics the nitrogen fixation is some 88 kg/ha/hear. In Oreganon it is 12 kg (Todd et al., 1978) and at Kevo (at 70 latitude N) 4 kg (Kallio & Kallio, 1975). This is typical amount is given even by Sweden at the same latitude as that by Kallio & Kallio, 1975 in a mire (Granhall & Lindberg, 1978).

There is, however, a "Zeitfactor" as discussed by Larcher (1969) or Hustich's hazard coefficient (e.g. 1975; Holtmeier, 1987). Both are important because the time-factor is always involved in productivity. In some years there is good productivity, but in other years the plant is totally dependent on stored energy reserves. Continentality, which is clearly seen in the distribution of Racomitrium lanuginosum moss in Finnish Lapland (cf. also Jalas, 1955) and also in many other species in plants, is another important factor. The forest line is also dependent on the same factor as many ecologists have discussed (Kihlman, 1890; Payette, 1983; Hustich, 1975; Holtmeier, 1987). Also nutrients have a very low content especially of nitrogen and phosphorous (cf. Haag, 1974; Kallio, 1974; Tieszen, 1978; McCown, 1978; Oechel & Sveinbjörnsson, 1978).

The photosynthesis of bark is a typical phenomenon in northern latitudes

All tissues which contain chlorophyll are able to fix CO_2 in the light. The bark of different tree species contains chlorophyll and is thus capable of fixation and can produce energy. Two Fenno-Scandian scientists can be mentioned, who have studied this problem: Larsen (1936) and Stålfelt (1962). Thereafter the study of stem photosynthesis has moved to North-America and the most popular object has been Populus tremuloides. Many American scientists have achieved all their results with this plant. Such examples are Ames & Tepper (1978), Schaedle (1985), Iannocence and Foote (1968), Strain & Johnson (1963), and Davis & Evert (1968). The Australian researches have studied Vitis vinifera woody shoots (Kriedeman & Buttrose, 1971). The American researchers have also studied white pine (Pinus strobus), ocotillo (Fouquieria splendens), douglas-fir (Pseudotsuga menziesi), American beech (Fagus grandiflora), Rhododendron (Parker & Philpott, 1963), Pinus thunbergii (in Japan) as Oku & Tomita have done (1971), in Cercidium floridum (Adams & Strain, 1969).

In addition to all other Finnish trees we have also the bark photosynthesis of Betula tortuosa (cf. Kallio et al., 1983; Vaarama & Valanne, 1973; Sulkinoja, Inki & Valanne, 1981; Sulkinoja, 1981; Elkington, 1968; Chepurko, 1972; Hagman, 1971).

Because some institute or organization is always responsible for the studies of particular, the organization are often biological field stations, whose role e.g. Wilson has emphasized (Wilson, 1982; Eisner, 1982; Brussard, 1982; Kallio 1980). I have stressed the botanical research possibilities in the north (Kallio, 1981; Sonesson et al., 1975; Kallio, 1979). Also, when speaking of the essence northern ecology (Kallio, 1984), some aspects are already known, that are also important in all ecology and in all fields of biology. All these examples are indicator of lack of energy. The summer is too short. No organism are able to collect energy enough in this time, because in winter the respiration needs energy. Therefore all living beings have som adaptations to lengthen the too short growth period. Therefore even the bark photosynthese is a fitness. It can lengthen the too short growth period, because the photosynthesis in bark starts already in the Arctic or Subarctic at -20 °C, as does Betula tortuosa. There are, possible, to find a "hardening" in barkphotosynthesis. We have not had Pinus pumila and other Pamir plants in our disposal. The bark photosynthesis functions even in Italy in low temperatures, which has already active photosynthesis at -10 °C. Hence in all latitudes appears, that the barkphotosynthese has lower optimum temperature than the needles or leaves.

The total photosynthesis of bark can be as high as 40 % of the total photosynthesis of the tree, most of which takes place in the leaves. In winter, when tere are no leaves on the tree, the role of bark photosynthesis may be as high as 86 % of the total. These figures are both from Adams & Strain (1969). Seasonal photosynthesis may be very different. Hence late March or early April is most active, when companion cells and even parenchyma cells are activated (Davis & Evert, 1968). Cessation of function begins in late September or early October. By late November all the structural growth is complete (Davis & Evert, 1968, p. 5 and Figs; Adams & Strain, 1969).

Because there is a system of reassimilation of CO_2 produced by respiration, there is much higher content of CO_2 in bark than in the leaves (Knowlton et al., 1978, Table 1; Adams & Strain, 1969; Davis & Evert, p. 5 and Figs; Derr & Evert, 1967). Consequently photosynthesis may be even higher (Billings & Godfray, 1967; Kriedeman & Buttrose, 1971). Because the trunk releases little light to the chlorophyllous tissue, it is clear that the trunk in different directions has a different light in the chlorophyllous layer. On the southern side of the trunk in one case it was 54, on the western side 86 and in northern side 96, while in blue shadow it was 100 (Schenk, 1952). This means that light can either promote the photosynthesis or inhibit it. This can also depend on the fact that transpiration is at too low a level. In twigs or branches near the base, in one case concerning Populus tremuloides this ratio was as high as 100:5 when compared the base and something upwards (Pearson & Lawrence, 1958, p. 385). On the other hand, as regards the whole tree the greenery is more intense in the upper part of the tree and therefore also photosynthesis. Seasonality is very clearly seen. A 5-year old Acer pseudoplatanus has a photosynthetic capacity more than ten times that of old Acer pseudoplatanus has a photosynthetic capacity more than ten times that of a year-old one (Schenk, 1952, p. 299). Photosynthetic activity also varies according to season. In December photosynthesis produces 0.02 mg $CO_2/dm^2/$ hour, but in July it is. 5.5 mg CO_2 $/dm^2/$hour (Knowlton et al., 1976).

It seems that photosynthesis plays a most active role stem in cold seasons, at the time when the cambium is activated. This is early in the spring when the soil is still frozen. The stored energy cannot move, because the trunk is still frozen. Therefore the trunk can photosynthesize at the very low temperatures prevailing in polar zones. Therefore it is possible to see the bark photosynthesis as an indication of fitness in polar areas.

KEVO as a Research Station

When the Kevo research people came to Kevo some 30 years ago, it was the only possibility to study the surrounding environment, animals, plants and morphology of the landscape. The aim was to make it a "known spot" in the Subarctic. We started the study of the fauna in order to make maps of Inari Lapland, an area of some 20.000 km². Now we already have some 580 maps of vascular plants and samples of many other groups of many other plants; even fungi, lichens and algae as well as mosses. The fauna-research people have already published in KEVO NOTES one issue of evertebrates, especially butterflies, made a list of vertebares and have studied already the Coleopteras. They also have estimated the bird dencity and bird fauna in KEVO nature park.

Because Kevo lies at the forest line, the forest line everywhere is surrounding us. We have constructed together with the National Board of Forestry and the Forest Research Institute in Finland three different tree-line arboreta. One of those are at the birch-line (Betula tortuosa -line), one, near by KEVO is at the Kevo-pine-line and one is in Inari at the main pine-line. There are, however, not so many trees in the subarctic forest-line, about 12-15. But because we will have as many provenance as possible, the total number of trees will be some hundreds and the total number of trees in our arboreta will be about 100.000. At Kevo arboreta there are some 30 thousands of trees. We have started to study at first different Betulas, because this study is ready as soon as in some tens of years. The coniferous trees from Siberien have, perhaps already then ready to transplantation. Because the Kevo's role is to collect the seeds for the forest-line arboreta. It has called some difficulties, because we have not money in our budget, it has some times caused some difficulties in financing. For our lucky some students making fungal research at forest-line have helped us much and financing mycology, have our forest-line arboreta got money for seed collection. By the way, we have some 80.000 Betulas in our forest-line arboreta at present and some thousands of coniferous trees. Earlier we have also taken twigs and tried to get them to grow. Later, however, they strongly were affected by many pathological fungi and no longer have permission for this. Some Larix-species seem to thrive well and we have tried to visit the place from where the most prominent Larix-species have come, the Archangel area, but in vain. Still we have some possibilities. We have had the possibility of visiting Siberia twice, in Jakutsk and in Tsuktsi peninsula, where a very large collection of Pinus pumila has been collected. The co-operation between the different organizations has functioned well.

Because the forest line is subject to different changes, it is necessary to follow the changes. These are of great significance and may depend on climatic changes or on pollution, caused by man as is often the case in Central Europe. There are now some 26 sites in North-Finland. They will be mapped every ten years continuously. The mapping is most important; this was started at the 1980's. All the trees and small plants of all trees will be measured with an accuracy of one centimetre. Since mapping will take place every ten years, it is possible that some of the trees will not be found, indicating that something has happened. The large trees will be measured, both for girth and height. Soil tests will also be taken since the soil can also be affected by climatic changes or pollution. All the data will be computed by the Forest Research Station in Rovaniemi and the results will be discussed together.

Kevo has embarked upon international co-operation with it's involvement in the IBP. We represent the tundra-biome together with Norway, Sweden and Iceland. We have also had contact with Greenland and material from Greenland was found in our arboreta. In the Kevo area we have three different biota: one in pine forest, in valley S of the Station, a birch ecosystem on the slope above us, and a subalpine heath on Jesnalvaara mountain. The sites have been described by Sonesson et al. (1975). The pine forest has an average productivity 38659 kg/ha/year, while birch forest produces 12075 kg/year. The lowalpine heath produces 270 kg/ha/year. Oulanka, which lies on the Arctic circle, produces 1000 kg/ha/year, and we can see how latitude affects productivity. When tropical rain forest produce some 100 times as much as our lowalpine heath, we understand how productivity is dependent on latitude.

Kevo has co-operated with all Nordic countries even after the IBP-period. An example is SBP (Subarctic Birch Programme). Because many reindeerherder, hunter and fisher is dependent in these forests, this is also important for man. All the Fennoscandian countries participate in this project. In addition to this Iceland and Greenland participate in the project. Every year we hold a meeting of the participating countries, although rarely in Greenland. Only one meeting has been held in Greenland, but several in Iceland. This is one way of making contacts with polar people as hunters and reindeerherders.

In the same way we have tried to make contacts with the local people, who have used old, traditional methods of cultivation or, as in Finland, collected Angelica-roots, which have also been used by industry for flavoring alcoholic beverages. Because their aromatic content as their quality are better in Lapland than in Central-Europe, there are some possibilities of cultivating Angelica for industry. It is easily cultivated because the plant is native here and grows in brooks or the banks of brooks. We have here contacted industry and this co-operation seems to be good. Even dill grows (Anethum graveolens) and its arom is better than in Southern Finland and Central Europe.

Another important subsidiary occupation for many Saami people, is collection of Arctic cloudberries (Rubus chamaemorus). This provides some 50 millions in Lapland, while in the best years ptarmigan can bring almost the same amount. At Kevo attempts even been made to cultivate cloudberries in order to study the insects, the enemies or fungi that use them as host. It is easily cultivated under plastic, where the too low temperatures have no effect. It has been shown that the mostly dangerous insect is Calerucella, which can also attack cultivated strawberries. The frost is the worst, if it comes at a time when cloudberry flowers. There are only a few possibilities of preventing this, perhaps the desiccation of the whole bog.

Kevo has even tried to help reindeer management in some way. Although opportunities are few, one way is to weigh the calves and see whether this affects mortality. One method of improving this might be to give the mother reindeer more food. This is, however, difficult in many cases. Entomologists are also working in methods to repel or otherwise counter insects, which in many ways have affected reindeer movements.

Kevo has a major programme together with fishmen and fisherybiologists in Norway. The Tenojoki (in Norway: Tana) constitutes the border between Finland and Norway and is one of the best salmon rives in Europe. All the others have been polluted or changed in other ways. The Tenojoki is now Subject to continuous monitoring. All the factors affecting salmon are monitored and the movements of the salmon followed by marking their fins. With the aid of these tests has been shown that Teno-salmon have been found in Labrador, Northern Greenland and the Faeroe Islands. Part of the programme is to follow up fishing catches so that as the salmon becomes rarer mesh sizes are increased allowing only large individuals to be netted. Protected area are established for spawning. So far this has only affected Norway and Finland, but Soviet scientists have also shown an interest and many Kola-Peninsula fisherybiologists and Ponoifishries are interested in Teno salmon.

International co-operation between Kevo and the rest of the world

As we have already heard Kevo has its IBP, SBP, MAB and Northern lights programmes. One of these joint operations has, however, been the co-operation in Finnish birch and its herbivores. Because Epirrita autumnata in the mid-60's this century caused major catastrophe in Finnish Lapland and in the whole of Fennoscandia (Kallio & Lehtonen, 1975; Kalliola, 1941; Tenow, 1972). Our lead in the whole problem has given us good conferences e.g. in autumn 1981 and later, in 1983, a whole Oikos 40 has devoted to this symposium. Research scholars from Alaska have been interested, in particular people from Fairbanks (Arctic Biology) have often visited Kevo, especially to study our forest arboreta. These scientists also have new and modern methods and their own instruments and our students have learned much from their apparatus. As results of their visits we have become familiar with the ^{14}C method for studing photo-synthesis.

The forest line arboreta, as has already been mentioned, have stimulated circum-polar co-operation. Because many American scientists have their own instruments and quite new methods, we at Kevo have learned much from this co-operation. There are quite new ideas, e.g. mycorrhiza - birch co-evolution and many other new ideas.

In the same way, in every fisherybiology and fishery there have been many contacts with other countries and especially contacts with countries with which we seldom have contact, e.g. the Faroe Islands, Northern Greenland, the Falkland Islands. The contacts have also brought us into contact with Archangel and Ponoi, known from earlier periods in Finland's science.

We have made some flora studies in Labrador and Ungava Bay, Quebec (Mäkinen & Kallio, 1980) for comparison with the Kevo area. The times have been many years and in this respect it may be comparable with the Kevo area studies. In the same way it has been it is important students to see different countries and to become acquainted with the polar culture of different polar countries.

DISCUSSION

The north differs greatly from the south (Kallio, 1984; Kallio, 1985; Haukioja et al., 1983; C. v. Linné, 1732; Kallio, S., 1976) and even polar culture deviates from that of the south. There is a controversy between these two cultures and it has proved very difficult to resolve this problem. Many attempts have been tried in Canada. One of these has been to legislate but it has not entirely succesfull. The Inuits (Eskimos) or Indians have been in opposition. A greater success has been the Inuit Museum University - system, IMU, in which Inuits have been participating. It has succeeded better whereas legislation has succeeded in the McKentzie River (Tizya, 1975). A critical factor is that the white man comes only to extract energy of minerals from the soil, whereas polar people living permanently in the region; people from the south live only a short time, until the iron or energy is exhousted (Kallio, 1984; Kallio, 1985; Tizya, 1975). Even small disturbances can cause permanent "catastrophes" for the polar people in their livelihood (Bliss, 1962), and cause conflicts between polar people and people from the south. Because nitrogen production is small at the northern latitudes, for example it is much dependent on time, and polar people have not time, these people can die without any food; time for them is a matter of survival. They cannot wait a long time; time for them is a matter of survival. They cannot wait a long time, when they have lost four kg of soil nitrogen (S. Kallio & P. Kallio, 1975), which is the time needed for a new harvesting of nitrogen is some 880 kg.

Even light conditions are not the best possible because most plants cannot stand permanent light for a long period (Kallio & Valanne, 1975; Valanne, 1971; Aro & Valanne, 1979; Aro & Karunen, 1979). Because soil composition is also poor in the tundra (Rossvall et al., 1975) nutrients are replaced only rather slowly. The low nitrogen (and partly phosphorus) situation is discussed by Kallio (1974; Kallio & Kallio, 1975). Nitrogen is generally low in polar areas and this is mostly poor adaptability of the nitrogenase enzyme to low temperatures (Kallio, P., 1974; Kallio, S., 1975). All in all, it is environmental factors that account discrepancy between polar people and people from farther south.

Our contacts at Kevo with one of the most important economics among polar people, that of the Saami people in Lapland mean that we are better ask to understand the life of polar people. Consequently, I, personally, have had an opportunity to participate in the IMU-system in Canada and we at Kevo have some understanding of polar people. There is another reason for this. In Finland the polar people (Saami-people) have for many hundreds of years had some kind of contact with the polar people from more southerly regions. In other parts of the world (In Siberia, Canada and Alaska) the people from more south have been separated by a wild forest many hundreds of kms wide from the polar people. This may explain why we do not have the same problems in northern Finland as in Siberia, Canada and Alaska. We know our polar people better and have co-operated a long time at a high level.

In our programme co-operation in flora studies, e.g. with Labrador and Ungava, has been quite prominent. We are, therefore, able to compare the two different subarctic countries better than earlier. Without this local knowledge, it would be impossible to understand all the problems of different polar peoples environment.

If we think of polar people and their adaptation to the north, we can say that they have not had time for biological adaptation because time has been too short (Dunbar, 1968). Their culture is, however, adapted to the north (Discussions with Dr. Müller-Wille in 1980). For example, they have such head-wear that they have no possibilities of snow blindness. They dress in furs, which protect them from all kinds weather. The culture of polar people is more adapted than their biological adaptation. Perhaps there is some biological adaptation, too, but our IBP-studies of Skolt Lapps and Eskimos have not revealed any such adaptation (Kallio, 1985; discussions with K.O. Donner and Dr. Müller-Wille from Canada). The old traditions of polar people can partly compensate for the lack of biological adaptation in their culture.

Kevo has also participated in the MAB-programme in earlier years. The entire SBP was financed by MAB. This means that MAB started the financing of the most important Nordic international studies. Even some proceedings of IBP were started with the financing of MAB. Every country has tried to continue the IBP, but it remains unfinished in almost all countries. We now know the methods continuation seems to be very necessary. MAB also provides such a possibility as also in many other Nordic countries. Usually, however, the object is different. So, e.g. in Norway Svalbard was another object for study.

Studies of the forest line would not have been possible without help from other researchscholars than those from Kevo. Many scientists from Alaska and Canada have helped us have also the people financing trips to different parts of the circumpolar north. Especially welcome possibility to thank the many mycologists from Turku and Helsinki, whose research activity tells in the same area and same season as that suitable for seed collection.

Summing up it may be said that although most plants can well adapt to long hours of daylight, some difficulties are caused by continuous light and in winter no activities are possible during the complete dark. Photosynthesis is well adapted to northern low temperatures, but the short summer causes many difficulties. Most of these, however, have been eliminated by adaptation in different ways: e.g. by rising plant temperature or ability to grow at low temperatures, but short summer causes many difficulties. Both are the long results of evolution. Life has its home in the tropics and a long period of adaptation is needed to cope with the cold of the north. Man has not adapted, but culture has to some degree, especially polar cultures. Perhaps human beings can also learn to adapt and cope with the difficulties posed by living at high latitudes.

If we compare the south and the north, there are mary differences. Productivity is high in the tropics and smaller in the tundra, especially the tundra desert, where the plants grow very separately. The amounts of nitrogen and phophorus are small and their quality is poor, but there are some adaptations for these. E.g. reindeer now have phophorus in their dung (own observation), and the plants adapt in different ways.

Polar people have difficulties with the people from southern areas. This has an ecological basis. Mostly it is a question of isolation. In Finnish Lapland the contacts have always functioned and in Finnish Lapland the differences are smaller. Polar people's reaction are, however, understandable, because survival is important for any organism. Therefore the governments of all countries, in Siberia as well as in Canada and Alaska, have thoroughly participate in the survival of the polar people and help them in some way. This is needed for the continuing existence of Polar culture as such, and the pluralism of all cultures gains from is this.

I am of the opinion that man has not adapted biologically to northern latitudes but his culture has. This is something we can learn from polar cultures.

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SEED PRODUCTION OF SCOTS PINE CLOSE TO TIMBERLINE IN FINLAND

Erkki Numminen

ABSTRACT: Pine seed crops are large even in Lapland. According to extensive measurements carried out by Sarvas during 19 study years over a million seeds per hectare have annually fallen in Rovaniemi and over half a million further north in Utsjoki. The figures include also empty seeds. However, seeds rarely ripen near the timberline. Seeds were last collected in the winter of 1972-1973 and the stores are running short. Yet, natural regeneration may succeed even with incompletely ripened seeds.

INTRODUCTION

The timberline of pine in Finland is affected by ground elevation, it is in other words alpine, for there are pine stands on the shores of Norwegian fjords and river valleys (Fig. 1) which are north of Finland. The ground rises steadily along the Kilpisjärvi road in the western border in Lapland. The northernmost roadside pine stand is in Maunu (Lat 68° 29', Long 22° 14'). Yet, further up in the north fine pine stands of commercial value grow on the shores of Lake Inari (118 m above sea level). Close to timberline there are large areas where pine does not thrive because of compact soil consisting of

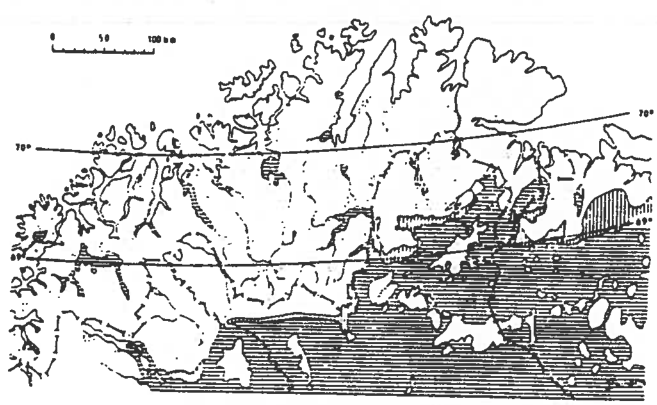

Figure 1.--Pine timberline in the Arctic area of the Nordic countries. Horizontal lines indicate pine forests, vertical ones groups of pine and dots single pine trees according to Hustich (1958).

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fine soil fractions. These areas are stocked with spruce and birch stands, the best-known of which is Pomokaira.

Research into seed crops of forest trees and regeneration have long traditions in North Finland. Renvall published his investigations of the variation in pine seed crops on timberline as early as 1912. Heikinheimo launched systematic measurements of seed crops in 1925 and published the results in 1932, 1937 and 1948. Sarvas carried on these investigations and wrote a number of publications. This very extensive material has been the basis for the investigations on flowering and seed crops (Koski & Tallqvist, 1978), the figures of which have also been used in this paper. Information on seed ripening has been collected at the Kolari Research Station of the Finnish Forest Research Institute.

SEED CROPS

Table 1 shows pine seed crops in 13 localities in Lapland over different years. Pine seeds do not ripen until the year following flowering. The seed crops of pine do not vary as much as those of spruce. Such an overwhelming seed crop of spruce as occurred in 1970 has probably never occurred in pine.

However, good seed crops of pine, judged by its own standards, are more frequent than those of spruce. Four good and two or three satisfactory seed crops occurred during the 19 study years. Therefore, the average seed crops of pine are not much inferior to those of spruce in the long term. The seed crops of even pine are extravagant. In a top stand at Hietaperä mineral soil site in Kivalo an average of 108 seeds fell on each square metre annually and even in the poorest site at Jyppyrä in Enontekiö 18 seeds. Even at Utsjoki the figure is 61. The seed number in Sarvas´ material refers to all fully grown seeds without distinguishing between full or empty seeds or different germinating capacity.

Sarvas´ material shows that seed crops have been prolific all over Finland, even in the north and elevated areas where pine stands grow.

Adequate flowering is a necessary precedent for a seed crop. Flower buds mature in the preceding growing season so that the primary concern is the wheather in the current summer. There is a common belief that a warm growing season leads to a large number of flower buds. Using Sarvas´ pine material Koski (1978) investigated the correlation between the years of vigorous inflorescence of staminata flowers and temperature sum of the previous summer as well as seed crops and the sum of growing seasons two years earlier. According to his findings, such correlation, although not very solid, exists. However, as a consequence poor flowering occurred after an exceptionally cold growing season. Thus a warm growing season does not always lead to abundant flowering in the following year and more seldom to a good and ripe seed crop in the next two years. The explanation to the latter is that the effect of the temperature sum during the growing season on the ripening of seeds is absolutely unambigous. The two-year development of a pine seed involves may factors that prevent a good seed crop from developing, such as poor pollination owing to rain , storm or other causes during the flowering. These factors may also lead to falling of conelets, as too small a number of ovules become fertilized. Severe frosts may also damage conelets. Numerous fungi and pests are harmful to cones.
A vigorous flowering and seed crop may also "exhaust" a tree. Even this point is ambigous, because two good seed years may follow each other. Successive and prolific seed crops have occurred in 1926-1927, 1961-1962 and 1971-1972 (Fig. 3). The seeds have not necessarily

Table 1--Annual seed crop of Scots pine (seeds/m^2) in some experimental areas set up by Sarvas

Latitude	Place of the seed traps	Stand age	54	55	56	57	58	59	60	61	62	63	64	65	66	67	78	69	70	71	72	$\bar{x}$
			Years of flowering																			
66°21'	Rovaniemi	119	5	3	14	3	77	31	133	14												48
	"	116	2	1	12	7	56	30	105	167												48
	"	100	4	2	13	5	38	53	134	159												51
	"	108						84	320	180	13	1	232	68	5	10	31	10	362	186	16	108
	"												144	20	2	2	16	26	289	164	11	75
67°22'	Sodankylä	130						28	158	130	62	7	153	73	13	40	14	14	76	173	39	70
	"	191						13	112	17	7	3	42	46	29	6	28					30
68°01'	Kittilä	216				1	9	16	132	92	36	8	22	30	8	4	6	1	71	221	8	42
	"	191				2	3	4	134	121	39	3	41	39	15	4	9	7	52	117	4	37
68°20'	Enontekiö	195						2	37	19	37	6	9	4	5	42	19					18
68°28'	Inari	199			4	0	3	11	86	42	60	23	41	54	88	7						35
	"	195					9	5	100	131	87	22	57	35	46	6						50
69°44'	Utsjoki												65	48	24	10	26	18	138	199	17	61
Temperature sum, d.d. in Sodankylä			894	768	694	800	744	826	1071	938	580	928	740	641	773	817	627	749	947	724	990	

been ribe in these years. The 1962 seed crop was good but remained almost totally unripened, as the temperature sum in Sodankylä was 580 d.d. This prolific but unripened seed crop in 1962 clearly seems to be caused by the preflowering summer 1960 which was the second warmest in the whole century (in Sodankylä 1071 d.d.).

Even long time series have not revealed such regularity as would help predict the future seed crops of forest trees, as the weather is the primary determining factor. In addition to the weather many other factors affect the quantity and quality of seed crops. Therefore, it is inportant that enough seeds will be collected for storage whenever the seeds ripen in North Finland.

RIPENING OF SEEDS

The seed crop has an afforestational value only if it is ripe enough. In Finland, especially after the Second World War, the existence, thriving and ripening of seeds of northern forests have been compared to the temperature sum, the threshold value being five degrees centigrades in Finland and six in Sweden. The temperature sum is more frequently used than the mean temperatures of June, July and August. The thirty-year period from 1941-1970 (Fig. 2) is nowadays used for the comparison of temperature sums.

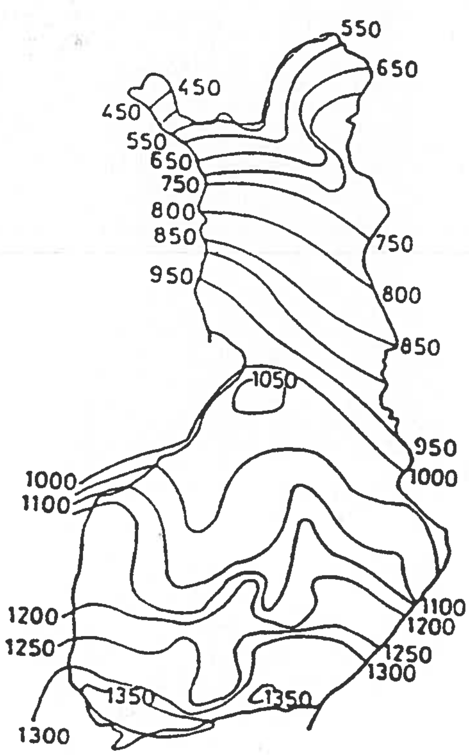

Figure 2.--Mean temperature sums of growing seasons in 1941-1970.

The long-term variation in the temperature sum can best be studied using the values released by the Sodankylä observatory (Fig 3), which is the oldest one in Lapland, established in 1908. The broken line shows a strong annual variation and rise in the temperature sum since the establishment of the station up till the end of the 1930s. The coldest summers in Sodankylä correspond to the mean values in 1941-1970 of the alpine birch area and the warmest years to those of the Jyväskylä area in Central Finland.

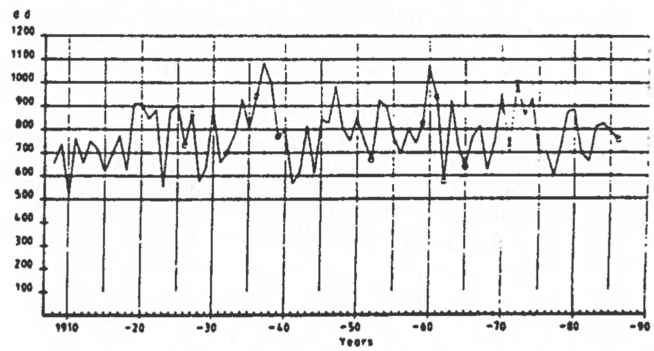

Figure 3.-- Temperature sums measured at Sodankylä observatory in the growing seasons in 1908-1986.

The Karesuvanto (established in 1883) and Jokkmokk (in 1865) weather stations in Sweden are older than the Sodankylä station. Their records show that the minimum values of cold summer periods occur at the turn of the century and that the previous warm period remained much colder than the warm one in the 1930s. The variation in the temperature sum in different parts of North Finland in 1971-1986 can be found in Figure 4.

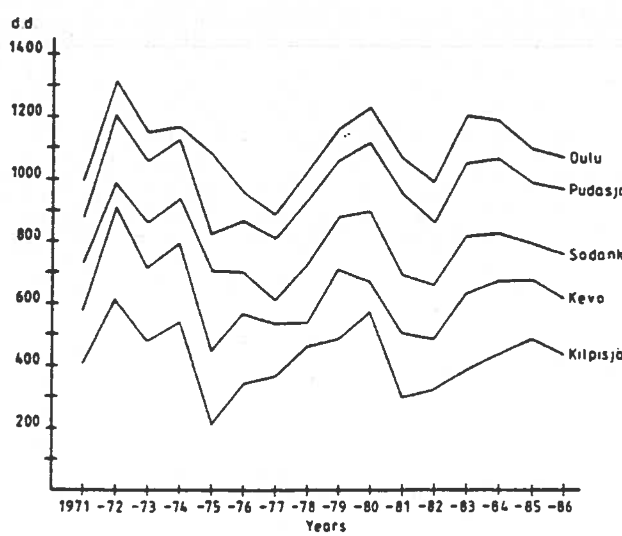

Figure 4.--Temperature sums of growing season at some weather stations in North Finland in 1971-1986.

According to Sarvas pine seeds ripen well enough in the area of 950 d.d. North of this limit ripening gradually weakens. It has proved very difficult to work out clear regularities of how ripening weakens as the temperature sum decreases and what the temperature sum limit is where even the seeds of the northernmost pine provenance do not germinate even in a germinating apparatus. All the investigators do not even agree that the temperature sum is the right way of defining the ripening of seeds. It is certainly true that one would need the correction coefficient of total radiation, hours of sunshine, rain or other factors for support. The temperature sum can, however, be a satisfactory way of finding out the level of ripening.

The Kolari Research Station has been engaged for over 15 years in the determination of the annual ripening of pine seeds in North Finland. It is carried out by X-raying and germinating seeds from sample stands and drawing curves of temperature sums from approximately 50 weather stations of the Meteorological Institute.

Each autumn the definition of the ripening of pine seeds is started by drawing temperature sum maps. Only few stations provide us with that information in September. Usually the final temperature sums will not arrive from the Meteorological Institute until January. As most of the temperature sums have accumulated till the middle of September, the advance information will help estimate the zone south of which seeds have ripened enough for collection. Cones are sampled from and around questionable areas for the investigation of ripeness, which is also affected by ground elevation from the sea level. For this purpose X-raying is the fastest, most inexpensive and accurate method.

The temperature sum investigations and consequent sampling aim at finding out the border zone of collectable seeds. There has not been much interest in studying the zone of poor ripening as it is worthless from the collection point of view. Even incompletely ripened seeds were collected in cases of emegency before 1972 when the seed stores were nearly exhausted in Lapland.

Incompletely ripened pine seed crops are common near the timberline except for infrequent warm summers. Even such seeds germinate and may suffice for the needs of natural regeneration if the weather in the seedfall year is favourable, the soil surface has been prepared or it is otherwise a favourable substrate for the development of the germlings. Occasionally cutting areas on the timberline are stocked with well-developed and naturally regenerated seedlings. It is, however, hard to say for certain which seed year they come from as post-germination does occur, in other words a seed may germinate one or two years after seedfall.

Many experiments have been carried out to improve the quality of incompletely ripened seeds. Especially researchers in Umeå and Sävar in Sweden are worth mentioning, as they have, among other things, developed the so-colled Prevac and IDS methods.

Pine seeds do not require stratifying, as they will be ready for germination during the winter in trees or seed storage until spring (e.g. Numminen, 1977). However, seeds collected in the early autumn do not germinate immediately after collecting without special measures.

The sorting of incompletely ripened seeds has gained importance along with the development of modern nursery techniques, since poorely germinating seeds cause economic losses because of empty paper pots and wasted space in greenhouses. On the other hand, the more seeds are assorted, the smaller is the amount that can be used. Possibilities of ripening seeds by keeping collected cones in warm and wellventilated stores are small if the aim is to make the endosperm or embryo grow. There is also apparent danger of seeds becoming mouldy.

The staff the Kolari Research Station have collected cones from individual trees in pine stands in various parts of North Finland for 15 years. Collection times per trees would be about 2,000 and the number of X-rayed seeds about 700,000. Figure 5 indicates that the germinability of seeds develops as the

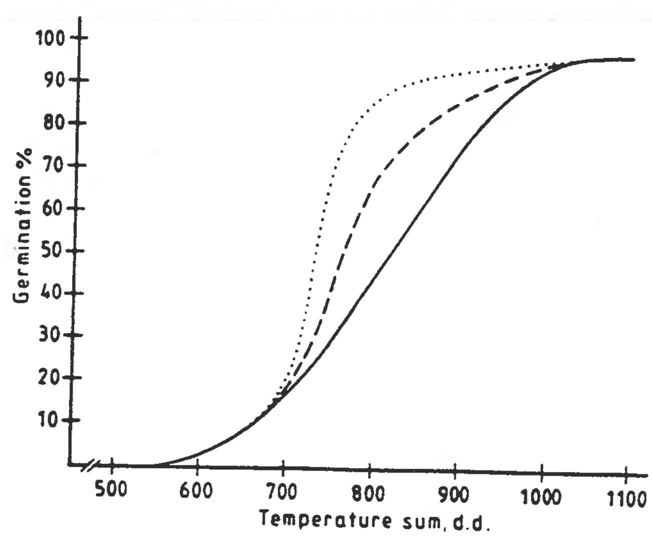

Figure 5.--Germination development of pine seed ... close to timberline, --- in middle Lapland and ___ in south Lapland.

temperature sum increases faster near the timberline than south of it. Up till 700 d.d. germinability develops equally fast in the whole of North Finland. After that differences start. These differences level down when the temperature sum reaches 950 d.d., the point at which the seed is ripe in the entire North Finland.

It is vital for natural regeneration to know what the ripening of seeds is like in North Lapland in such summers as the temperature sum reaches only 500-700 d.d. The X-rays taken at Kolari show that poorely germinating seeds that have ripened under favourable circumstances can be found in rather large amounts on the timberline if the temperature sum has exceeded 600 d.d. Even in colder summers some germinating seeds can be found. The limit for totally sterile seeds is at about 500 d.d. Then the only way of opening the cone is by tearing.

Seeds are more ripened in the southern than in northern sides of the crown, although no differences in ripening could be found in slopes facing different directions (Numminen 1974).

SEED ORCHARDS

Plenty of pine seeds were collected in the winter of 1972-1973 when ripening was satisfactory also on the timberline. After that winter it has not been possible to collect seeds and storages are already empty in the northern parts of the Kittilä, Sodankylä, Savukoski and Salla communes. There were abundantly seeds in the unelevated area in Inari, from where they have been transferred to the "empty" areas so that the before-mentioned stores are running short. Now the focus is the seed orchards in Central Finland. Due to background pollination the range of use has so far reached the southern parts of the Oulujoki watercourse (Kylmänen 1980). As the inflorescence of staminate flowers increases, the range of use gradually extends northward. However, it will probably last long before seeds from these orchards can be used near the timberline. There will always be background pollination also in the seed orchards so that dence afforstation spacing should be used near the timberline. It has been suggested that new seed orchards for the needs of North Lapland should be set up further to the south than nowadays, maybe even to Central Europe or preferably outside the range of Scots pine in West Canada and Alaska where the climate would be better suited for Scots pine than in Central Europe.

FUTURE PROSPECTS

Afforestation with pine has not always been successful near the timberline or elevated areas further to the south, especially when the soil has been compact, poorly permeable to water and unaerated and when the porportion of fine clay and sand particles has been high. Transferring seeds from the north to the south has not much improved the situation as a limiting factor has been the unavailability of northern seeds.

Efforts have been made to find individual trees in Lapland forests that would be more easily adjusted to the short growing season, in other words trees that would provide progenies that survive afforestation better than nowadays, grow satisfactorily and produce good-quality timber. Numerous experiments with progenies of plus trees have been carried out in Lapland. Significant, differences have been found out between the plus trees. Plus trees P 629 and P 550 with successful progenies are worth mentioning (Mikola, J. orally passed information). On the other hand, it is probably right to assume that a tree individual whose seeds ripen better than those of other trees in the stand year after year despite cold summers is also otherwise better adjusted to the short growing season. Such trees have been searched in the investigated stands in Lapland for years. It is not an easy task as differences in temperature sums of tree crown, healft of trees, position in the stand and other environmental factors have to be precisely recorded. Similarly, it is not easy to get annually 400 seeds which would be a sufficient ripening sampling.

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THE EFFECTS OF ELEVATION ON SITKA SPRUCE PRODUCTIVITY IN SCOTLAND

R. Worrell and D. C. Malcolm

ABSTRACT: Expansion of afforestation in upland Britain requires some estimation of productivity at higher elevations. Examination of the productivity-elevation relationship of existing Sitka spruce plantations indicated geographic variation which paralleled known patterns of distribution for accumulated temperature and windiness. Estimates of these factors combined accounted for 78 percent of variation in observed productivity. Addition of geomorphic shelter, aspect and soil type increased the precision of predictive equations but only to a small extent. Validation of the regression model suggested that productivity could be estimated to about $\pm$ 1.0 m^3 ha^{-1} yr^{-1}, which is adequate for management and investment decisions.

INTRODUCTION

For the last 2500 years the climate of Scotland has been strongly oceanic in type. The climate is characterised by generally low summer temperatures, lack of severe winters, high precipitation and associated cloudiness and, in particular, the frequency of strong winds. These climatic factors must have had a marked effect on the distribution of the forest species that had invaded post-glacially and which had extended their elevation range to about 800 m a.s.l. However it is still difficult to distinguish between a depression in the elevational range of forest due to climatic change and that due to the effects of prehistoric man. A further complication is the separation of Britain from continental Europe about 5000 BC so that only one native conifer, the Scots pine (*Pinus sylvestris* L.) became established and survived to historical times and that only in northern Scotland.

Forest destruction which began in Neolithic times continued throughout the historical period until the present century when, after the First World War, only 3 % of the land area was forested. The subsequent expansion of forest to about 11 % of the land area has been achieved by using exotic species, especially those from North west America.

The predominant species has become Sitka spruce (*Picea sitchensis* Bong. Carr.) which, apart from its desirable productivity, has demonstrated that it is generally well adapted to the climate of the Scottish uplands and is capable of adequate growth in conditions in which the native Scots pine cannot survive. Together with the development of site amelioration techniques (cultivation, drainage, fertilization) the scarcity of land led to the steady expansion of afforestation on to less fertile, more exposed sites at higher elevation. It thus became important to be able to identify the climatic limits, usually expressed in terms of elevation, for the economic production of timber - the so-called 'commercial planting limit'. Based on an evaluation of the 'internal rate of return' on the initial investment in planting, this limit is often quoted as a productivity of about 8 m^3 ha^{-1} yr^{-1}. This

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arbitrary value varies, of course, with the economic assumptions used in its calculation and thus the elevational limit will also vary. It is more useful therefore to be able to define the relationship between climatic factors (or elevation) with tree productivity in more general silvicultural terms and allow the investor to make his own judgement of profitability.

Diminishing productivity at increasing elevations has been demonstrated for both natural forest ecosystems and plantations in many parts of the world. It is frequently expressed as changes in dry matter production, mean volume, height or diameter. The relationship between productivity and elevation in continental climates has been shown to be curvilinear (Oswald 1969; Ott 1978) but in Britain the relationship appears to be linear (Malcolm 1970; Mayhead 1973). The relationship is nevertheless complex as most environmental factors that influence tree productivity also vary with elevation and even distinguishing between climatic and edaphic factors can be difficult. The most obvious factor is the reduction of air temperature at higher elevations both in terms of the actual values attained affecting tissue temperatures and the duration of the period in which metabolic activity can be maintained and thus influencing the maturation of tissues. Increases in elevation reduce the so-called growing season more in oceanic than in continental climates because of the flatter shape of the march of temperature curve. Windiness increases with elevation affecting tissue temperature, plant water status and mechanical damage (Grace 1977). Cloudiness and precipitation also increase with elevation often leading to reduced light intensity and excess soil moisture in an oceanic climate. These effects are related to changes in soil temperature, nutrient availability and water status.

In general climate appears to have a dominating influence on forest productivity at higher elevations (Tranquillini 1979) but the interrelations between climatic, edaphic and topographic factors (slope, aspect) make it difficult to attribute specific effects on tree growth when the physiological processes governing productivity are also strongly interacting.

The aims of the study reported here were, therefore, to (1) characterize geographic patterns in the relationship between the productivity of Sitka spruce plantations and elevation; (2) to identify environmental factors that could be readily assessed to predict productivity and define upper planting limits.

STUDY BASIS a) Field sampling

Productivity was estimated as yield class ($m^3 ha^{-1} yr^{-1}$), which is the maximum mean annual increment of stem volume. It is estimated from stand top height at a given age (Edwards and Christie 1981), a relationship which could be influenced by establishment difficulties, fertilization regimes and changes in tree form on exposed sites. This estimate of productivity (General yield class) however is readily assessed and the problems in its use can be largely avoided through site selection.

The topographic variables measured were elevation, geomorphic shelter, aspect and slope while soil factors were recorded as soil type. depth and rooting depth attained. Details of the methods used to estimate these factors are given by Worrell (1987).

Temperature was expressed as the mean accumulated temperatures above 5.6 °C and the mean air temperature of the four warmest months (June - September) both derived by extrapolation from standard meteorological stations (Birse and Dry 1970) using a standard lapse rate (0.6 °C per 100 m). Windiness of the sites investigated was estimated by the rate of 'flag tatter' extrapolated from the results obtained from a network of 1100 flags deployed in over 100 locations by the Forestry Commission between 1954 and 1984. As the 'tatter rate' observed varies in different parts of the country a series of geographic 'windzones' have been demarcated (Miller 1985) to take account of this variation.

The other climatic factors assessed were mean annual precipitation, estimated potential water deficit and oceanicity, each derived from published maps (Birse and Dry 1970).

b) Distribution of experimental sites

Field sampling was conducted by establishing 187 temporary plots (0.04 ha) located at 37 sites throughout Scotland and N. England. To investigate the effect of elevation the plots were laid out in series at 20-40 m vertical intervals (random start) in 18 main transects. A further 19 supplementary sites were chosen to increase the overall geographic cover with fewer sample plots in each.

c) Analysis of elevation - yield class relationship

Productivity (GYC) was regressed on elevations for each of the 18 main sites. At most sites the relationship proved close and $\underline{r}^2$ values ranged between 53 and 98 percent and were best estimated by linear functions. The average reduction in productivity was 4.3 $m^3 ha^{-1} yr^{-1}$ per 100 m increase in elevation (range 1.7-7.4). When the data were pooled the overall regression coefficient was only 0.0174 with $\underline{r}^2$ = 36.1 percent and it was clear that there was considerable site-to-site variability. Examination of the data suggested that sites located at higher elevations have higher GYC values for a specific elevation and that these sites were also in relatively sheltered inland areas whereas low level sites were more coastal.

To estimate the effect of location on the elevational relationship an analysis of covariance was carried out where effectively an 'average' regression line is fitted and the mean displacement from this line of the individual site regressions gives a measure of site-to-site variation.

The analysis was done by multiple regression using 'dummy variables' to express the effect of location (Worrell 1987). The model used was:

$$GYC = a+b(elevation) +b_1X_1 +b_2X_2 \ldots b_nX_n$$

where X_1, X_2, X_3 are dummy variables (Nie et al. 1975). To solve the normal equations one site must be used as a 'reference category' (for which the value of b = 0) with which all other sites are compared. The 'reference' site chosen was Glenbranter Forest in west central Scotland. The data from the main locations were regressed in this way to give the equation:

$$GYC = 27.3-0.043(elevation)+\text{'site effects'} \quad -(1)$$

The individual b coefficients (the site effects) ranged from -4.32 $m^3ha^{-1}yr^{-1}$ to 8.57 $m^3ha^{-1}yr^{-1}$ and the effect of location was highly significant (f = 27.5). When fitted to the whole data set (187 plots) the relationship was:

$$GYC = 26.5-0.0404(elevation)+\text{'site effect'} \quad -(2)$$

(r^2 = 80.7 percent)

Site effects now varied between -9.45 and +8.34 $m^3ha^{-1}yr^{-1}$ and were highest in the south and inland areas and lowest on western and northern coasts. The site effects were contoured mapped by computer (Figure 1). Using this figure and equation (2) the productivity (GYC) at any elevation within the original range of data can be estimated for any area in Scotland. Despite the relative precision of the model it assumes equal linear slopes in the elevational relationship at all locations. Although there is evidence (Worrell 1987) that a quadratic model might be a better fit for the whole elevational range a linear model seems most appropriate to the restricted elevational range sampled in this study (about 65% of plots were between 300-550 m).

From this initial investigation it can be concluded that productivity is strongly related to elevation at any one location but that the relationship alters between sites, productivity being lower in northern and coastal areas for a given elevation than inland or southern sites. This pattern of variation (Figure 1) bears a close resemblance to the known patterns of windiness (Hardman et al. 1973; Miller 1985) and of growing season temperature in Scotland (Met. Off. 1952).

ACCUMULATED TEMPERATURE AND WINDINESS

Tree growth is well known to respond to temperature variation in many different ways (e.g. Mikola 1962; Tranquillini 1979). Temperature effects can be conceived in terms of a threshold value for metabolic activity (e.g. 5.6 °C) and a range in which growth rate is proportional to temperature. These concepts have led many researchers to use accumulated temperatures (heat sums) to integrate growing season length with actual temperatures (e.g. Mork 1960; Farr and Harris 1979). However the paucity of meteorological data for upland and remote forest areas entails extrapolation of data both spatially and altitudinally using lapse rates. There are of course inherent sources of error in making these extrapolations but useful results can be achieved (e.g. Hunter and Gibson 1984).

Wind has marked effects on tree growth through cooling of tissues, effects on stomatal control and mechanically by altering tree form and physical damage. Windiness is also quite closely related to topography and elevation.

In an attempt to relate productivity more closely to climate, quantitative relationships between tree growth and indices of temperature and windiness were explored for the sites studied. The main indices used were:

1. Mean annual accumulated air temperature above 5.6 °C (day °C).
2. Flag tatter rate (cm^2 d^{-1}).

Both indices were adjusted to sea level values and contour plotted as shown in Figures 2 and 3 (Worrel 1987). Functions relating these values to those estimated for individual sample plots were then derived. In the case of tatter rate the function included elevation, topex, aspect and location (Worrell 1987). Productivity as measured at each plot proved to be significantly correlated with elevation (r = -0.601), accumulated temperature (r = 0.683), tatter rate (r = -0.587) and the cosine (r = 0.263) and sine (r = 0.290) of aspect for the whole data set. Higher values of r were obtained if the data was confined to those plots that had received current silvicultural treatments. For the latter data set the model including estimated values of temperature and windiness had a r^2 value of 78 percent:-

$$GYC = 9.53 - 0.902 \text{ (tatter rate)} + 0.0134 \text{ (acc. temp.)} \quad -(3)$$

The combination of tatter values with temperature acknowledges the fact that windy coastal sites experience higher temperatures than equally windy sites in inland mountainous areas. The model shown in equation (3) provides a basis for prediction of the GYC of Sitka spruce established with standard silvicultural techniques.

Other Site Variables

The inclusion of other site factors in the regression models improved their predictive ability (r^2 = 86 percent). For example using stepwise regression techniques it could be shown that geomorphic shelter, aspect and soil type had an influence on GYC. The pattern of productivity in respect of aspect is the converse of that of flag tatter rate suggesting that wind exposure is more important in this context than increased solar radiation input, for example on southerly aspects. Although the effect of soil type was significant its inclusion only raised r^2 values by 2-4 percent. The influence for a brown earth raised GYC by 2m^{-3} ha^{-1} yr^{-1} from the average while unflushed organic soils (peat) decreased GYC by a similar amount.

Predictive Value and Validation

The confidence limits for the 'best' regression equation were calculated initially on the assumption that the error variance was not location-related (Worrel 1987). This gave values of $\pm$ 1.0 or 1.4 m^3 ha^{-1} yr^{-1} for mean or extreme values of X variables. However a location-related component of the error variance was detected and the prediction of GYC for an area of plantable land had confidence limits of $\pm$ 2.3 and 2.6 m^3 ha^{-1} yr^{-1} for mean and extreme values of X. When estimating the mean deviation of predicted values from actual values a precision of close to $\pm$ 1.0 m^3 ha^{-1} yr^{-1} is obtained which is adequate for practical purposes. Validation of the regression models was achieved by independent collection of data from 32 new sample plots distributed in 9 forest areas. Compared with the values of GYC predicted by the regression the observed yield classes differed by an average of $\pm$ 1.48 for the 32 single plots, $\pm$ 1.01 - 1.28 for the individual forest areas and by 0.02 - 0.67 m^3 ha^{-1} yr^{-1} for the mean of all the plots. The regression of actual values on predicted values had a r^2 value of 63 percent. The values of mean deviation for individual forests are close to the estimate of precision based on the standard error of the regression (above). One could therefore expect to be able to predict GYC with a mean error of about $\pm$ 1.0 m^3 ha^{-1} yr^{-1} for a single forest block.

CONCLUSIONS

Previous attempts to classify site productivity for Sitka spruce in upland areas of Scotland (e.g. Malcolm 1970, Blyth 1981) have relied on topographic variables such as elevation and geomorphic shelter to characterise climatic conditions. They also anticipated that soil variables (physical and chemical) would account for a large measure of the variation in productivity. In the analysis the productivity relationships were dominated by elevation and soil factors played a relatively small part. In this study the elevation - productivity relationship was defined for a range of sites across the country so that it became clear that the relationship varied in a pattern that bore a close resemblance to the known distribution of accumulated temperatures and windiness. Both factors are also closely related to elevation. The good correlations between the extrapolated values of accumulated temperature and the crude estimate of wind climate provided by the tatter rate of flags encouraged the development of predictive equations. These factors together accounted for about 75 percent of the observed variation in Sitka spruce productivity while only small increases were obtained for other factors such as soil type, aspect and geomorphic shelter. Nevertheless from a practical forest management viewpoint the predictive ability of the equations were validated and offered a precision of estimate not previously available.

In studies of site-productivity variation it is usual for there to be a number of combinations of site variables that give equally good predictive ability. Their utility for management is enhanced if a few variables that are readily assessed can be used. In this study the 'best' equation comprised elevation, estimates of accumulated temperature and flag tatter rate at sea level, geomorphic shelter (topex) and crop age together with aspect and soil type and accounted for 87 percent of the variation observed in Sitka spruce stands which had received standard silvicultural treatment.

In view of the potential sources of error in extrapolation, both spatially and altitudinally, of climatic measures as crude as day-degrees and tatter rate it is surprising how closely the estimated values accorded with observed productivity. The physiological basis of these variables in terms of tree growth is very unclear and they take no account of other known effects such as mechanical damage or winter desiccation. These factors however appear to integrate the effects of the general environment as it influences the growth of Sitka spruce and reflect the decreasing production at higher elevations. The lack of importance attributable to measures of moisture availability (precipitation, potential water deficit and soil depth) is probably due to the range of elevation sampled and at lower elevations (<200 m) moisture stress may limit growth.

This study was based on plantation grown Sitka spruce in a windy oceanic climate and one would expect that for other species and in other climates its applicability might be limited. Nevertheless the statistical treatment of the data by using dummy variables in regression analysis allowed the pattern of variation with location and the effects of categorical variables such as aspect and soil type to be estimated. The use of this technique in other studies where climatic factors have not been adequately represented might improve the understanding of site-productivity relationships.

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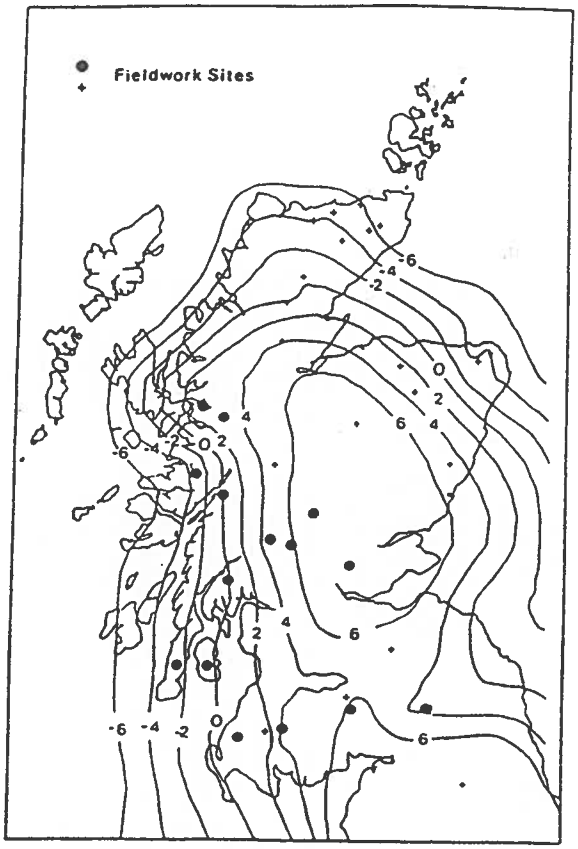

Figure 1. The effect of location on the elevation-productivity relationship. For any given elevation and location GYC is increased or decreased by the amount shown by the contour line.

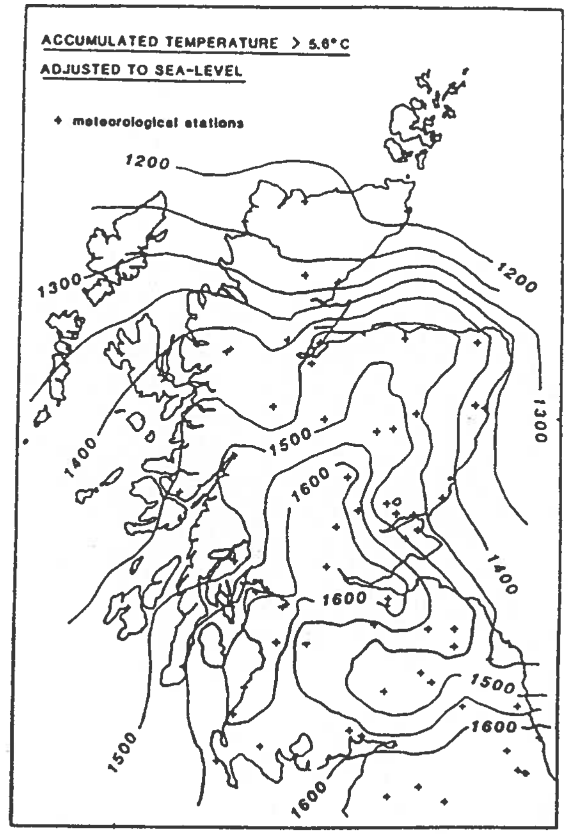

Figure 2. The distribution of day-degrees extrapolated to sealevel using a standard lapse rate (0.6 °C/100 m).

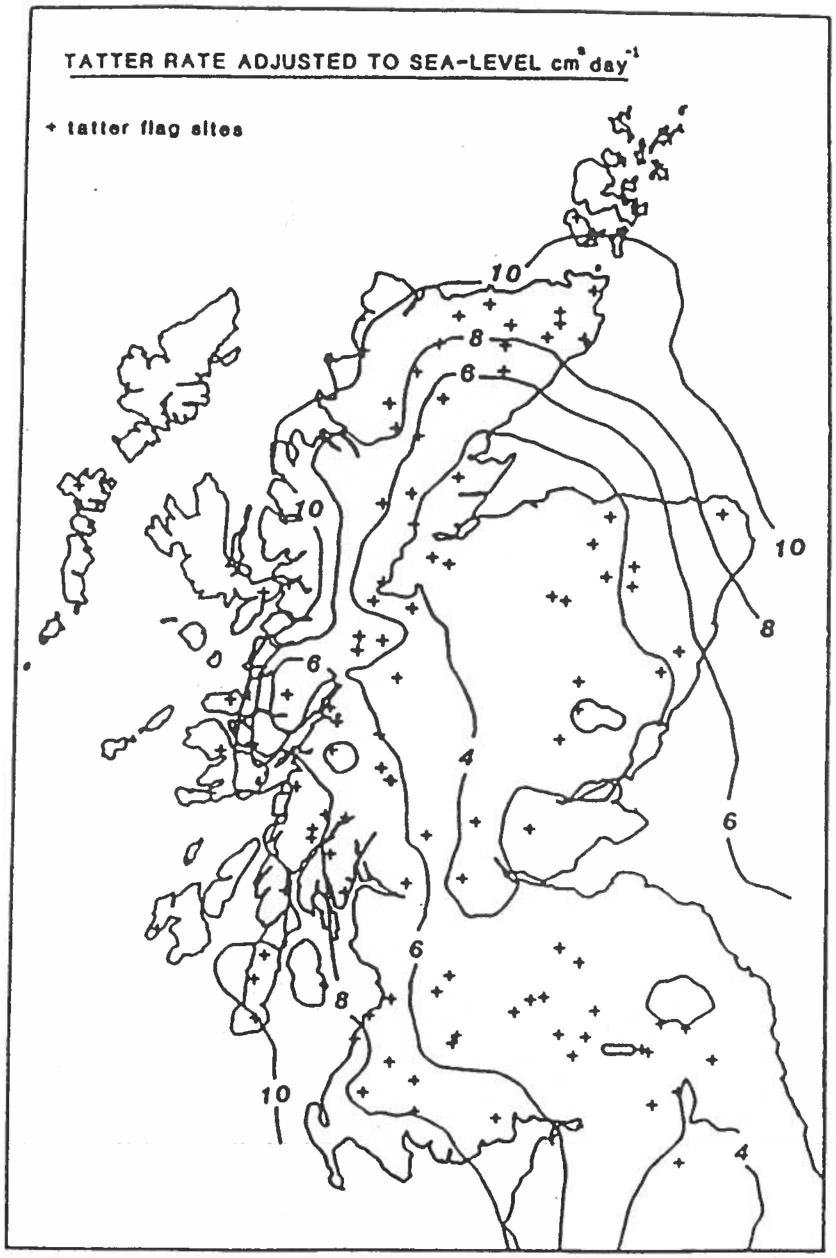

Figure 3.--The distribution of flag tatter rate ($cm^2\ d^{-1}$) adjusted to sea-level.

NATURE AND RATIONAL USE OF PRETUNDRA PINE FORESTS IN THE EUROPEAN PART OF THE USSR

A.A. Listov and B.A. Semyonov

Pretundra forests of the Arkhangelsk region and Komi ASSR located north of 65°N extend as a continuous band from the eastern shore of the Dvina Inlet in the west to the border with the Tumen region in the east. The southern boundary of this zone is very tortuous. Along big rivers it rises to the north, while in the interstream areas, in the sites with poor river network, and in the Urals it moves to the south.

The terrain is characterized by the smooth relief and spreading extensive swamped lowlands. Nearness of the northern seas, frequent incursion of cold air from the Arctic Regions and Siberia, passing cyclones define the cold and humid climate with unsteady weather. In the west, an intensive influence of Atlantic cyclones becomes apparent, in the east, climate continentality increases. Snowfall and frosts are possible in any summer month. The total solar radiation does not exceed 70 Cal per cm^2 per year, but its entry during the year is highly irregular. In June-Jylu the amount of the total solar radiation, including photosynthetically active radiation does not yield to that of the south-taiga subzone. The presence of numerous rivers, lakes, and bogs contributes to great air humidity (at an average 82 per cent a year). All of this affects the temperature regime, defines the length of cold and warm periods. The most warm month of the year is July with the mean monthly temperature of 12,8°C and the absolute maximum of 33-34°C in the air and 42-49°C on the soil surface. The most cold months are January and February when the temperature decreases to -50-55°C with its mean monthly value of -15-16°C. The mean annual air temperature is -2,9°C. The frost-free period is 62 to 110 days, the growing season averages 109 days with the period of active

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vegetation of 60 days and accumulated temperatures during this period somewhat more than +710°C. Mean annual precipitation is 437 mm with 65-70 per cent occurring in April-October. Moisture evaporation is low; the total evaporation volume is significantly less than that of the precipitation. The depth of snow cover is irregular ranging from 40-50 cm to 1.0-1.5 m and reaching 4 m (in the Urals).

A soil-forming process is characterized by the poor microbiological activity, accumulation of peat-humus horizon and of gleyic one under it. Tundra, podzolic-gley, and bog soils are distributed. In other habitats with leaching regime typical sandy and clay sand podzols are developing. The main parent rocks are moraine drifts, fluvioglacial and ancient-alluvial deposits represented by sands and clay sands. Soils are poor in nutrients, especially in nitrogen; soil reaction is acidic, base saturation is low.

About 70 per cent of the total land area of the pretundra zone in the Arkhangelsk region (without Nenets Autonomous Area) and Komi ASSR is turned over to various state enterprises, organizations, collective and state farms in the long-term use. Forestry possesses about 4,4 mln ha, of which 59,4 per cent are forest lands; 40,6 per cent are nonstocek forest lands, principally bogs and tundras.

Spruce occupies 73 per cent of the forested area, birch about 11,5 per cent, and larch 1,7 per cent. Aspen, alder and willow forests are also found.

Pine stands cover about 13 per cent of the area. Pine is often crowded out by spruce; the most stable positions it retains on podzolic light soils and sphagnum bogs. From time immemorial and in the first place pine forests have been subjected to felling and fires, especially along the rivers and in the vicinity of settlements. With increasing climate continentality and deteriorating the site from west to east and from south to north a proportion of pine forests takes off.

Maturity and old-growth pine stands dominate covering 77,9 per cent of the area; young-growth stands occupy 10,5 per cent of the area and middle-aged ones 11.6 per cent. The total volume of pine in the pretundra forests exeeds 26 mln m^3, of which 85,8 per cent are overmaturity stands, 1,8 per cent are young-growth stands. Pine productivity is reduced (see table 1). Stands of site index V-V^a dominate, the part of the pine stands of site index V^b is also great. Typically, the pine forests in the west of the pretundra zone (Arkhangelsk region) are characterized as a whole by higher forest assessment indices than those of the eastern part.

<u>Typological compositon of pine forests</u>. - In the area of the Arkhangelsk region and Komi ASSR the assessment of pine forest types was carried out only in the southern part of the pretundra zone. The vast areas under pine forests in the Nenets Autonomous Area and in the most part of the pretundra zone of Komi ASSR (64 per cent of the pine forest area) were studied very poorly from the typological point of view. The available data show that the most wide-spread type here is Pinetum sphagnosum occupying 35,4 per cent of the area in Komi ASSR and 35,9 per cent in the Arkhangelsk region. The widely presented types are Cladonia-type (18,2 and

Table 1. Mean forest assessment indices of pretundra pine forests.

Region republic	Forest assessment indices of pine stands					
	Age (years)	Site class	Density	Volume (m^3/ha)	Increment (m^3/ha)	Volume of maturity and old-growth stands m^3/ha)
Arkhangelsk	168	V.5	0,51	91	0,54	106
Komi	140	V.9	0,46	47	0,34	54

15,4 per cent), Vaccinium-type (7,6 and 16,7 per cent), and Ledum-type (11,0 and 8,6 per cent). In the west of the zone fresh Pinetum myrtillosum (13,8 per cent) is distributed; in the east wet Pinetum myrtillosum (5,6 per cent) and Pinetum polytricosum (9,7 per cent) are common. Considerable areas are occupied with Pinetum bryoso-lichenosum, Pinetum menyanthoso-sphagnosum; other forest types are also found.

The pine forests of the pretundra zone are distinguished by their lower stories of vegetation. In the undergrowth Juniperus communis, Betula nana, Sorbus aucuparia, subarctic species of Salix, Betula tortuosa are common; Lonicera coerulea, Rosa acicularis, Alnus fruticosa are found more rarely. The soil cover is dominated by lichens and dwarf shrubs such as Ledum palustre, Vaccinium uliginosum, Vaccinium myrtillus, Empetrum nigrum L., Arctostaphylos uva-ursi and in the west part by Calluna vulgaris.

Pine forests don't form great continuous tracts. The main habitats of pine here are small hills and ridges, elevations, rolling plains, lake boggy plains, bog edges. Pine forests are often found on sandy deposits along the rivers.

Forest management, effective conservation of pine forests, and their rational use cannot be done without regard for the typological structure and peculiarities of forest types. Regularities of woody species regeneration, formation, growth, structure, and productivity of stands are related to a forest type. Thus, Pinetum cladinosum stands are single-storied, mainly conditional even-aged, primarily, pure. Birch admixture is not more than 10 per cent, sometimes with spruce and larch in the composition. The stands are often formed by two or three generations of trees. Closing of leaf canopy in Pinetum cladinosum is 0,3-0,4, the stands refer to the site class V^a-V^b and at age 140-160 years their volume amounts to 60-80, sometimes 100-110 m^3 per ha. Under the tree canopy abundant seedling and young growth of pine (5,000-50,000 stems per ha) is frequent.

The stands in Pinetum vaccinosum are more often conditional even-aged, single-storied: uneven-aged stands forming under the influence of forest fires are also found. Along with pine (60-100 per cent), birch (upto 30 per cent) and spruce (up to 15-20 per cent), more rarely larch are common in the stands. Prevailing stand density is 0.4-0.5, the site class V-V^a. The timber volume makes up 80-100 m^3 per ha, sometimes reaching 150-160 m^3 per ha. The pine young growth under the canopy amounts to 3,000-10,000 trees per ha. The spruce seedling and young growth is more often found here; in the absence of fires its amount in continually increasing.

Besides pine (70-90 per cent) spruce (up to 30 per cent) and birch (up to 10-20 per cent) are common in the composition of fresh Pinetum myrtillosum. The stands are mainly single-storied; conditional even-aged stands prevail, but unevened ones are also found. The stand density is 0.5-0.6, site index IV-V, the stock volume ranges from 110-120 to 160-180 m^3 per ha. The main species under the canopy regenerates satisfactorily, but the proportion of spruce in the young growth makes up 20-50 per cent, sometimes the amount of birch is great.

In Pinetum polytricosum pine accounts for 50-90, spruce up to 40 and birch up to 30 per cent of its composition. The stands are single-storied, uneven-aged and have great tree height variations. Closing of leaf canopy and density are 0.3-0.4, the site class V^a-V^b, the timber volume amounts to 50-90 cm^3 per ha. The young growth is commonly sparse (1,000-3,000 stems per ha). The proportion of pine in its composition ranges from 10 to 60 per cent, that of spruce and birch is 90 and 50 per cent, respectively.

Pinetun sphagnosum is widely distributed. The stands are uneven-aged, pure, sparsely closed, open. The site class is V^b, the timber volume amounts to 10-60 m^3 per ha. The composition is commonly dominated by pine, sometimes with spruce (up to 30 per cent) and birch (up to 20 per cent). Pine young growth under the canopy amounts to 3,000-10,000 stems per ha, not infrequently spruce is present.

Forest regeneration is characterized by the close relation to fires, rare and low seed production of pine, slow height growth of woody species. Pinetum cladinosum, vaccinosum and myrtillosum are the most successfully regenerating types following fires. Especially high amounts of young and seedling growth under the canopy occur at fire age from 15 to 40 years. In pine forests growing on moist and water-logged soils forest regeneration has low relation to fires; there is a high proportion of spruce and birch in the young growth composition.

On pine forest felling sites the proportion of the seedling and young growth of advance generations depends upon their safety during logging and is defined by plant surviving in the time of their adaptation to new ecological conditions. Younger seedling growth and young growth, which are successfully adapted to conditions of cutover areas and after 1-5 years increase in height growth, are the most viable. Forest fires contribute to succeeding regeneration of pine on pine forest cutover areas with drained soils. However, wind and water erosion may occur following heavy and repeated burns; unfavourable conditions for seed germination and young growth are being created. Unsatisfactory pine regeneration also occurs on cutover areas having moist and wet soils with the developed moss cover. In Pinetum cladinosum and similar forest types successful pine regeneration occurs there, where the soil cover is disturbed and the ground litter is loosened. On the cutover areas from Pinetum vaccinosum, myrtillosum and similar forest types favourable conditions are created after removing the soil cover and decreasing the litter depth.

Seed sources play an important role in the cutover area seeding. Pine rapidly colonizes the sites in the vicinity of seed trees. Under the conditions of the Far North the cutover areas are considered to be provided with seed trees when their boundaries are moved away from seed sources (groups, bands, single seed trees) by no more than 50-60 m.

Climate deterioration toward the north and associated reduction of soil fertility, deterioration of the hydrothermal regime of soils affect stand productivity and their growth intensity.

Pine forest height increases markedly until 89-90 years of age after that no considerable changes occur. Depending on the forest type, age structure of the stand and its density, the most intensive height growth of pine occurs at the age interval of 15-30 years. Average heights of pine forests at age older than 100 years in the pretundra zone are by 20-40 per cent less than those of the north taiga pine forests. Differences in diameter growth are expressed to a lesser degree because of a lower closing of leaf canopy in the Far North. Quantitative maturity of the pretundra pine forests was found to come in the age class IV. Production forests (Vaccinium-type) reach it earlier than others (at age 65). Maturity on the middle-sized wood comes in 40-50 years and that on the large-sized one still 60-100 years later. To the time of technical maturity timber assortments, mainly of middle sizes can be logged in the stands of the site classes V and V^a (68 and 46 per cent, respectively). The proportion of large loggs does not exceed 10 per cent even in the most productive stands.

Not the productive potential of forests but the value of their protective functions plays a decisive role in pine forest management in the pretundra zone, because timber exploitation of pine forests with their slow regeneration and growth causes inevitably reduction of protective, environment-building properties of the areas. Therefore a natural maturity age of pine forests is of great importance when managing them. According to available data it is expedient to take the following natural maturity ages of pine forests: Pinetum cladinosum and sphagnosum - 240, Pinetum vaccinosum and polytricosum - 220, Pinetum myrtillosum - 200 years.

Polar location of the area, severity of the climate conditions, important protective role of the forest cover require to take protective silviculture as a principal direction of forestry. Forest management in the pretundra zone should be based on the zonal-typology principle. The nature of forests and level of managing them require development and use of the zonal pretundra forestry system. The main tasks of forestry should be conservation, rational use, and improvement of protective and environment-building properties of the forest lands by meeting local demand for timber and other products. It is necessary to maintain and increase the area of pine forests, to improve their climate-protective, environment-building, recreational functions. Along with this pine forests should be used as deer pastures and hunts, as a source of receiving the required amount of timber and side products. Forest management activities should be generally directed to forest fire protection, forest regeneration, regulation of deer grazing and other uses. It can be only allowed here sanitation and group-selection cuttings aimed at rejuvenation and sanitation of stands losing protective properties; in the zones of wind erosion of sandy soils forest regeneration is also needed.

Forest fire protection is generally carried out by aerial methods; fire-preventive organization of the areas is needed as well as protection against excessive nonregulated anthropogenic influences (cuttings, damage etc.). The main objects of forest management activities are pine forests of Myrtillus- and Vaccinium-types. In Pinetum cladinosum, polytricosum and sphagnosum forest management activities are restricted. Forest regeneration should be realized by both natural and artificial ways. Main attention is given to natural overgrowing areas. Forest plantations are established by both seeding and planting pine only on economically accessiable lands. When preparing soil one should seek to its minimum mineralization, mix the litter with the upper mineral horizon. The width of the mineralized strips in Pinetum cladinosum and vaccinosum is 20-30 cm, in Pinetum myrtillosum and polytricosum up to 0,4-0,5 m, size of plots ranges from 20 x 20 to 50 x 50 cm. By reforestation of Pinetum cladinosum cutover areas and postfire Pinetum vaccinosum cutover areas no soil preparation is needed.

Thinnings may be only performed on some sites in the closed young-growth stands with a considerable proportion of hardwoods (more than 50 per cent). The principal purpose of these treatments is increasing viability and stability, improving environment-building and recreational properties of the stands, optimizing the area structure. In the mixed young stands removals and early thinnings are performed first at birch age 10-15 years. The succeeding thinnings are performed in 15 and 20 years, repectively.

Sanitation cuttings are only permitted in the damaged stands by removing only dead standing and dying trees.

With a great area (more than 100 ha) of conditional evenaged Pinetum cladinosum, vaccinosum and myrtillosum strip thinnings are used. The width of cutting areas is no more than 100 m. In process of cutting single seed trees and seed tree groups are left at a distance 30-40 m between the trees and from the forest edges. A date of adjoining cutting areas is defined by time of tree canopy forming on them: on the sites with the undergrowth remained it amounts to 10-12 years and without undergrowth no less than 15-20 years. On the tracts with the area less than 100 ha and without undergrowth under the canopy groupselection cuttings with the annual cutting area no more than 1 ha are recommended. The succeeding thinnings are only performed following tree canopy formation on the site previously thinned.

In the mixed pine forests having 2 or 3 pine generations two-stage cuttings are possible. In the first thinning (intensity 40-50 per cent by volume) pines of the first generation (older than 200-220 years) are removed, as well as trees of undesirable species and forms, the composition and the amount of undergrowth are regulated. In 30-50 years the second thinning is performed. Afforestation is provided with the young growth of the previous generations and the most young trees of pine in the composition of the initial stand. In the uneven-aged Pinetum cladinosum, vaccinosum and myrtillosum without pronounced generations the older trees (no younger than 160-180 years) are removed, as well as 80-90 per cent of hardwoods and spruce in the first thinning. Intensity of the thinning is no more than 40-45 per cent by volume. Succeeding thinnings are performed in 40-60 years. If required, soil preparation under the canopy is carried out prior to the seed year as a measure contributing to natural pine regeneration.

In Pinetum sphagnosum and polytricosum selection cuttings are performed. Along with pine a greater part of spruce and birch (60-70 per cent) is felled. Selection cuttings can reach 35-40 per cent by stem number, 20-30 per cent by volume, subsequently decreasing to 15-20 per cent.

Young growth maintaining is a necessary condition of the regeneration and sanitation cuttings. Therefore the cuttings would be most desirable in winter with steady snow cover. When performing cuttings in summer caterpillar machinery cannot be used.

Pine forests are winter pastures for deers. However, their grazing should be regulated considering the state and nature of forests, regeneration under their canopy, forage supply, degree of soil disturbance. In some cases the deer grazing on a part of the lands should not be allowed, before the soil cover fully regenerates, mineralized soil sites are overgrown, the stand state improves. Any anthropogenic influence on the pine forests located at the boundary with tundra and in the isolated sites among bogs and tundras (cuttings, deer grazing, transport passage etc.) should be categorically excluded.

Thus, all that indicates the necessity of increasing conservation of the pretundra pine forests under these conditions, maintaining and expanding their areas. The forest management activities discussed ensure differentiated approach to the management of pine forests considering typological diversity, peculiarities and purpose of the forests. Only in such a way one can reach the rational use, permanent maintaining and improving their protective functions with the satisfaction of the local demand for timber and other usefulness of the pine forests.

FOREST RESEARCH IN AREAS CLOSE TO THE TIMBERLINE IN SWEDEN

Mats Hagner

ABSTRACT: The paper presents current research and running projects concerning; description of the standing forests, the quality of regeneration, injuries to young conifers, natural and artificial regeneration techniques, shelter trees, soil amelioration and scarification, climate, provenances, genetic improvement, seed supply, introduced species and multiple use. Lists of literature and addresses of scientists are added.

Background

In Sweden we have two borders in the forests drawn along the mountains covered by tundra. Mountains without trees are called "fjäll" and we call the close-laying forests "fjällnära skog". The two borders (fig 1) are "skogsodlingsgränsen" and "gränsen för svårföryngrad skog".

"Skogsodlingsgränsen" was set by the governmental Domänverket in 1950. Above this border one should not harvest the forest at all, the reason being unsufficient scientific knowledge about regeneration. This border was abandoned by Domänverket in 1980 but in 1985 it was reestablished by the Skogsstyrelsen and extended also to private land. Some special rules about forestry were introduced at the same time.

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"Gränsen för svårföryngrad skog" means "The border over which there is difficult to regenerate the forest". Above this the forest owners have to get a permit from the Governmental Board before they are allowed to harvest the forest.

After a public debate in 1984 concerning forestry close to the mountains, eight forestry scientists were asked to state the current knowledge. In a report the conditions for forest production and regeneration are stated (Odin 1984, Bäckström 1984, Nykvist 1984, Sjörs & Zakrisson 1984, Bergman 1984a, 1984b, Lindgren 1984) as well as the knowledge about the quality of the regenerations (Hagner 1984a). The report also contains recommendations for future work put forward by the above mentioned authors (Bäckström et al 1984). Documents published by Hagner during the debate are included in five appendixes(Hagner 1984b, 1984d).

In Bäckström et al (1984) the following is recommended.

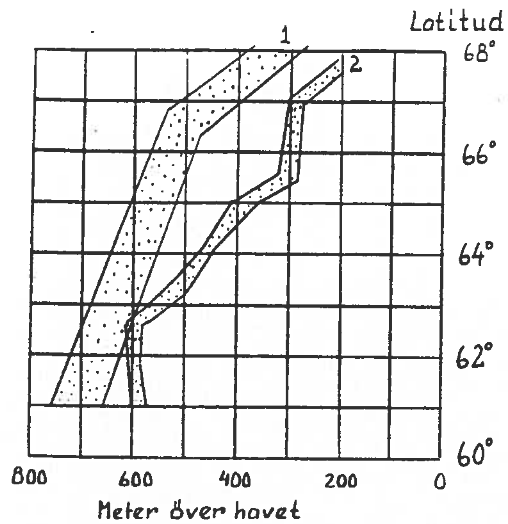

Figure 1. 1=Border "Skogsodlingsgränsen"
2=Border "Gränsen för svårföryngrad skog"
After Nyström (1986).
Meter över haver = Meters above sea

The size of logged areas should be decreased to below 40 hectares in order to obtain a mosaic with stands of varying ages.

In harsh areas with fine textured soil, where problems with regeneration can be expected, clear cutting should be avoided. The same applies to areas where seed supply of hardy Scots pine is lacking. In all cases where advanced growth is available, logging and regeneration operations should be adjusted with the aim to save and use the natural regrowth. Sheltering trees shall be left in all areas where summerfrosts are frequent. A careful analysis of the stand carried out before logging should form the base of a detailed plan for regeneration activities.

The most important measure for preservation of soil fertility is considered to be a well-growing forest. Soil scarification may temporarily lower the fertility if this is a prerequisite for good regeneration. As extensive soil treatments, such as ploughing, may decrease the long-term fertility, it must be restricted to moist areas where no alternative seems to be available.

Native spruce has greater ecological amplitude than pine and it should be used wherever it is considered feasible. Pinus contorta should not be used on high altitudes north of latitude 64-65. The reason is a lack of experimental results. Several other exotics have some potential but scientific tests have to precede large-scale use.

The density of young stands should be increased by the use of smaller spacing. The recommended minimum numbers of plants per hectare mentioned in the law must not be used as a recommendation. Wherever possible direct seeding should be used as a means to increase the density of the stands. Accordingly, at least 3000 stems per hectare should be left after the first cleaning of sown stands and natural regenerations. The final cleaning could be done fairly late and it should be remembered that procuction of high quality timber requires a very high density in the young stands.

The young stands have to be monitored closely and the final inventory has to be done not earlier than ten years after planting.

Finally, the group of scientists recommends additional education of foresters employed with forestry in very harsh areas and it is of special importance that detailed records are kept concerning regeneration measures taken. This enables future generations of foresters to learn from failures and successes.

In addition to this Hagner (1984d), in a special report included in the same edition, stresses the following:

Open clear cuts offer an unnatural environment. In a burnt forest (the natural environment) the dead trees are left standing for one or two decades and they give substantial shelter from wind and radiation. Accordingly, the regeneration in harsh areas should be sheltered.

The advanced growth might be saved if sheltering trees are left. If mechanical scarification could be abandoned it would be possible to use the advanced growth to a greater extent. A method comprising a plastic shelter adapted to the plant in the nursery has resulted in good survival after planting in the humus. This method should be developed for practical use.

The genetical variation in climatic adaptation among trees within all progenies is so great that the survival in areas close to the tree line is bound to be low. Planting is too expensive to enable formation of a sufficient number of trees per hectare. Direct seeding encounters an untolerable seed volume. Accordingly, natural regeneration is the only method that gives an economical solution. However, the optimal solution might be a combination of planting and advanced growth, which could be realized by employing the method "planting without scarification".

Finally Hagner stresses that where planting is used, every single container should harbor several seedlings from at least two species; spruce and pine.

Current research

The following is a condensation of current research employed today by swedish scientists. I want to stress that the list is a result from a questionnaire put forward to the largest scientific institutions. Quite certainly, many projects that are carried out have not been mentioned. Therefore, the list should not be considered as complete.

The list contains results that recently have been published, but in addition to that currently running unpublished projects are taken into consideration. This is done also where funding for the moment is lacking.

The list of publications is completed by a list of addresses of scientists involved in research close to the timberline.

Description of the standing forests

Kullman (1981, 1983a, 1983b, 1986a, 1986b, 1987) has paid great attention to the dynamics of tree line species and their reproduction and he has clearly demonstrated the close correlation between climate and ability to regenerate. Zackrisson (Sjörs & Zackrisson 1984) and Linder P are also working with the structure and dynamics of the stands close to the timberline. Engelmark (1987) just presented his dissertation dealing with the fire-history of forests in the Muddus national park. Engelmark will continue the Reivo-project, "The ecology of a burnt forest", started in 1973. In this eleven scientists have been engaged to demonstrate different aspects of the ecological processes after the fire in 1966. A new "wild fire" is planned to be started after scientific studies in the Reivo national reserve. In the project the following scientists are still active; Hagner M, Westman L, Rudin D, Essen P A, Karlman M, Wiklander G. Esseen P A carries out a project "Fragmentation of the biotope" intended to illustrate in which way islands of uncut forest left on the clear felled areas will enable endangered species to survive. Zackrisson O is developing a special site classification for forests close to the mountains.

The quality of regenerations

The debate on forestry policy in areas close to the timberline made it clear that the knowledge about the quality of regeneration was very scarce (Hagner 1984a, 1984b, 1984d). Since then some limited investigations have been published. Gabrielsson & Tibblin (1985) investigated in great detail a few clearcuts planted with spruce. They described the position of every tree. Nyström (1986) showed that the young stands of planted pine are fairly open and that the natural regeneration from spruce and birch will constitute a major portion of the mature trees. Olofsson G is carrying out a vast inventory of randomly chosen areas that were clear cut twenty years ago. Elfving B is heading a large project, "potential production of new stands", with around 1500 plots (100 m2) in plantations established on a practical scale (fig 2). The coordinates of every tree is known. Zakrisson O is studying clearcuts close to the mountains to find "an elevational limit for artificial regeneration".

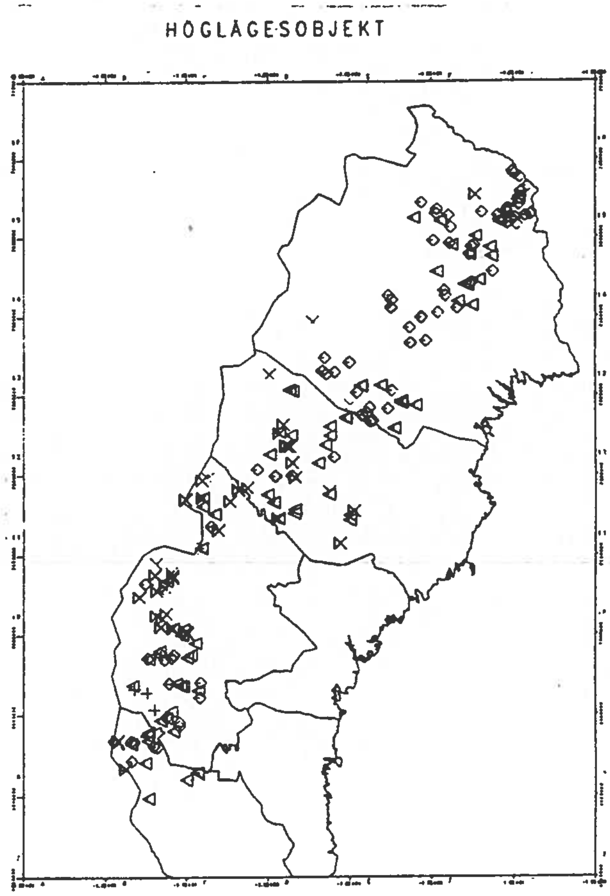

Figure 2. Fixed plots for monitoring the quality of young stands on high altitudes After Elfving B.

Injuries to young conifers

Martinsson et al (1983), Bergman & Odin (1984) and Karlman (1986) describe the common diseases and mechanical injuries to young trees. Karlman is continuing inventories on regenerations. In a cooperate project with Canada, Pinus contorta as well as Pinus silvestris is compared on test sites in both countries. Näslund (1986) used a large number of fixed plots for simulations of the long term effects of damage and mortality in young stands. Linder P and Zackrisson O are studying breakages by snow and wind in high-elevation forests. Hagner (1980b) showed hidden frost injuries in the cambium of several conifers growing in Sweden and Canada. Damage caused by reindeer was investigated by Ekberg (1987).

Natural regeneration technique

Bergman (1984) describes the presumptions of natural regeneration. Hagner (1987) estimated the potential production of advanced growth on several areas far north of the polar circle and found it most valuable. Falk J is studying in which way advanced growth can be used to form stands with two or three layers. Jeansson E carries out research on natural regeneration in harsh areas (Jeansson 1985). Several other scientists have shown interest in extensive studies on advanced growth in areas with very harsh climate. So far no funding has been raised.

Lindman (1983) showed the potential production in a few stands in which selective cutting was carried out. Jonsson B and Jacobsson J continuously follow the growth and long term production of old stands in which thinning has been done. Hagner (1980c) compared the natural regeneration in a burnt forest with the artificial regeneration on a nearby clear cut. Hagner (1987) showed that planting can be performed without scarification and he considers a combination of advanced growth and planting to be the optimal method for regeneration.

Artificial regeneration technique

Bäckström (1984) discussed areal production at different number of stems per hectare and found the present density of the regeneration in harsh areas to be low. Gemmel P and Örlander G are investigating the possibility of increasing survival by simultaneously having two species, pine and spruce, in the pot when planting containerized seedlings. Lundmark T has demonstrated that small shelters of cardboard placed on the southern side of pine seedlings had a beneficial effect on survival. Hagner & Hansson (1987) have shown that containerized seedlings can survive well when planted directly in the humus layer, if they are enclosed in a simple cylindrical plastic shelter. De Jong (1986) is studying the areal distribution of factors affecting survival and growth. He will try to use the information for design of site adapted regeneration methods.

As there is a shortage of seed for the harsh regions direct seeding in which great amounts of seed is used cannot be performed. However, much seed can be saved if seeds are covered by plastic shelters (Hagner 1981b, 1984c, Hagner & de Jong 1981).

Sheltering trees

It has been shown that the environment close to shelters has a very positive impact upon survival of pine (Hagner 1984d). Fries C is studying twenty-year-old plots with sheltering trees under which advanced growth is supplemented by planting. Hagner M is monitoring some plots where seeding and planting was done under trees that were killed at the time of planting.

Soil amelioration and scarification

Nykvist (1984) gave a good general description of soils and hydrology of sites close to the mountains. Huss-Danell K and Zakrisson O are studying the ability of lupins and alder to ameliorate the site by nitrogen fixation.

Mechanical scarification and its influence upon survival and growth is studied in several projects; Bäckström P O, Juntti K, Lundmark J E, Lundberg S, Örlander G. Hagner (1987) showed that enhanced growth occurring after ploughing may delay the inwintering process in pine. Holm & Kullman (1983) and Hagner (1985b) showed the relationship between topography, survival, growth and weather injury.

Climate

Odin (1984) describes the climatic conditions of trees growing close to the mountains and he is still working with studies of the climate in these areas.

Provenances

Lindgren (1984) discribes the climatic adaptation of forest trees and its influence upon survival and growth. Provenance research on Norway spruce has recently been published (Rosvall 1982a). Prescher (1986) and Ståhl & Andersson (1985) have given the data of survival, growth and volume production at the age of 30 years for Scots pine in a large series of provenance tests. Yazdani & Nilsson (1986) showed the variation of monoterpene among natural populations of pine.

Pinus contorta, now used on a practical scale in Sweden, has been tested in many provenance trials (Rosvall & Strömberg 1980, Rosvall et al 1984, Lindgren 1985) and recommendations have been published.

Genetic improvement

A large number of scientists are working to enhance the hardiness of the regeneration material for the most northern areas of Sweden. Great efforts are directed towards early tests and a freezing technique has been proven to be suitable (Ericsson 1983, Ericsson & Andersson 1983, Nilsson & Eriksson 1986, Rosvall 1982b). Various breeding plans are discussed (Andersson 1985a, Gullberg 1987, Nilsson 1986, Lindgren 1985, Presher 1985, Ståhl & Persson 1985). Rosvall (1985a) suggests hardiness could be increased by proper maintenance of existing seed orchards. Ståhl et al (1985) suggest that special measures should be taken to increase the timber quality of the progeny. Nilsson J E has paid extra attention to hardiness features of orchard clones (Nilsson 1985, Nilsson & Aman 1985, 1986). As a breeding population he has selected 200 pine clones very close to the tundra. Andersson (1985b, 1986), Ericsson (1986) and Ericsson & Hadders (1980) are intensively following the progeny from seed orchards with respect to their hardiness. Freezing tests are often used in this work. Lindgren (1987) has described the potential production of Pinus contorta and its relation to Scots pine on various sites.

Seed supply

As there is a pronounced shortage of seed for harsh areas, great attention has been paid to availability, collection practises and efficient use of such seed. Prognoses founded on climatical measurements and early seed tests are published in late fall by the Institet Skogsförbättring in Umeå and the Skogshögskolan in Umeå. Cone collection is mostly organized by the Skogsvårdsstyrelsen.

The variation of seed maturation within the tree has been studied by Bergman (198?) who showed a pronounced difference between the south and north sides of the tree crown. Hagner (1980a, 1982) found great differences between individual trees in their generative adaptation to the climate (Pinus sylvestris and Pinus contorta). Hagner M has established a seed stand by selection of generative plus trees in a very northern area. This is a cooperative project with Mo and Domsjö AB.

For efficient use of live seeds in the nurseries great effort has been paid to sorting live from dead seeds (Simak et a 1985, Lestander 1986, Bergsten 1987) and to the use of germinated seeds (Hagner 1981a, 1985a). Methods for practical use are functioning well for pine but less well for spruce. Andersson B and Lindström A are trying to develop a suitable system with small containers, aimed to be transplanted after assortment.

Introduced species

It is well known that exotics may be hardier than native pine and spruce in high-elevation areas. One such example i Abies lasiocarpa which is able to prospe in the birch zone at latitude 64, where only scattered spruce survive. Other species that are paid great attention is Larix sibirica, Picea mariana and Abies sibirica. Martinsson O and Rosvall O are heading projects encountering measurements in old test plots and establishment of new trials (Martinsson & Vinsa 1986, Rosvall 1985b).

Multiple use of the forests close to the mountains

Economic evaluation of competing forms o use of the forests close to the mountains; lumber producers, reindeer farmers, tourism, recreation etc. is carried out by Hultkrantz L and Mattsson L. The project aims to recommend rules and jurisdiction that would bring about an "incentive compatibility".

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Addresses

Below are listed addresses of the scientists mentioned in the text and presently working on projects concerning forestry in the areas close to the swedish Scandes.

Abbreviations

Sveriges Lantbruksuniversitet Umeå=SLU U
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Umeå universitet Umeå =Um Un
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RESTRICTIONS ON FOREST MANAGEMENT CLOSE TO THE TIMBERLINE IN NORTH AMERICA

J. Peter Hall

ABSTRACT: Forest management in the boreal forest is restricted by:
- the idea that forest management is unnecessary (conceptual),
- the failure of the landowner to assign responsibility for forest management (political)
- the nature of the harvesting and utilization of the forest resource (economical),
- the lack of knowledge needed to apply management on all forest sites (technical)

These restrictions are being addressed at a rapid pace in the 1980s. These trends are encouraging and suggest that in the near future intensive forest management will be the rule in boreal forests in North America - not the exception.

Forest management includes a wide spectrum of managerial objectives employed to preserve and protect the natural productive capacity of forest land, to restock recently cut sites and to protect the growing stock. Elements of forest management include improvement of site, trees and stands, site preparation, regeneration, stand conversion and protection against damaging insects and diseases (Todd 1982).

As foresters, we assume that there will be increased and more intensive harvesting of the forests in the future. As forestry shifts in emphasis from the mining of natural stands to the harvesting from managed crops a number of other factors change. The change to higher levels of management means that policy makers require different types of information on which to base decisions. High levels of silvicultural investment means that the quantity and quality of research results must also be high (Draper 1982). Research results applicable to current forestry practices may not be applicable to management of second generation forests.

The timberline, in the strict sense, is the climate-controlled ecotone between the dense forest and the open treeless barren (Arno and Hammerly 1984). In North America the timberline ranges from 68°N in Alaska southeastwards to 60°N in Manitoba to 47°N in Newfoundland. There is an altitudinal limit, as well, ranging from 1,500 m ASL in north-central British Columbia to nearly sea level in Newfoundland. Forest activities are located in forests south of the ecotone area - the boreal forest. This forest type dominates the northern part of the continent and is part of the circumpolar boreal forest (Larsen 1980, Arno and Hammerly 1984).

The economy in these areas of northern forests is dominated by forestry and forest products. Overall in Canada forestry contributes C$14 billion net to the balance of trade - more than other natural resources including mining,

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petroleum products and fish and agricultural products (Anon. 1986). Employment is provided for 270,000 people directly and for 750,000 indirectly. Large areas of forest are harvested, an estimated 800,000 ha in Canada, the majority of it in the boreal forest. Nearly all of this area is clearcut and less than half of the area regenerates naturally to standards which are considered adequate. Ownership of this forest land is vested in public authorities; federal or provincial governments (Anon 1986). Forest management is practised in much of the boreal forest and at much more intensive levels than the "clearcut and get out" philosophy which is familiar from the past. Large areas remain unstocked, untreated or treated unsuccessfully and there is a backlog of unregenerated areas from past cutting.

Forest management is practised in those parts of the boreal forest which are biologically capable of producing a merchantable crop of timber which currently is about 90 m^3/ha. Merchantability levels affect management options in that only the most productive sites are treated or managed. This may be to the long-term detriment of the forest if marginal sites are harvested, left untreated and do not regenerate to productive forest.

This paper discusses restrictions on the management of these productive and potentially productive areas of the boreal forest.

DESCRIPTION OF THE FOREST

In order to describe and discuss restrictions on management it is necessary to describe the nature of this forest. Many of the restrictions arise from the nature of the forest; location, climate, geology, species composition, effects of insect and disease damage and of succession following disturbance.

The forest occurs in a wide belt from Alaska in northwestern North America (68°N, 162°W) to Newfoundland in the southeast (47°N, 55°W). It ranges in width from 7° to 10° in latitude or 400 to 800 km (Rowe 1972, Larsen 1980).

The boreal forest is characterized by a cold climate with short summers and long cold winters. Summer mean monthly temperatures generally range from 6° to 15°C. Large continental air masses originating in the Arctic dominate the climate. There is a wide range in annual precipitation from 230 to 1500 mm (Rowe 1972, Larsen 1980).

Soils in the boreal forest are mostly derived from granites, forming coarse grained rock and sand. Where precipitation is abundant water leaches out soluble sodium, potassium, calcium, iron and aluminum causing varying degrees of podzolization (Larsen 1980). Soils developed on clays or calcareous sites form brunisols and where drainage is poor gleying occurs. Organic matter accumulates on these cold, wet soils and slows nutrient cycling which in turn restricts growth rates. Nutrients are tied up in the organic matter; disturbance of which enhances the nutrient cycling process. Boreal forest soils are usually shallow and acidic (pH of 3.5-4.0 is common). Where the rate of humus accumulation exceeds decomposition peat bogs are formed which may range up to several metres in depth. Here it is difficult for trees to grow at all.

Restrictions on forest management in the boreal forests arise from the biological nature of the forest. Some restrictions are fixed; climate, elevation, aspect and to some extent soils (Vyse 1973). Others which are controllable by the forest manager include seedbed conditions, seed supply, insects and diseases, animals and vegetation.

The boreal forest is characterized by a limited number of species with wide geographical ranges and high levels of adaptability to various site conditions. The more common species are black spruce _Picea mariana_ (Mill.) B.S.P., white spruce _P. glauca_ (Moench) Voss, balsam fir _Abies balsamea_ (L.) Mill, white birch (_Betula papyrifera_ Marsh.) and trembling aspen (_Populus tremuloides_ Michx.)

Other species predominate in parts of the boreal forest:
Lodgepole pine (_Pinus contorta_ Dougl.) in the northwest.
Jack pine (_Pinus banksiana_ Lamb.) from Alberta west to Quebec.
White pine (_P. strobus_ L.), **Red pine** (_P. resinosa_ Ait.) and **Yellow birch** (_B. lutea_ Michx.) along the southern limits of the boreal forest.
Balsam poplar (_P. balsamifera_ L.) more common in the northwest Alaska, Yukon) and declining in abundance towards the southeast until it becomes a rare species in Newfoundland.
Big tooth aspen (_P. grandidentata_ Michx). which is most common in the central boreal forest in Ontario and Quebec.

These species occur singly or in association with others forming distinct cover types (Rowe 1972). The cover types vary continuously throughout the forest (Larsen 1980). For example in Alaska, cold sites both upland and lowland tend to be dominated by black spruce whereas on the more mesic sites, white spruce dominates in association with aspen and white birch. These associations vary with time as the forests respond to cutting, insect attack and fire (Viereck and Little 1972).

Successional trends are often not completely understood in the boreal forest especially where cutting has been undertaken on a large scale or where natural succession has been influenced by forest management. For instance cutting in mixed spruce-fir forests has resulted in large areas of second growth balsam fir which is damaged by the spruce budworm (Choristoneura fumiferana Clem.). Forest management techniques have controlled wildfires to the extent that black spruce, which depends upon natural wildfire for regeneration, is becoming less and less common in the boreal forest. In areas where forest management and harvesting are minimal such as the Yukon successional trends are better understood (Oswald and Brown 1986). When spruce or Jack pine are burnt, they generally regenerate to black spruce or Jack pine (Vincent 1965). In the continued absence of fire these stands become decadent and opengrown until they are destroyed by windthrow or fire (Larsen 1980). Black spruce can also come in as an understory in Jack pine stands and eventually dominate the stand. Before cutting became widespread in the boreal forest, fire was the major successional factor affecting all sites. This resulted in the establishment of pioneer species such as black spruce, Jack pine, white birch and trembling aspen. Balsam fir comes in later in the succession but does not maintain itself after fire because both the advance growth and seed source are destroyed.

The spruce budworm is the best documented insect affecting the boreal forests (Hardy 1985). The budworm has caused widespread damage in spruce-fir forests for at least 300 years and attacks have increased in frequency and severity during this century. Budworm maintains the spruce component of the spruce-fir forest as both insect and host have evolved together. The budworm now causes a loss of 45 x 10^6 m^3 of wood annually. Outbreaks are believed to begin on white spruce in mixed wood stands and then spread to balsam fir stands. The attacks cover extensive areas; in 1981, 22.9 x 10^6 ha had 'significant volumes of dead and dying timber' (Kettela 1983).

Large areas of the forests are harvested annually, but less than half regenerates adequately. The most common reforestation treatment is planting, (63.8%) of treated sites, followed by direct seeding with 22.2%. Scarification is the most common site treatment (66.4%) followed by prescribed burning (14.8%). Most planting stock is container-grown (since 1980, 73.7%) and the proportion of container over bareroot is increasing (Kuhnke and Brace 1986).

For boreal species, generally, the response to seeding or planting is good; they are adapted to a wide variety of sites and seedbed types.

RESTRICTIONS ON FOREST MANAGEMENT

A review of the literature on forest management describes as many restrictions as there are forest types or forest management systems. In this paper they are arbitarily combined into four groups; **conceptual, political, economical and technical.**

1. Conceptual

Forest management is restricted in an overall sense by the concept that all is well and therefore nothing needs to be done. This is the most significant restriction of all and has widespread influence (Hearnden 1975). It acts as a drag on all forest management policies, plans and operations.

Overall in the boreal forest there is enough wood to meet current and projected demands and in many areas cutting does not even reach the levels of the annual allowable cut (AAC). There are, however, local wood shortages and there is a vague realization that all is not well in the forestry sector. Application of good forest management principles now cannot avoid current shortages but they can affect on medium-term shortages and can prevent long-term shortages. The ability to produce forest products is based on the area of productive land available, the volume, age and condition of the current growing stock, the depletion rate and the intensity of forest management (Honer and Bickerstaff 1985). Unfortunately logging and silviculture are often seen as separate entities with the sole objective of getting wood as cheaply as possible (Hearnden 1975). Professional foresters too are accused of being silent in pressing for better forest management (Hearnden 1975).

There is also a historically low level of public and political awareness of forestry matters. It has been bluntly stated more than once that the main obstacle to forest management is socio-political, that reforestation methods are well known and only time and effort are lacking (Ternent 1984, Hearnden 1975). The low level of awareness also has as its consequence a low level of public support. In 1986 the Canadian Council of Forestry Ministers[1] was formed to enhance public support for forestry and forest management. This restriction, the most significant of all, can be overcome by a program of public information and public education.

2. Political

Forest management in the boreal forest is restricted by the reluctance or failure of the landowner to assign responsibility for the maintenance of forest productivity. Forest land is owned by the state (public lands in the U.S., Crown land in Canada) and the state has

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[1]This group consists of the eleven Canadian Ministers responsible for forestry matters.

allowed private individuals to harvest the wood from the land upon payment of fees. These fees (commonly called stumpage) have not been sufficient to cover reforestation costs and are usually part of the provincial or state revenue rather than being directed to forest management. Therefore there is no incentive for the landowner to practise sound forest management. Ownership of forest lands is overwhelmingly in the public domain, in Canada 92.3% of forest land is owned by Provincial (80.8%) or by the Federal (11.5%) government (Anon. 1986). In the boreal forests of nearby Alaska two thirds of the productive forest land in state-owned.[2]

There has been little awareness in the past of the need for assigning responsibility, however, this has changed as the possibility of wood shortages has shown the need for management.

In the Province of Alberta agreements have been developed between the landowner and the forestry companies which allows cutting and removal of timber and provides for building and maintaining access roads, reforestation and other forest improvements. The objectives of the agreements are to provide for management on a perpetual sustained yield basis (Anon. 1981).

These policies reflect a newly-developed awareness of the need for effective forest management.

The national government as a minority landowner does not apply forest management policies on a large scale; its role is confined largely to research. The Canada Forestry Act (1949) provides for the shared cost for fire protection, reforestation, inventory and research (Bickerstaff and Hostikka 1977). The federal government maintains six regional research centres and two national institutes to direct and co-ordinate forest research in Canada.

Land alienation also restricts forest management. As the population increases and more leisure time is available and forests are more accessible there is an increased demand on forest land. Land is taken out of forest production for recreation and wilderness areas, hydroelectric dams, rights of way, summer cabins and for parks and wildlife habitat. Forestry has as good a claim on land as these other demands and too often this claim is not recognized. Public awareness may be the means of overcoming these restrictions of land alienation and the failure to accept responsibility for forest management.

3. Economical

There is a restriction imposed on forest management by the nature of harvesting and utilization in the boreal forests. There is a quantitative and qualitative aspect to this problem.

In a quantitative sense there are many hardwood sites (mostly white birch and trembling aspen) where harvesting is minimal. As late as twenty years ago only a tiny fraction of the annual allowable cut in hardwoods was harvested because none of the species were of commercial value (Maini and Cayford 1968). Now the development of oriented strand board and the establishment of production facilities means that there is a demand for aspen (Anon. 1987). Contrast this with 1968 when research efforts concentrated on ways of eliminating the species (Maini and Cayford 1968). Apart from the potential loss of fibre from not harvesting these species, remnant trees left after harvesting interfere with silvicultural operations.

Even in softwood stands containing economically valuable species utilization standards are low. It has been estimated that approximately half of the standing biomass is left in the forest in the form of high stumps, tops, branches and even logs (Case 1982a). Depending on the type of method of extraction used varying amounts of fibre are left behind. Under the full tree system 20.7 oven dry tonnes/ha are left, under the tree length system 53.8 and under the shortwood system 70.7 (Case 1982b). Higher levels of utilization improves the environment for reforestation and reduces the area harvested to produce the same amount of fibre.

The qualitative effects are related to the long term productivity of the site. Before the mechanization of harvesting, the harvesting process did not greatly damage or disrupt the site. Roads and landings and small skid trails were present but soil compaction or erosion was minimal. Advance growth was only slightly disturbed. Some mixing of soil and the organic matter occurred but this was generally beneficial to natural regeneration (Hearnden 1975, Draper 1982).

Since 1950, however, the increase in use of wheeled skidders, forwarders and other heavy machinery has seriously disturbed forest sites. It is estimated that 15 to 20% of seedbed areas are disrupted to an extent that natural regeneration is impossible (Hearnden 1975). Damage to site productivity results from soil compaction, erosion and destruction of advance growth.

Advances in logging methods have extended the boundaries of the productive forest. Steep slopes, formerly inaccessible can now be harvested. Little thought has been given to subsequent possibilities of erosion or of

[2]T. Gasbarro - Pers. Comm.

reforestation methods. The trend is common in forest operations where machines are designed to get wood out as cheaply as possible. This short term event has long term consequences on forest productivity.

Another effect of harvesting is the problem of nutrient depletion. Full tree harvesting, which removes most of the biomass from the site, can be employed in mixed hardwood-softwood stands with minimal nutrient losses (Gordon 1981). However, in pure black spruce stands significant amounts of nutrients can be lost using this method. Short rotation systems also result in nutrient losses. Our knowledge of the extent of these losses is insufficient (Jovic 1981).

What can be done to ease these restrictions? Products can be and are being developed to use currently unwanted species. Higher utilization standards increase efficiency and facilitate reforestation operations. Logging can be done on some sites in winter rather than summer to minimize site damage (Todd 1982). Changes then will be needed in harvesting, transportation, handling and processing of materials. This will enable site treatments to be based on biological considerations rather than the reforestation manager reacting to the harvesting method and being left with a 'problem site' with fewer silvicultural options. Advantage can be taken of machinery already developed for extraction and adapt for reforestation purposes. For instance, cones can be collected using machinery often used or designed for harvesting (Haig 1969, Bailey and Sullivan 1981). Logging methods might be varied, black spruce is a good seed producer and strip cutting is a feasible method for regenerating the species (Haavisto 1975). Thinning or selection cutting may harvest the mortality and permit a variety of harvesting techniques other than clearcutting (Nickerson 1970, van Nostrand 1973). The manager must consider harvesting as a part of the succession of forests and not as a one-shot 'cut and run' exercise. If the forest operation is not biologically sound then in the long run it will not be economically sound.

4. Technical

Forest management is restricted in that the optimum reforestation treatment is not known for all forest sites. Although a large body of research results is available for the boreal forest, many conditions are not identified or adequately described.

This restriction arises from the failure to transmit research knowledge and in not getting the best from what we do know. This is currently being addressed by an increased emphasis on technology transfer, joint researcher-user symposia and subject working groups.

Forest management is sometimes restricted by a lack of trained personnel able to do silviculture, though this can be overcome through training and job creation projects. Management is restricted by shortages of planting stock and by the inability of current machinery to provide the micro-environment needed for seedling development. This can be overcome by the research and development of new technologies, the major change being the attitude that new machines must be designed to accommodate the biological needs of the seedlings.

There are cultural and legal restrictions on forest management. A good example of cultural restriction is that of opposition to prescribe burning. To most North Americans exposed to the Smokey the Bear culture, fire is an enemy of the forest rather than a silvicultural tool The most prominent legal restriction in forest management is that on the use of herbicides. Court challenges mounted by various environmental groups have prevented even the testing of herbicides and widespread use on public lands. However, professional foresters seldom agree on when and where herbicides should be used nor can researchers always show what the effects of herbicides are on forest succession Thus it is necessary to win public (hence political) acceptance through public relations efforts while ensuring that the prescriptions are based on sound scientific data.

A brief review of the literature shows that a great deal of research has been done on management prescriptions for the boreal forest. This research has gone a long way to alleviating the restriction imposed by technology. This paper lists several under three categories of research showing the type of work done and the breadth of current knowledge.

1. <u>What type of sites do we need to treat and how?</u>—Forest management concentrates on the best sites to get the best return on investment (Forster 1969). These sites must be identified and this process has led to the development of site preparation manuals (Jones *et al*. 1983, Corns and Annas 1986, Anon. undated).

Productive forest land can also be extended by draining peatlands or by afforesting lands such as barrens (Payandeh 1975, Hall 1987).

Site factors affecting regeneration success have been described for white spruce (Draper 1982) and black spruce (Vincent 1965) and for other boreal species. Temperature, light, competing vegetation, soil texture, structure and nutrients, moisture and aeration have been studied. It has been demonstrated that soil inversion or mounding results in improved aeration and higher temperatures and provides some natural control of competing vegetation. Increased planting success can be achieved using larger rather than smaller stock.

Controlled burning has been shown to be a management tool in manipulation of species composition, and stand conversion (Hall 1973, Armson 1985, Innes 1985). The degree of fire intensity governs the success of reforestation treatments (Brown 1984).

The microsite conditions must be adequate for seedling survival but failure to provide these basic conditions is where most regeneration failures occur.

2. Stand Establishment.--A considerable body of data has accumulated on natural and artificial stocking of stands. Methods for regeneration establishment have been described for Jack pine (Clarke 1984, Smith, B.W. 1984) and white spruce and black spruce (Richardson 1973). Direct seeding appears promising but is not widely used in reforestation operations (Hellum 1973). Success of seeding is strongly dependent upon precipitation which varies greatly during the growing season (Brown, 1984).

Most boreal species are also easy to regenerate, it is easy to raise them in the nursery or greenhouse, they are easy to plant and they usually have rapid juvenile growth. The problems arise when the forest manager has failed to take into account some basic biological factors necessary for success.

In some reforestation projects herbicides are needed to overcome weed competition (Dennis 1984). Evaluation of weed effects is difficult but usually only localized treatments are needed. Other methods have been studied for weed control including manual brushcutting, fire and biological control (Sutton 1985). Planting methods, mounding and use of large stock can also be used to overcome vegetation competition hindering seedling development.

Tree improvement programs designed to replace wild seed with genetically improved seed have affected reforestation programs (Miller 1984). The growth rate in boreal conifers is partly genetically enrolled and considerable advantage in growth rate can be gained by using superior genotypes (Yeatman 1984). Within reforestation programs tree improvement methods have a sound economic basis (Cornelius and Morgenstern 1986).

3. Stand Tending.--Various studies have been done on fertilization and precommercial thinning (spacing) of boreal conifers. Fertilization with nitrogen, phosphorous and potassium stimulates growth in black spruce and lodgepole pine (van Nostrand 1979, Yang 1983). Greatest response is in young stands approaching crown closure but positive results have been obtained in fertilizing 60 year-old black spruce and 70 year-old lodgepole pine.

Precommercial thinning is a necessary and valuable tool when managing lodgepole pine (Johnstone 1983) and Jack pine (Smith, C.R. 1984) where considerable response in diameter growth results after treatment.

Finally insect and disease pests though theoretically serious have yet to become a serious management problem in plantations. Large reservoirs of budworm-infested stands near plantations may cause problems in the future. Planted stands tend, on the whole, to be more susceptible to damage by *Armillaria mellea* than seeded ones (Singh and Richardson 1973) although this may only be a result of early stress on planted seedlings. Previous forest pathology research was concerned with diseases of older mature trees in natural stands but now research is concentrating on plantations.

CONCLUSIONS

Forest management in the boreal forest is restricted by:

- the idea that forest management is unnecessary (conceptual),
- the failure of the landowner to assign responsibility for forest management (political),
- the nature of the harvesting and utilization of the forest resource (economical),
- the lack of knowledge needed to apply management on all forest sites (technical).

These restrictions are being addressed at a rapid pace in the 1980s. Expenditures in silviculture as a proportion of all expenditures on management have shown a steady increase over the past 10 years. Between 1977 and 1982 this increase was 54%. New Federal - Provincial forestry agreements in Canada have provided for several hundred million dollars for forest management with emphasis to be placed on forest renewal, nursery development and stand tending. These trends are encouraging and suggest that in the near future intensive forest management will be the rule in boreal forests in North America - not the exception.

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RESTRICTIONS ON FOREST MANAGEMENT
CLOSE TO THE TIMBERLINE IN NORWAY

Oddvar Haveraaen

ABSTRACT: In Norway, the uppermost forests above spruce and pine consist of birch. The ecological conditions are harsh and unstable, resulting in low yield and difficult natural and artificial regeneration of conifers. Multiple use aspects based on ecological knowledge ought to be the primary guideline for management of these forests.

DEFINITIONS

The definition of mountain forest, or forest close to the timberline, is not very exact. In particular, the lower border causes difficulties whereas the common definitions of the uppermost borders are more clear in Norway. The treeline is drawn where scattered trees have a height of 2 m, while the timberline is where the maximum distance between trees is 30 m and minimum tree height 3 m (MORK & HEIBERG 1937). The upper limit of what we define as a productive forest is somewhat below the timberline. A productive forest should have a mean annual yield potential of at least 1 m3 per hectare.

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A general characteristic of mountain forest is that in such forest temperature is a strong limitation for both forest yield and tree reproduction.

AREAS OF MOUNTAIN FOREST

MORK (1958) roughly estimated the average horizontal width of the mountain forest in Norway to be 500 m. By using figures for the length of the timberline, estimated by Norges Geografiske Oppmåling to be 47 000 km, we end up with nearly 2.5 million hectares, or about 1/3 of the total forest area in Norway.

The current timberline is sometimes lower than the climatic timberline. For instance, local mountain farming, with browsing domestic animals and heavy cutting of firewood, may temporarily lower the timberline.

In the high mountain area in southeastern Norway the climatic coniferous timberline is over 1000 m a.s.l. Generally the height of the timberline varies considerably from south to north, from the interior to the coast, and even from the central part of southern Norway to the east (ABRAHAMSEN et al. 1977) (fig. 1). Hence, to relate the lower limit of mountain forest to a certain height above sea level has no meaning. According to BØRSET (1986), some researchers have used 60-70 % of the height of the timberline as the lower limit of the mountain forest.

BERGAN (1974) has on the basis of climatic studies, suggested relating the lower limit to a vertical height difference from the climatic timberline. This vertical belt could then be valid all over the country. This means that under unfavourable conditions, as in the far north, all forests should ecologically be classified as mountain forest.
We have no figures on the area of mountain forest in Norway today. Assuming 15-20% of the total forest area would give 1.1-1.5 million hectares.

FOREST LAW

Since 1976 the general objective of the Norwegian forest law has included a clear multipurpose statement. In addition to production of timber, giving income to forest owners and raw material to various types of timberusing industries, forest management must have in mind the recreation aspects, the esthetic value of trees and forests, and the habitats for all types of animals, and plants.

Figure 1. Isogram in m for the climatic timberline of birch (Betula pubescens var. tortuosa) in Fennoscandia. (ABRAHAMSEN et al. 1977.)

For the forest close to the timberline the law has for a long time contained a particular paragraph about cutting regulations. In every district of the country an imaginary line is drawn some vertical distance below the timberline, often 100-200 m. Above this line the forest owner can only cut dead trees without special permission. If more cutting is requested by the forest owner, the national forest service must carry out the marking. This regulation was stated long time ago, when mountain farming and heavy cutting were a real threat to the future of the mountain forests.

For various reasons the cutting activities in the mountain forests have generally been quite low for some decades. This has taken the restriction paragraph out of practice, although it still exists.

TREE SPECIES CLOSE TO THE TIMBERLINE

Birch (Betula pubescens var. tortuosa) is the dominating tree species in the upper belt close to the timberline in the western part of Fennoscandia. Mixed with the birch we find groups or single trees of aspen (Populus tremula), gray alder (Alnus incana), mountain ash (Sorbus aucuparia) and bird cherry (Prunus padus). All these species have a temperature demand for the four summer months of about 7.5°C, while spruce (Picea abies) and pine (Pinus sylvestris) require about 8.4°C. The difference between the mentioned broadleaved trees and the conifers means a vertical altitude difference of 100-150 m. Thus, on steep slopes the belt of broadleaved trees is quite narrow, while on nearly flat ground, it will dominate large areas.

Birch also occurs quite frequently in the upper coniferous belt. In the most arid mountain regions, pines form the coniferous timberline. However, since humidity dominates the Norwegian climate, spruce is the most common conifer.

FOREST REGENERATION

The broadleaved tree species can regenerate either generatively or vegetatively. The production of birch seeds is generally abundant. No registration is available to tell the proportion of seed or sprout regeneration. We assume, however, that vegetative regeneration is quite frequent in the mountain regions. Before the last world war farmers commonly kept their domestic animals grazing in the forest close to the timberline. Small seedlings of birch were then browsed near to the ground every year. When pasturing in the mountain regions decreased, the new vegetative shoots had the chance to develop into trees. Today we often find abundant young birch trees among scattered old trees or young birch trees higher up than the old ones.

Pinus sylvestris does not regenerate vegetatively. Usually we find the most frequent pine regeneration where the layer of raw humus is thin. However, at high altitudes young pine is susceptible to snow blight fungus, Phacidium infestans.

The seed production of conifers, particularly spruce, decreases drastically with increasing altitude (BONNEVIE-SVENDSEN & SKOKLEFALD 1965). The temperature demand (average June-September) for development of mature seeds is about 10°C (HAGEM 1917, EIDE 1930). This is 1.5°C higher than the requirement for vegetative growth. Aslo for seed germination the temperature is an essential factor (MORK 1938b, LØKEN 1970) (Fig. 2). However, it seems that these factors to some extent can be modified depending on the natural seed storage conditions during the winter prior to germination.* Often in nature loss of seeds and young seedlings by predators can reduce a promising crop to a poor regeneration (NILSEN 1987).

Spruce, Picea abies, however, has the ability to regenerate vegetatively by sinkers. When the lower branches from a "mother tree" lay on moist raw humus for some years, the branches start to develop roots from the touching point. The branch tips bend upwards and a new generation of young spruces grow up more or less regularly around the "mother tree". In due course new generations may develop outside these again. The belt of vegetatively regenerated spruce in this way is

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* Investigations done by P. Nilsen. Manus under preparation.

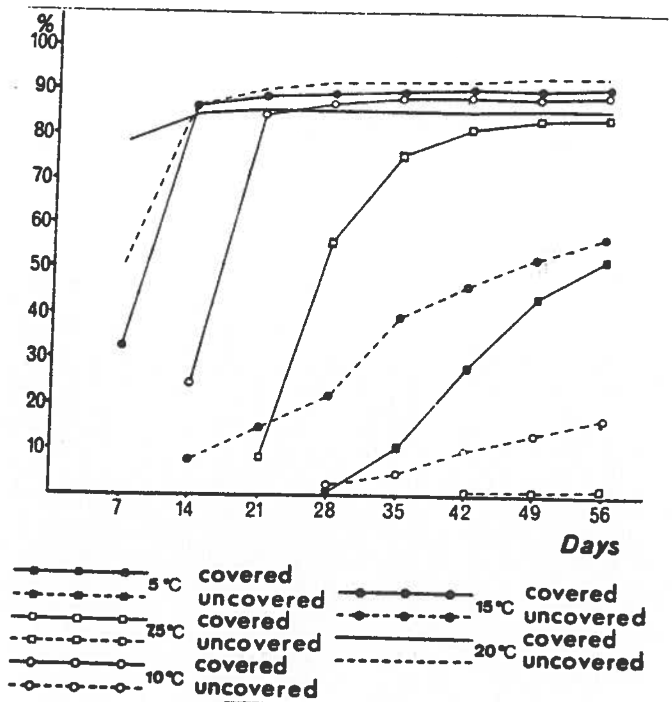

Figure 2. Germination curves for spruce seed, ____ covered and ---- uncovered, at different temperatures (LØKEN 1970).

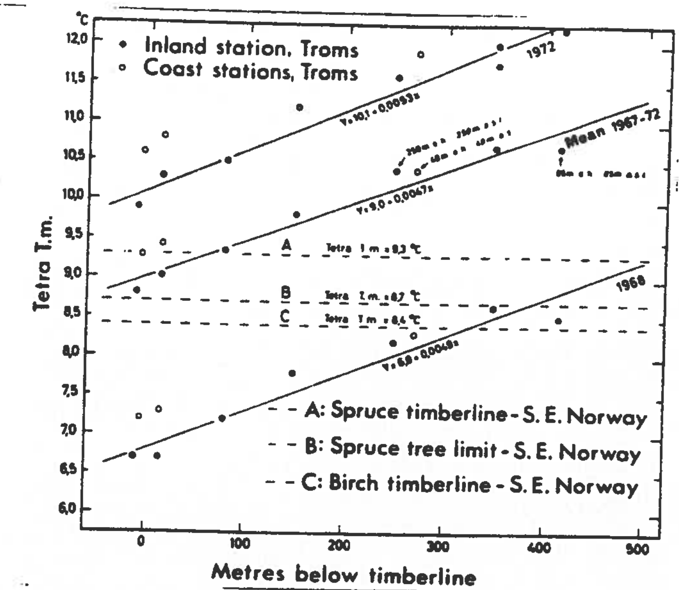

Figure 3. The relation between vertical distance below birch timberline and mean temperature June-September (Tetra T.m.). Inland and coast stations in Troms, North Norway (BERGAN 1974).

usually limited to the uppermost, say 50 m, vertical belt from the timberline.

Young plants of spruce are very sensitive to frost damage in the summer months. This is particularly the case in flat areas such as plateaus and valley bottoms (MORK 1968, FRANK & KIBSGAARD 1973). Regeneration, natural or artificial, under such conditions will therefore hardly be a success on clearcut areas.

The ecological balance in the forest close to the timberline is very unstable. Great differences in average summer temperature, 1-2°C, often occure from one year to another. There also exist oscilllations with intervals of 5 to 10 years (MORK 1968, BERGAN 1974) (fig. 3), and even long term fluctuations. Treatments carried out in a climatically good period may lead to success, while the same treatments under less favourable conditions can result in a complete failure. A change in the average summer temperature of 0.6°C (June-September is equal to an altitude difference of about 100 m.

MORK (1933) found a higher soil temperature on clearcut areas than in forest stands. In this investigation all the clearcut areas were smaller than 1 hectare (0.2 and 0.7). Wind generally lowers the effect of maximum daily temperature. In mountain regions the positive effect of clearcutting could thus be turned to a negative effect if the clearcutting results in increased wind speed above a certain level. FLEMMING (1968) has found that in Middle Europe the wind speed on clearcut areas even as small as 2 hectares approaches the wind speed on wide open land (Table 1).

Table 1. Width of clearcut area and windspeed (FLEMMING 1968). Presuppositions are square areas and 15 m tree heights.

Area width in tree heights	0	10	20	40
Wind speed in per cent of speed on open land	15	64	82	92
Size of clear cut area, hectare	0	2,2	9	36

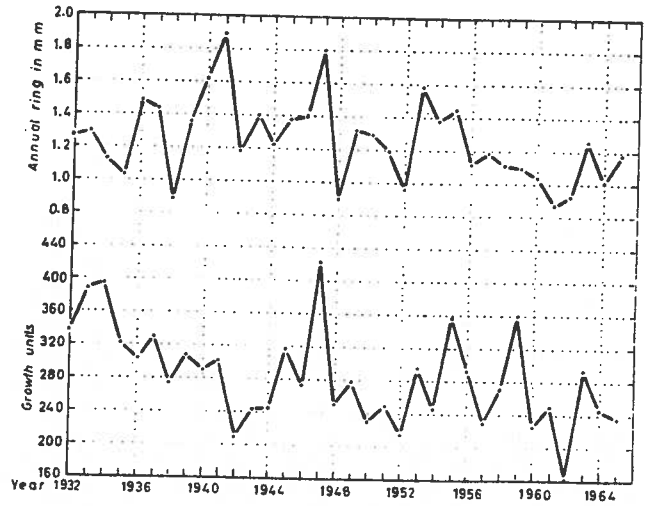

Figure 4. Widths of annual rings of spruce and growth units during the growing season for the years 1932-65 (MORK 1968).

The low temperature and in most places rather high rainfall (>800 mm) do not favour a rapid decomposition of the organic matter deposing on the top of the mineral soil. The soil material is also often acid and poor in nutrients. This again leads to a podzol profile which usually gives difficult conditions for both natural and artificial regeneration of conifers (MORK 1938a, LAG 1961).

FOREST YIELD

The factors affecting regeneration also have great influence on the yield of wood and timber (MORK 1944, 1968, BERGAN 1983, 1984) (fig. 4). The yield will vary depending on how far below the timberline we draw the lower limit of the mountain forest, but is usually less than 2.5 m3 per hectare and year. However, higher yields can be found at relalatively high altitudes on slopes facing south or southwest and where the soil fertility is aslo good.

In much of the mountain forest top and stem breakage caused by heavy load of snow and sometimes even ice occurs frequently. The wind often adds additional restrictions both summer and winter. Wind in summer reduces the maximum temperature within and close to the needles and leaves. Strong wind can also damage the needles physically in winter by snow and ice drift and by drying in both summer and winter.

Forest close to the timberline usually has low stand density and trees with a deep crown. There are also stands with a relative high number of trees per hectare of the same size and age, but the common feature is variation (NILSEN & HAVERAAEN 1982b).

Investigations by NILSEN & HAVERAAEN (1982a) have also shown that the forest yield is sustainable to a much larger extent than in more highly productive forest. The low yield in the forest close to the timberline does not generally encourage high investments in forest regeneration and stand treatment.

From an ecological point of view it seems reasonable to take advantage of the variation that exists. Cutting the most mature trees and leaving the middle-sized and smaller individuals for further growth is a treatment that has received increasing attention the last years. Clearcutting of small areas, adjusted to local conditions, is also an alternative. At lower locations and under less harsh conditions, the ecological restrictions on forest management do not need to be so strict.

MULTIPLE USE OF FOREST CLOSE TO THE TIMBERLINE

Many factors have brought the mountain forests more in focus the last years. Higher economic living conditions makes it easier for the population to spend more of their leisure time away from home. There has been an increasing interest in and understanding of the necessity for nature conservation among many people. There is an ever-increasing demand from nonforesters, and also from some professional foresters, that nature has to be treated with emphasis on ecology and multiple use.

The economical trend has for several years more favoured development of towns or town-related industry than forestry. The official policy in Norway now tries to encourage a higher level of activity and harvest in the forests away from the economic centers. It is expected that this will increase the logging activity also in the mountain forests. The technical development with more efficient equipment makes it easier and more profitable to carry out heavy cutting, like clearcutting in these regions.

Many individuals and organiztions in Norway dealing with nature conservation, recreation, wildlife and hunting fear that the economic income from timber harvest, partly state subsidies, will drastically increase the logging activity in the forests close to the timberline. These organizations have recently asked the government to reconsider the management policy for the high-altitude forests. To be sure, this is a complex matter. In addition to the factors mentioned above, rural policy is of great importance. As it is, many forest owners in mountain parishes do not have sufficient income from sources other than low-yielding agriculture and forestry.

Recreation and tourism are being launched as partial substitutes for the traditional primary industries. If these substitutes are to really be of economic relevance to the landowners, they have to bring income. To achieve this, the attitude to such new land-use systems has to be changed, among both many of the landowners and the receipients of these new benefits.

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RESTRICTIONS ON FOREST MANAGEMENT CLOSE TO TIMBER LINE IN FINLAND

Matti Leikola

ABSTRACT: Pessimistic views on the regeneration capacity of Scots pine near the northern timber line created the legislation on shelter forests in Finland in the 1910's and 1920's. In the Shelter Forest Area of Lapland all forest use is under state control. Also in the northern commercial forests the maximum size of the cutting areas has been restricted to 5 - 20 hectares. The conservative philosophy in forest management in the northernmost forests has proved to be successful even in modern times.

INTRODUCTION

The purpose of shelter forests, whose survival has been considered necessary for the local people and the existence of the forests themselves, is in northern Europe very old. In Sweden the first shelter forest areas were created in the 1840's and in old Imperial Russia the first Act on Shelter Forests was approved in 1888. The main intention was to protect forests that were situated near open sand dunes or steppes.

In Finland the first attempts to restrict forest utilization on ecologically vulnerable areas were made in the 1840's, but the efforts did not lead to concrete results. The Forestry Law of 1886 stated that

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forest was not to be "devastated open", but the supervision of the law was very superficial, especially in the northern parts of the country.

Only in 1900 the Committee on State Forests made the first serious effort to protect the northernmost forests. The committee proposed that the areas near the fjel region in the north: the parishes of Utsjoki, Inari, Enontekiö, and Kuollajärvi (Salla), as well as the north-eastern parts of Sodankylä should be separated as a special shelter forest area and be kept under state administration and supervision. The border line of the shelter area could be set to run "a few scores, perhaps 30 - 50 kilometres, below that line where the dense coniferous forests end". The committee also proposed a permanent expert group to be created in order to map, survey, and mark the area in the field.

THE PROPOSALS OF THE COMMITTEE ON SHELTER FORESTS

In 1907 a committee was appointed in order to make proposal on the shelter forest area of Lapland and the principles of forest protection and management in this area. The chairman of the committee was Chief Forestry Officer Wichman and the energetic secretary of the committee was Forestry Officer, later Professor, Olli Heikinheimo. In 1910 the more than 250 pagey thick report on the northernmost forests in Finland was published. The report also included the principles of forest management in these areas and a detailed proposal to establish a special shelter forest area near the timber line.

The committee vividly described the lavish use of forests by the Finnish settlers, the old habit to cut timber trees and smuggle them to Norwegian Finnmark, and the practice to cut large areas for reindeer husbandry or only because of neighbour hate or revenge. The detailed and well made report included proposals for acts on reindeer husbandry, settlement, and forest use in the shelter forest area. Two new shelter forest areas were proposed; those of Pallas-Ounas and Pyhä-Luosto fjel areas. Also the valleys of the rivers Kitka and Oulanka were proposed to be protected from all cuttings. These proposals were realized but 30-50 years later under the Law of Nature Conservation.

RESEARCH ACTIVITIES ON NORTHERNMOST PINE FORESTS BEGINS

The northernmost parts of the Fenno-Scandian peninsula had awakened the interest of Finnish naturalists already in the last century. The ecological conditions of the forests by the timber line were well known at the turn of the century even if the forestry points of view had not been considered very much. In 1890 A.O. Kairamo (Kihlman) had proposed his famous theory on timber line as a result of climatic conditions during the winter time, and Hult, Norrlin, Palmen, Sahlberg and Wainio, among others, had explored the northernmost forest and fjel areas collecting and studying plants and animals.

Even if the report of the committee on shelter forests was officially set aside, it aroused much interest on the northernmost forests of Lapland. The first academic dissertation on forestry sciences was published by A. Renvall in 1912. He had studied the regeneration capacity of the Scots pine stands near the Arctic timber line and he ended with a very pessimistic conclusion: good regeneration years occured on the timber line only once or twice in a century. Even in the more southern regions regeneration years were seldom, occuring only once in a decade. The need to create shelter forest area on the timber line was very urgent indeed!

Renvall published his further studies on the problems of Arctic shelter forests in 1919 as a 600-page long monography in six parts. In this he dealt with almost all aspects of the northernmost forests and forestry, analyzed deeply the philosophy of forest protection and finally made his own proposals to improve the situation: a new committee on shelter forests should be established and law on shelter forests should be made.

Renvall was the greatest Finnish authority of his time in the field of northern shelter forests, and his pessimistic views influenced decisively that the Law on Shelter Forests was approved in 1922. No shelter forest area was created in Lapland yet, but the National Board of Forestry began to take the general instructions of the Law into consideration in its own settlement policy and forest management.

After Renvall, three forestry researchers made one after another their academic dissertations on regeneration of the northernmost Scots pine forests. In 1915 O.J. Lakari confirmed that the general conditions at the timber line had stayed the same during the last 300-400 years and that Renvall's conclusions had been right. The general opinion on the slow and difficult natural regeneration of Scots pine in Finnish Lapland was confirmed by V. T. Aaltonen (1919) and I.K.D. Lassila (1920).

The research on the ecology and management of the forests near the timber line were not on permanent ground before the Finnish Forest Research Institute, with the leadership of Olli Heikinheimo, had established two large experimental parks near or beyond the timber line. In 1925 more than 17 000 ha of fjel and forest land at the Saariselkä area (Laanila) was tranferred to the Forest Research Institute and two years later the Forest Research Institute got 54 000 ha of barren tundra from Petsamo, near the Arctic Ocean, to serve as an experimental park for timber line studies.

THE SHELTER FOREST AREA OF LAPLAND IS FOUNDED

Interest in the Arctic shelter forest problems dimished in the 1930's when the climate turned warmer and made the general opinion more optimistic. May 4th, 1939, the Finnish government at last established the Shelter Forest Area of Lapland where all timber cutting, with the exception of taking away dry stems and twigs from the ground, was under the supervision of state forest officials. More detailed instructions were not given except general remarks on careful forest use and management. The shelter forest area was intended to be marked in the field immediately but the work was stopped by the outbreak of the Finnish-Soviet "Winter War" in 1939. Not until the 1970's was the task completed (Fig.1).

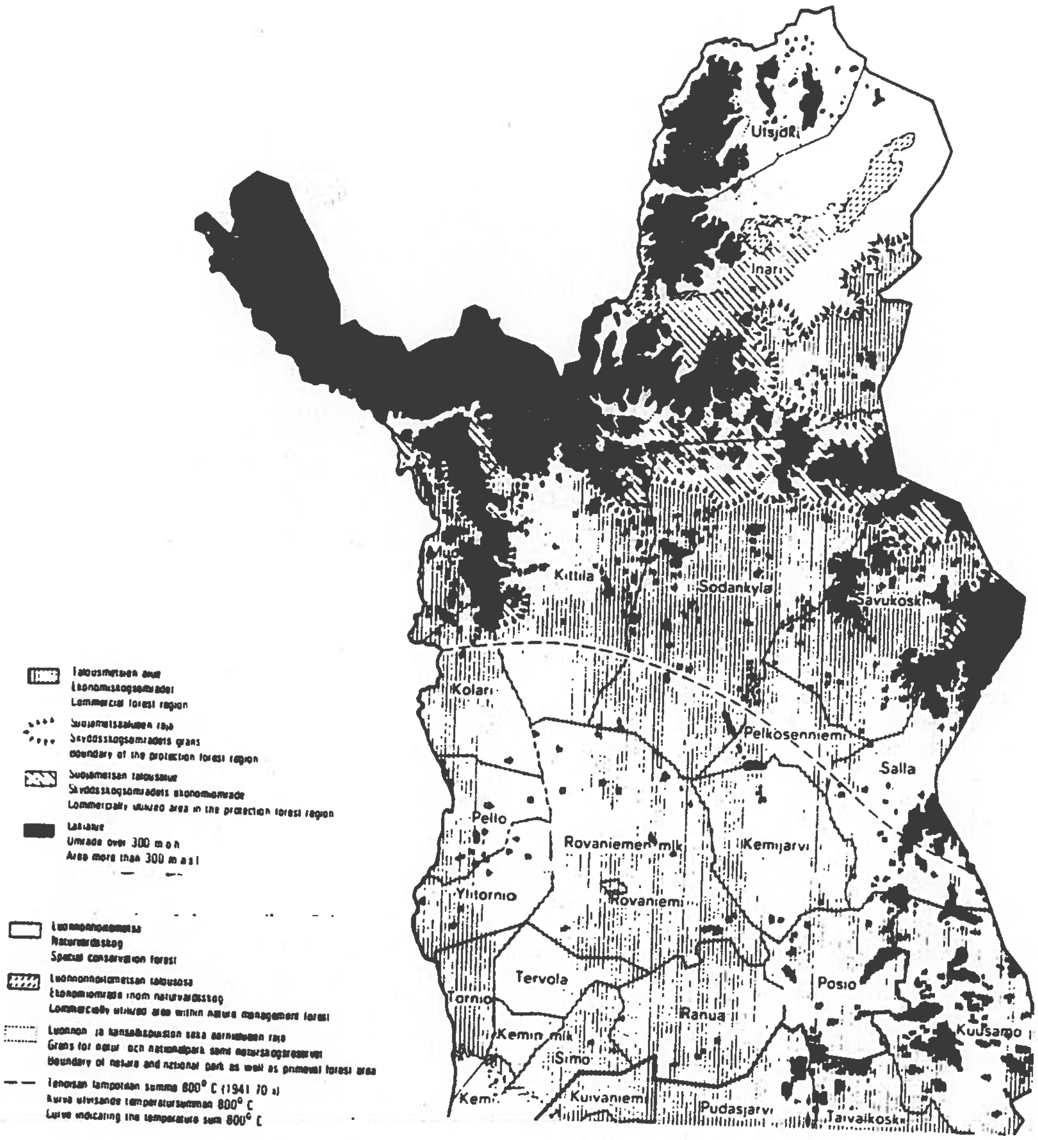
Discussion on the areal size of the Shelter Forest Area of Lapland did not come to an end immediately. When Hustich (1948) and Mikola (1952) had concluded that the northernmost Scots pine stands had regenerated better than was expected earlier, Siren (1960) proposed that the shelter area should be diminished towards the north. Later on the need for raw material of the saw mill and pulp industry of Lapland has created new interest in the Shelter Forest Area. Until now there has been no real reason to change the old regulations, at least since the more cool climatic period which started in the 1940's has made forest regeneration in whole Lapland more difficult and has required greater caution when working near the timber line (Leikola (edit.) 1979, Pohjois-Lapin... 1982).

GUIDELINES FOR SILVICULTURE AND FOREST MANAGEMENT AT THE SHELTER FOREST AREA OF LAPLAND

In 1961 the research group at the Finnish Forest Research Institute: E. Oinonen, R. Sarvas, and G. Sirén, compiled the instructions for silviculture in the forests near the timber line. These instructions have remained in force until now at the Shelter Forest Area of Lapland.

The Shelter Forest Area is no nature park, the researchers emphasize at first. Its purpose is to prevent the descending of the coniferous timber line. The border line of the Shelter Forest Area can be compared to a traffic sign. It is not essential whether the traffic sign is in exactly right place, but it is important that one knows how to act in the dangerous spot. The border line of the Shelter Forest Area is a kind of alarm line. In most cases the requirements of the harsh climate must be taken into consideration already before arriving to the shelter area.

In addition to the northern situation also the vicinity of the Arctic Ocean creates difficulties north of the line: Lemmenjoki river - Lake Inari - Paatsjoki river. According to research experiences 250 - 300 meters above sea level seems to be the cardinal height above which regeneration of pine forests is really difficult and growth slow. Further down no corresponding lines



<u>Fig. 1.</u>Land-use classes and various protection areas in northern Finland in 1975.(Atlas of Finland 234 "Forestry", 1976).

can be separated. In this respect the researchers agreed with the permanent instructions of the National Board of Forestry from the year 1956 and 1961. According to these the utmost limit for artificial forest regeneration and commercial (clear) cuttings should be 250 m. on southern (sunny side) slopes and 300 m. on northern slopes. Above this limit commercial forestry should be extended only by special permission.

According to the instructions the Shelter Forest Area was divided into two parts: upper forests and commercial forests, the height of 250 - 300 meters above sea level as a divider. In general, no cuttings are allowed in the upper forests. Only when there are enough vigorous Scots pine seedlings among the subarctic fjel birch, can they be liberated. Old pine stems can be cut from above dense and vigorous young stands. This can not take place sooner than the saplings have reached the size of 1 - 2 meters. If the forest is open or in bad condition it shall be regenerated naturally. The parent stand can not, however, be cut before the young seedling stand has well established. Stands should be kept more dense than in the south. That is why there is no reason to make thinnings with the exception of clearing advanced birch away. Thinnings - if they are done - should be from beneath.

THE MAXIMUM SIZE OF CUTTING AREAS IS RESTRICTED IN LAPLAND

At the beginning cutting areas did not have any clearly stated maximum size. The moderate size of the unmechanized logging work camps kept clear cut and seed tree areas small. At the same time as logging concentrations grew in size and logging and transportation of wood was mechanized, the size of the logging areas grew from tens of hectares to hundreds and at last to thousands of hectares.

Cold and unfavourable summers in the 1960's made the National Board of Forestry revise its cutting policy in Lapland. In 1969 new instructions were given according to which the maximum size of a cutting area that was not be exceeded was in the District of Perä-Pohjola (Lapland) 20 ha, in the District of Ostrobothnia 30 ha, and in the District of Southern Finland more than 50 ha. Cuttings were concentrated on mature Norway spruce stands where enough old Scots pines were to be found to serve as seed trees. The old strip felling system which had not been practiced in decades was again taken into use in Lapland. In the Shelter Forest Area of Lapland the instructions by Oinonen, Sarvas, and Siren were still used almost unaltered.

Before long the direct strip cuttings created more and more public criticism. Their amount began to diminish in the 1970's, and they were left out in 1977. In other respects, both in the state forests and in the private forests, the silvicultural principles became more conservative in the 70's.

The National Board of Forestry gave new instructions on afforestation and reforestation in 1978, and they were followed by separate instructions for all Districts in 1981 and 1985. The division of forest land into climatic regions was now made according to the average effective temperature sum (d.d.) of the place, which could be calculated when the geographic location and height above sea level were known. If clear cutting and seed tree method were used, the maximum sizes of the cutting areas were as follows:

Temperature sum, d.d.	Maximum size, hectares
over 800	30
800 - 700	30 - 20
700 - 650	20 - 10
under 650	under 10

Special silvicultural instructions were given to the commercial forestry area, north of the fjeld ridge Saariselkä, according to which the size of the cutting areas was even more cautious than in the other commercial forest areas in Lapland. The instructions by Oinonen, Sarvas, and Siren were still used in the Shelter Forest Area of Lapland, but clear maximum sizes of the cutting areas were now given also for this area. In the upper forests (more than 250 - 300 meters above sea level) outside Shelter Forest Area the maximum size of the cutting areas was only 5 hectares. In the corresponding areas that were inside the Shelter Forest Area, all clear cuttings as well as seed tree cuttings were prohibited with the exception of careful liberation of young forest.

DISCUSSION

Restrictions on the use of the northernmost forests in Lapland were created at a time when wood was needed for the domestic use of the local people only. It is to be concluded, however, that if protective measures had not been made so early, short sighted exploitive cuttings could have devastated the forests in the fjeld areas. Cautious attitude, which was based on pessimistic view on the regeneration possibilities of Scots pine in northernmost Lapland, created the present day shelter forest legislation in Finland. Even if our present day picture of forest regeneration on the Arctic timber line is more optimistic than sixty years ago there is no reason to abandon the line of silviculture which has proved successful so far, not to neglect the difficulties of the timber and pulp industry of Northern Finland (cf. Kuusela 1982, Kuusela & Salminen 1978).

The only cutting method that has been allowed in the vicinity of the timber line has been cautious selection of mature trees from above the young stand, even if the harvesting and transport technology of today permit far more drastic cuttings. Accordingly, even today 60 per cent of the forests in northernmost Lapland are older than 160 years (Mattila & Kujala 1980). Since these forests have even greater value in the future for tourism and multiple use, conservation of these forests aside from heavy cuttings has received public approval. Protection measures that were planned already more than eighty years ago have proved correct and valuable even in changed conditions.

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REFORESTATION EXPERIMENTS AT THE PINE TIMBERLINE IN NORTHERNMOST FINLAND

Gustaf Sirén

ABSTRACT: After a retrospect of reforestation efforts before 1950, the present-day experiments are reviewed. A Series of re- and afforestation pilot experiments initiated in 1951 along the road Kaamanen-Karigasniemi are demonstrated. Various site types at altitudes between 200-300 m.a.s.l. and north of the pine timberline were subjected to different reforestation measures. The influence of the solar activity cycle upon the recurrence of pine seed years is discussed.

INTRODUCTION

Research results from different disciplines indicate that climatic changes have caused both advances and retreats of the subartic and subalpine timberlines in the northern hemisphere. Compared to the present situation, the pine forests of the northernmost Finnish Lapland covered a much wider area during prehistoric as well as historic periods. In addition to the ecological causes, Man has contributed to the retreat of the forests. During the 18th and 19th centuries, the local population suffered from repeated famines to such an extent that people had to bake bark-bread and eke out their fishsoup with meal made of bast (phloem) of pine. Hundreds of thousands of young pine trees were thus used for the support of existence of the Lapps e.g. in the Utsjoki river valley. Today the missings of the consumed age-classes in the age-class histogramme can still be recognized and easily observed in the landscape.

The earliest reforestation measures were carried out along the river valleys of Neiden (1911-14) and Utsjoki (1930-39). At lower altitudes about 100 m.a.s.l. the patch-sowing of pine resulted in excellent stands, especially along the Näätämöjoki (Neiden-river). Storms, however, hade devastated a part of the stands of well shaped young pines since 1960. Along the Utsjoki river the altitude of the sown areas varied around 200 m.a.s.l. At high altitudes the results were usually poorer than at lower levels, with the exception of frost-exposed depressions. The most remarkable stands of sown pine can be seen on the west slope of the Petsikko mountain.

Since the beginning of the present century the climate in the North has improved considerably. Dr Ilmari Hustich was first to observe the tiny signs of change. After decades of no or only poor seed years pine seedlings appeared after the seed year 1937. Forestry people remained skeptical however. Not even new

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seed years in 1947-49 changed the pessimism. In 1951 I got the task to actively consider the problem of getting stable pine-seedling stands in the area between the tree-line and the present timberline.

INITIAL SITUATION

Within the tree line the landscape was characterized by large stands of mountain birch varying in density and height with scattered groups or single trees of pine. Because of fires and lack of pine seed trees and seed years large areas were covered entirely with birch. In these pseudo-tundra-areas artificial regeneration methods only seemed possible if a rapid change was wanted. Where pine trees were present a few seedlings from 1937 indicated that vegetation per se did not prevent the germination of seeds nor the stabilization of the seedlings. Old stands had usually emerged after wild fires. The trophic conditions of the moraine or sandy mineral soil was generally well reflected by the species composition and fysiognomy of the vegetation. The best soils were usually covered with a thick raw-humus layer under canopies dominated by birch. Because of a very sparse network of meteorological stations before the war only extrapolations based on data from the Ivalo station (90±10 km to SE) were available for the compilation of climatic series. The growing season seemed short, cold and humid. Later collected data are in short: Mean length of growth period: 116 days, mean summer temperature: 11.4 xC, mean annual precipitation: 386 mm/year and mean evapotranspiration is so far unknown. Coarse-sandy soils could now and then be very dry, while the bogs remained wet through the summers.

THE PILOT EXPERIMENTS

Because of the expected low productivity of the future pine forest, only cheap methods of re- or afforestation could be subjected to large scale experiments of pilot character. The first thing to find out was the efficiency of prescribed burning on the extremes of vegetation and humus. For the purpose two sites were selected: A fresh site of Hylocomium-Myrtillus-type (HMT) covered mainly by mountain birch + a few groups of pine (area I) and a dry heath land (ErCl-T) with scattered fullgrown pines plus birch and only a few young pines or seedlings (area III). In both cases 50 % of the plots were burned in such a way that the seed trees left remained undamaged. The lay-out of the area I from 1951-53 is given in figur 1 and that or area III in figur 8.

After the relevant canopy treatments having been carried out, the entire area I was planted in 1951 with pine using a standard method. In spring 1952 an almost complete failure was noticed. A controlled burning-over was implemented in summer 1952. In spring 1953 both burned plots as well as control plots were sown with pine seeds of Lapland-origin. Inventories of the seedling stands have been carried out 1956, 1967 and 1986. On each 100 m2 circular sample plot the treatment, presence of seed-trees and altitude m.a.s.l. were noticed. The most important variables were number of healthy and damaged plants, dominant plant height, number of birch bunches and coverage of herbs, grasses, dwarfshrubs, mosses and lichens. The data was processed at the Finnish Forest Research Institute by Jouni Ristioja.

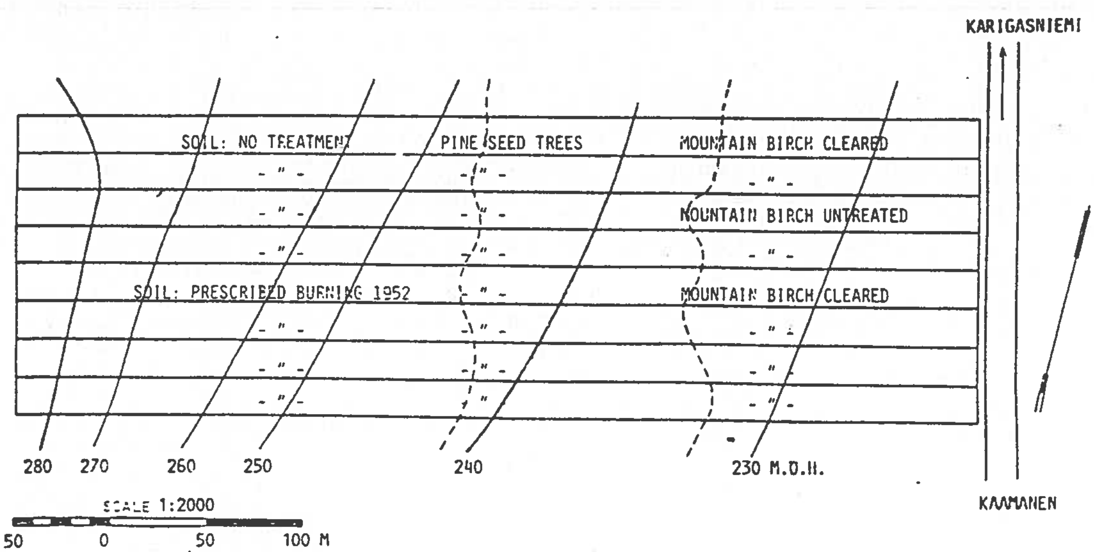

FIGURE 1. LAY-OUT OF PILOT EXPT-AREA I HYLOCOMIUM MYRTILLUS (SIEIDEVAARE)

The preparatory cut for regeneration experiment III on dry ErCl-T was carried out 1958. The number of seed trees per hectare was regulated to 15, 25, 35 and 55 stems per hectare respectively of the plots to be treated. The controlled burning destroyed the few seedlings from 1937 and 1949, the dwarf-shrubs and the rather compact cover of lichens. A seed year appeared 1961-62. A 25 % line survey of the seedling stands using 100 m2 circular sample plots was carried out 1986. The variables measured were number and height of healthy, damaged and dead plants, number of birch bunches and the dominant height of the healthy pine plants.

During the first visit to the Kaamanan area in early spring 1951 a dense pine seedling regrowth of 1-2 years age was observed under a medium dense birch-canopy with a few scattered pines of considerable age. This initial situation invited to ponder upon problems of the following type:

- What to do with the mountain-birch considering the risk of heavy litter-fall in the autumn? Or the frost-risk?

- Were the seed trees anymore necessary? If left untouched what was the immediate consequence for the existing 1-2 yr old regrowth? After 25 years?

- What to do with the plantless patches under the canopy of the birch-bunches?

A four hectare large demonstration area (experiment II) was established in summer 1951 with the following treatments:

a) clear cut
b) pines removed, birch thinned to 1-2 stems per bunch
c) pines removed, birch left untouched
d) no measures, control

During 1957-67 an ecological station was in function in area II. Vertical temperature variation, precipitation, evaporation, wind velocity and growth of seedlings were measured on all plots (size 1.0 ha). Inventories of the stands were carried out 1957, 1967 and 1986. At the last inventory the variables of interest were stem number, stemdiameter at 1.3 m, height of trees, bark thickness, radial growth taper of pine, the projection area of the birch bunches as well as the mensuration variables of the birch. Basal area, mean and dominant height, volume, annual growth etc were calculated using the standard programmes of the Finnish Forestry Research Institute.

The artificial regeneration experiments, including some large regular field experiments on the influence of the altitude will not be subjected to any deep-sounding discussion. The main results will be given in general terms only.

RESULTS

Regeneration of a birch-pine stand
Area I (Sieidevarre) HMT

On the pilot experimental-area I, natural regeneration was compared to patch sowing. The soil cover and stand treatments were respectively:

- prescribed burning of soil and control,
- clearing of mountain birch alternatively no clearing at all,
- natural seeding from seed trees versus artificial seeding.

The lay-out is shown in figure 1. The plot size is 20 x 500 m2 exposed to NE. The altitude increased from 225 to 285 m.a.s.l. The main results of the inventory can be seen in figures 2 and 3.

The conclusions of the reforestation pilot experiment in area I on fresh HMT are in short:

- Compared with the untreated control plots prescribed burning has improved the ecological conditions of the soil sufrace in a most positive way for natural as well as artificial regeneration.

- Plant number after natural seeding is significantly higher than after artificial seeding, although number of 0-patches is surprisingly low on burned surface (10 % only).

- In unburned plots, clearing of the mountain-birch has improved the conditions of establishment of the germinating seeds very little when compared with the totally untreated control plots.

- The height-growth of the plants has been best on burned plots and poorest on control plots (figure 3).

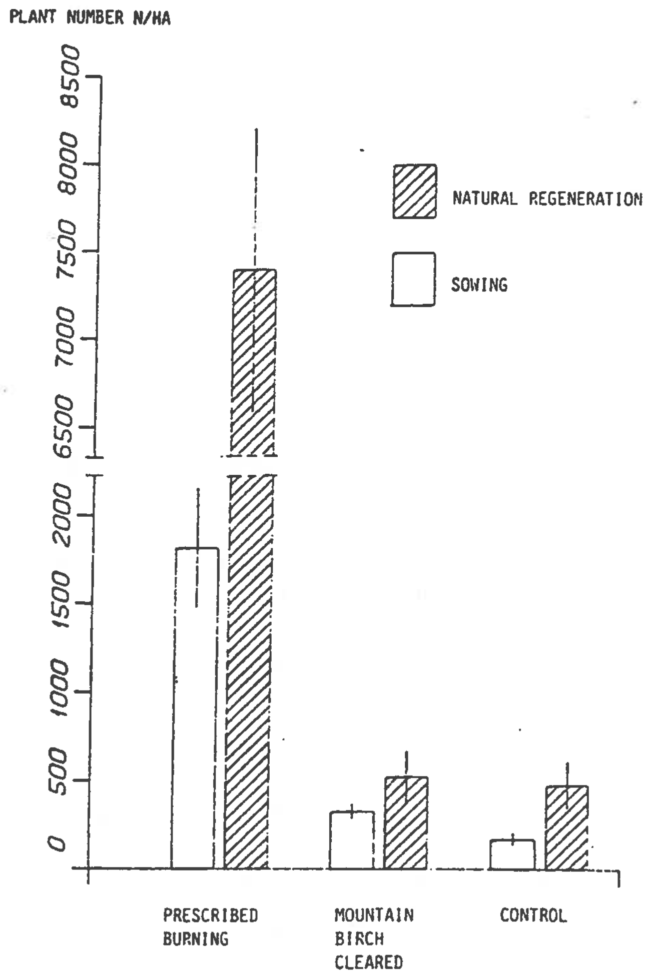

FIGURE 2: PLANT NUMBER DEPENDENCE OF REGENERATION METHOD AND SOIL TREATMENT

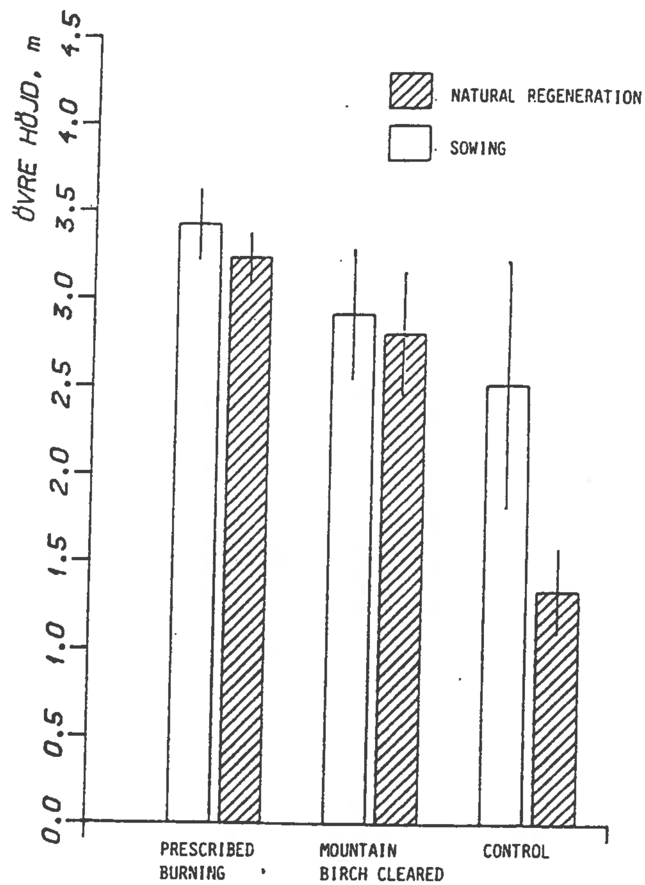

FIGURE 3. INFLUENCE OF REGENERATION METHOD ON THE DOMINANT HEIGHT (H_{100})

- The height difference between plants originating from sown seeds of N. Lapland provenance and plants of local origin despite the age difference is small (except on the control, where it is still significant).

- The effect of altitude appears from the function y=a+bx, where y=number of plants per 100 m2
  (=circular plot)
  x=altitude, meter a.s.l.
  l=a constant
  b=angle of inclination

The data available gave the function the form of y = 60.5 - 0.20x. If the plots of lowest part of the slope are excluded because of their badly burned humus layer the equation gets the form y=107-0.357x. At an altitude of 300 m.a.s.l. the plant number is 0.

In addition to this it can be reported that the mean height of plants is significantly higher in the altitude 225-260 than above 260 m. Under the canopy of bunches of birch the number of pine plants is extremely low, whereas the number under pine seed trees is rather high, but the plant height low.

Because of the geography of the excursion-route the other part of this pilot experiment (Area III) illustrating the effect of prescribed burning will be demonstrated at the third stop.

<u>Care-taking of pine re-growth</u>
Area II (Jäkälämorosto) ErClT

The lay-out of the demonstration expt is shown in figure 4. The main purpose was to obtain empirical experience of this cheap type of natural regeneration of pine. In the region there are tens of thousands hectares of mountain-birch stands with a few interspersed pines of seed tree character.

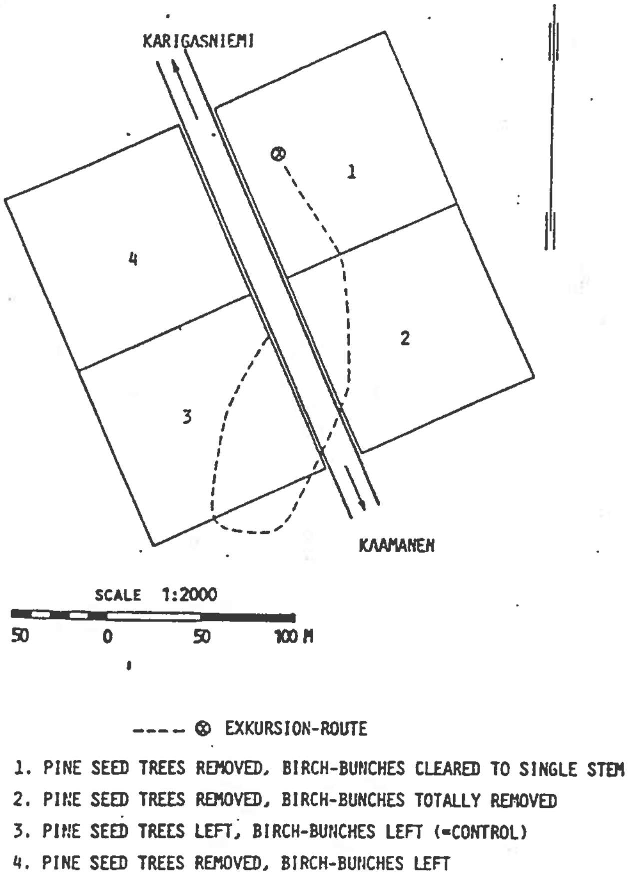

FIGURE 4. ALTERNATE REGENERATION MEASURES IN THE DEMONSTRATION AREA II (JÄKÄLÄMOROSTO)

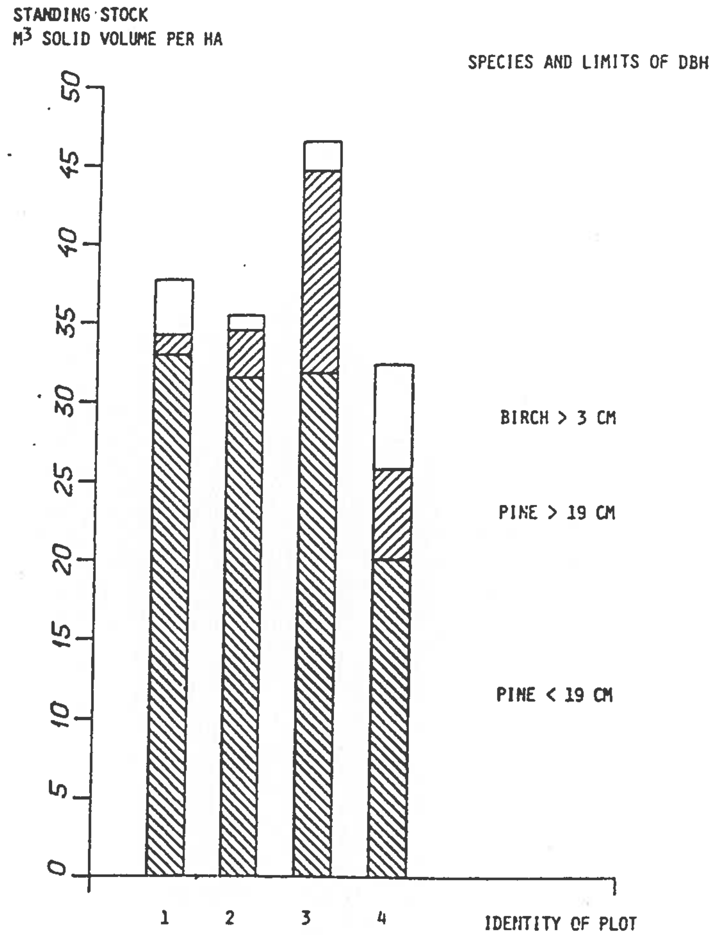

FIGURE 5. PRESENT STANDING STOCK

The 25 % line-survey using circular sample plots concentrated on measuring the standing stock, the current growth and the influence of the birch bunches upon the development of the pine stand. The inventory was carried out in early June 1986, which means that the present standing stock refers to the situation 1985. The main result is shown in figure 5.

The figure reveals the present (1985) distribution of species and diameter at 1.3 m. In fact the distribution also depicts the age class distribution of pine quite well too. Almost all of the birches are suckers from 1951 or from later dates. The main part of the pine stand is from the seed year 1949 (<19 cm) while a considerable part of the standing stock of sample plot 3 originates from seed year (>19 cm). The remaining trees (>19 cm) are from about 1860.

According to the definition of low productive forest land, the limit has been set at a mean growth of 1.0 m3 solid volum per hectare and year. At present the 36 year old part of the standing stock of pine has reached a level of 32-33 m3 solid volume in the sample plots 1-3. Including the volume of both the mountain birch and a correctly reduced share of the older pine stand constituents the question arises whether the site of the experiment II still is representative for low-productive land. The current annual growth volume (about 2.5 m3 s.v.ha-1.yr-1) indicates that an upward adjustment of the land use class may be justified soon - if the climate does not deteriorate rapidly too much (cf. fig 6).

The fourth sample plot has a stem number about 40 % lower than that of the other three plots 1-3. Mainly therefore, the annual growth is as low as 1.7 m3 solid volume per hectare only.

Assuming an annual macroclimate more or less similar to that of the 1980'ies, the standing stock would increase to some 46 m3/ha at an age of 40-41 years. Even considering the present variation between the plots it seems obvious that the mean annual increment will most probably exceed the upper limit of wood productivity for lowproductive land already at 1990.

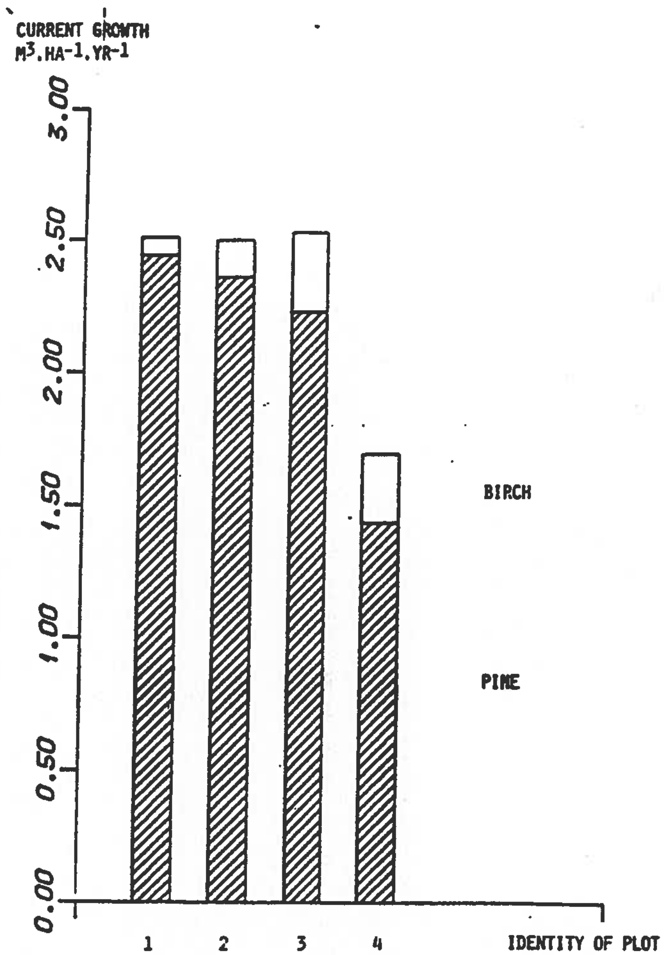

FIGURE 6. CURRENT GROWTH OF THE DEMONSTRATION STANDS

In best case this upward adjustment of the land use class would theoretically imply the possibility of an increase of the productive forest land with a total of some 0.4 million hectares. However the corresponding annual addition to the total annual growth of the forests of Finland would be of the magnitude of less than 1 %.

It must be recognized in this context that the northward pushed timberline forests will still be managed according to the law of the protection forests.

<u>Prescribed burning for natural regeneration</u>
Area III (Roavvetsobma) ErCl-T

The pilot experiment I at Sieidevarre revealed from the very beginning the superiority of wisely used fire as an efficient tool in the efforts for obtaining successful reforestation results on a fresh site type. However, there are many considerations to be observed for avoiding mishaps - especially when burning for improved germination and seedling stabilization conditions for natural regeneration under a canopy of pine seed trees on dry sites. According to special studies (Sirén 1973) an acceptable outcome of slash burning under seed trees depends besides the weather of weeks passed mainly upon the height of canopy above the ground, the calorific value or amount of the slash under the trees, the groundcover and the humus to be burned as well as upon the undergrowth canopy of tall shrubs, supressed trees and plants which usually have a damping down effect on the fire and finally on the solar radiation as well as wind conditions the afternoon, when the fire is set (cf. table 1 and figure 7).

Table 1. Regression functions for needle damage percentage pending upon x_1 = tree height, x_2 = slash amount and x_3 = standing brush under different conditions and at different hours of the day.

Time	T°C	R%	W m/sek	Functions
17-20	16	29	0-2	$X_0 = 18{,}48 - 1{,}50^{**}\ x_1 + 2{,}94^{**}\ x_2 - 0{,}50^{**}\ x_3$
15-17	18	27	2-6	$X_0 = 49{,}40 - 2{,}88^{***}\ x_1 + 2{,}80^{**}\ x_2 - 2{,}93^{***}\ x_3$
14-15	21.5	27	5-8	$X_0 = 75{,}70 - 3{,}30^{***}\ x_1 + 6{,}38^{***}\ x_2 - 1{,}38^{**}\ x_3$
13-14	21.0	29	3-5	$X_0 = 99{,}22 - 3{,}36^{***}\ x_1 + 4{,}76^{***}\ x_2 - 0{,}92^{*}\ x_3$

The clearing of slash around the seed trees is a categoric imperative for saving the cambium from damages. In this case the cleared area had a radius of 5 m.

Time	Functions	Lower limit of crown, m (damage = 0%)
17-20	$x_0 = 22{,}1 - 2{,}09^{**}\ x_1$	10,6 m
15-17	$x_0 = 43{,}2 - 4{,}14^{***} x_1$	10,4
14-15	$x_0 = 94{,}3 - 7{,}03^{***} x_1$	13,5
13-14	$x_0 = 99{,}0 - 3{,}28^{**}\ x_1$	30,4

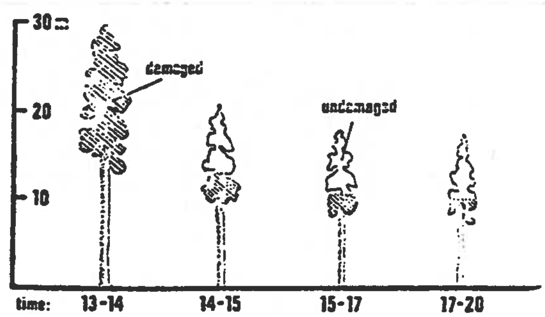

FIGURE 7. REGRESSION FUNCTIONS FOR LOWER LIMIT OF UNDAMAGED NEEDLES OF SEED TREES SUBJECTED TO PRESCRIBED BURNING UNDER CONDITIONS GIVEN IN TABLE 1 (SIREN 197

The use of fire on dry as well as dryish sites has often been subjected to critical debate among biologists, foresters etc (Uggla 1967). The finding of the antagonistic influence of lichen on the germination process of pine-seed (Oinonen pers comm 1955, Brown & Mikola 1974) finally persuaded about the advantages, provided that the thin humuslayer of dry sites was'nt too heavily burned. To this end a simple practical method was developed.

In order to demonstrate the differences between natural regeneration in an undisturbed cover of lichens and a carefully planned prescribed burning a light surface fire was applied on 50 % of the seed tree area. In addition to this - for elucidating the problem of the sufficient number of seed trees per hectare, the efficient coverage of the pine trees left on the experimental plots was arranged as appears from figure 8. No regulations regarding seed tree number were carried out in the control plots.

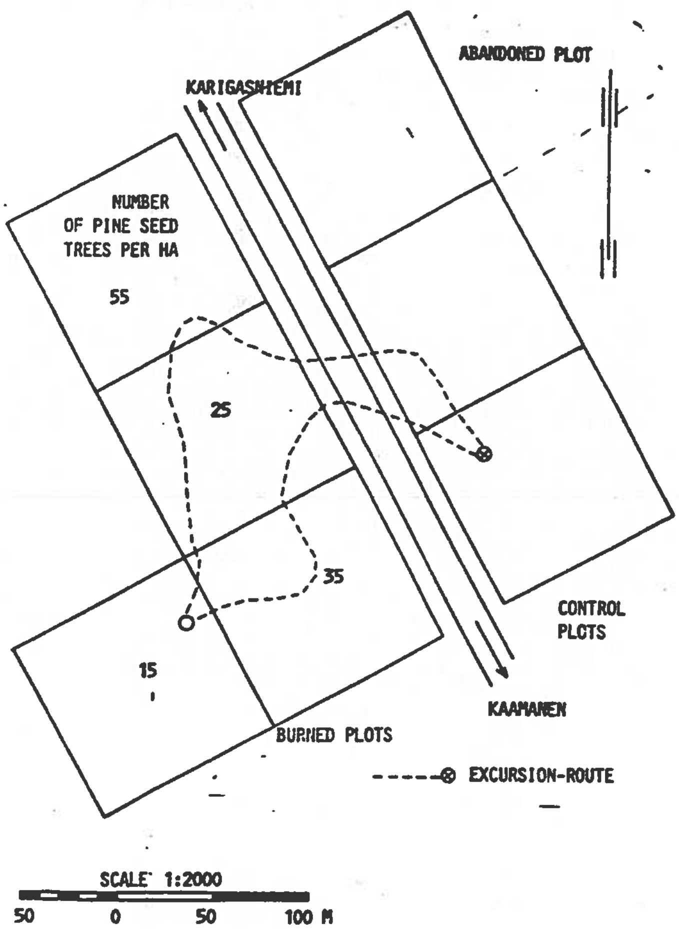

FIGURE 8. LAY-OUT OF DEMONSTRATION EXPERIMENT AREA III

The prescribed burning was carried out in summer 1959. The summers of 1959, 1960, 1961 were warm enough to produce an excellent cone year 1961. The present-day plants are from the seed year 1961-62, although some seedlings from 1972-73 do exist. One seedling only from the year 1984 was detected just outside the area III.

The seedlings and plants from 1937 and 1949 were removed as well as possible from the control plots in 1959 in order to obtain a good comparability regarding the regeneration process in all parts of the experiment. The results of this experiment are given in figures 9-11 and table 2.

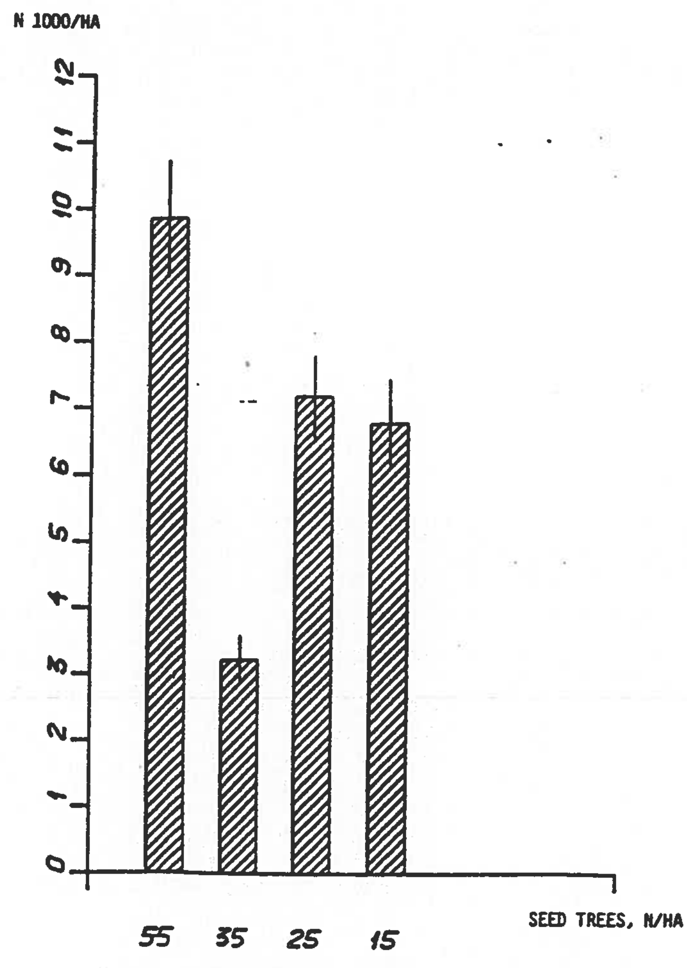

FIGURE 9. PLANT NUMBER AS FUNCTION OF NUMBER OF SEED TREES ON DRY HEATHLAND (ERCLT) AT THE TIMBERLINE IN NORTHERNMOST FINLAND

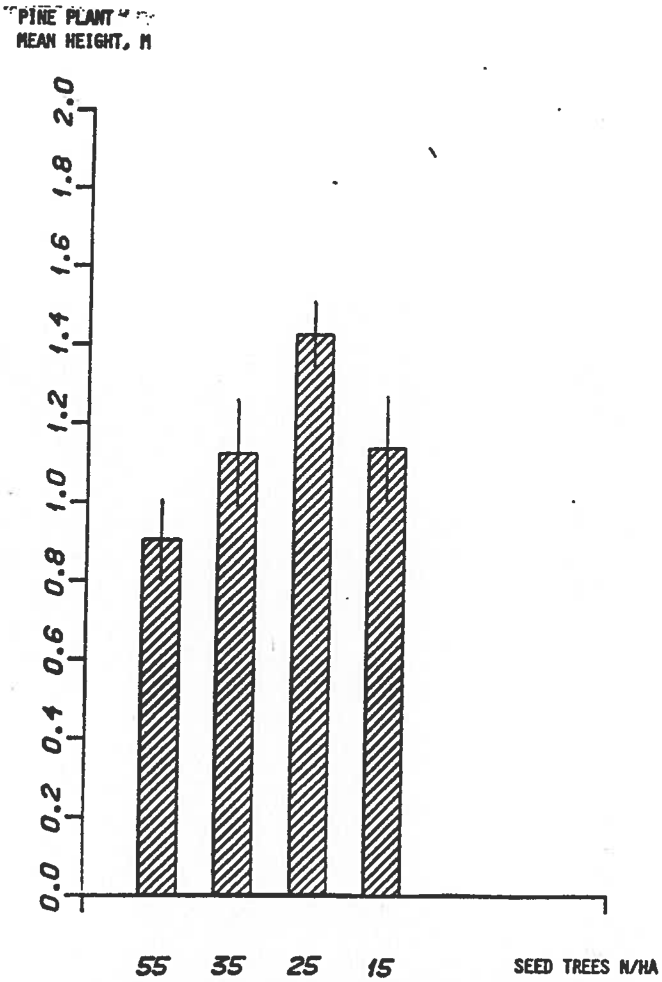

FIGURE 10. MEAN HEIGHT OF PLANTS AS A FUNCTION OF SEED TREE NUMBER PER HECTARE. THE BAR AT THE TOP INDICATES THE STANDARD DEVIATION.

According to observations made on empty cones and number of seedlings in 1966 the seeding capacity of the seed trees has been quite extraordinary in the expt-area III. However, 11-12 years later (1977-78) snow blight was observed especially in the seedling stand of the sample plot 35 seed trees/Ha. Still visible signs of camping fires and ski-tracks explain additional losses after 1980 in the same plot (closest to the gate in the snow-fence).

The most important results have reference to the differences between the treatments in the number, vitality, height and homogeneity of the seedling stands. The answer to the problem on effect of treatment has been obtained as a result of a test according to Tukey based on an analysis of variance.

The differences proved a good confidence at a level of 99 %

Treatments	No treatment	Prescribed burning
Mean number of plants, N.Ha-1	3008	6694
Number of observations	150	196

The prescribed burning of the slash and ground cover has resulted in more than twice as many plants than leaving the lichen-dominated ground cover untreated. A closer look on the variation between the four different seed tree plots reveals two interrelated results. With the exception of the 35 seed tree plot the variation of the number of plants (cf. figure 9) seems logical and in good agreement with results obtained from pine forests to south of the timberline (Sirén 1966). This applies to the mean height of living plants too (figure 10). Due to the growth reducing effect of the seed trees upon the nearest seedlings (cf. figure 11) the great number of supressed seedlings still alive on the 55 seed tree plot has its bearing on the mean height. At present the optimum number of seed trees seems to be about 25 individuals per hectare. Considering the low risk of wild fires in seedling stands established after prescribed burning, it seems possible to remove the seed trees at an early date for promoting the structure of the future stand.

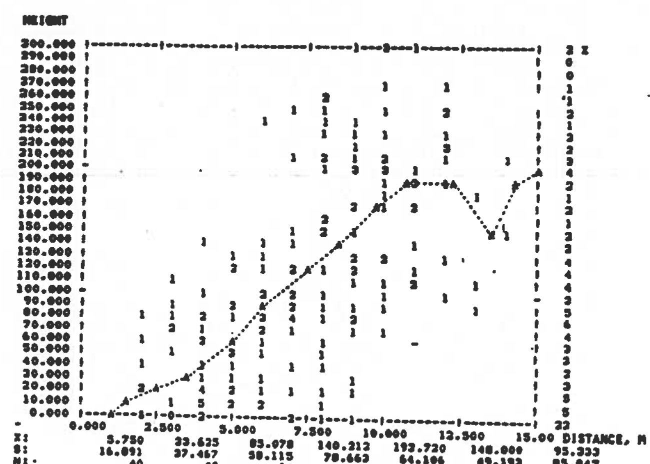

FIGURE 11. PLANT HEIGHT DEPENDENCE OF DISTANCE TO NEAREST SEED TREE

The homogeneity of the stand is of great importance considering the volume production. The longer the seed trees are overheld the greater the variation in height will develop. Close to the experiment area II openings with a radius exceeding 12 m are frequent around the oldest seed trees.

Table 2. Analysis of variance of dominant height of plants indicating the effect of prescribed burning

Source of variation	Sum	Degrees of freedom	Square sum	F-value	Probability
Between treatments	71603.63	6	11933.938	4.91 ***	99.963 %
Within treatments	148288.63	61	2430.96		
Total	219892.25	67	3281.97		

Significant differences (Tykeys test)

Plots compared		Mean values		SD	W	Diff.	Signif.
1	2	143.200	206.000	15.59	60.950	62.800	o
2	3	206.000	134.900	15.59	67.181	71.100	*
2	5	206.000	96.000	15.59	79.953	110.000	**
2	6	206.000	115.556	16.02	82.144	90.444	**

The comparison of mean and dominant height of the two treatments reveals that the difference between mean heights is far less than between dominant heights i.e. the 2000 highest trees per hectare. The averages of the above differences are 14.4 cm and 40.5 cm respectively in favour of the plants of the burned area. A closer view of the test result of the dominant height differences is shown in table 2. The difference between the compared treatments is highly significant. However, Tukey's test indicates that comparison between the individual plots has resulted in a slightly more complicated picture.

OTHER EXPERIENCES OF REFORESTATION

In total ten rather large experiments were laid out between 1951 and 1964. In addition to the results reported above, some interesting experiences has been gained from the rest of the field experiments. The conclusions today are in many cases different from those presented at the Unesco excursion in 1965. From practical point of view the most useful experiences are as follows:

- natural regeneration is - in addition to use of fire - promoted by a light 2-5 cm deep scarification of the soil surface of dry and dryish sites. This method will save the lichens, important for the reindeer-husbandry. The reindeer-pasture in wintertime will on the other hand reduce the chance of survival of the seedlings. - Fire used correctly from the ecological point of view has promoted the germination of seeds and stabilization of the seedlings everywhere on firm land (see figure 12). Slopes with instable surface should not be sown.

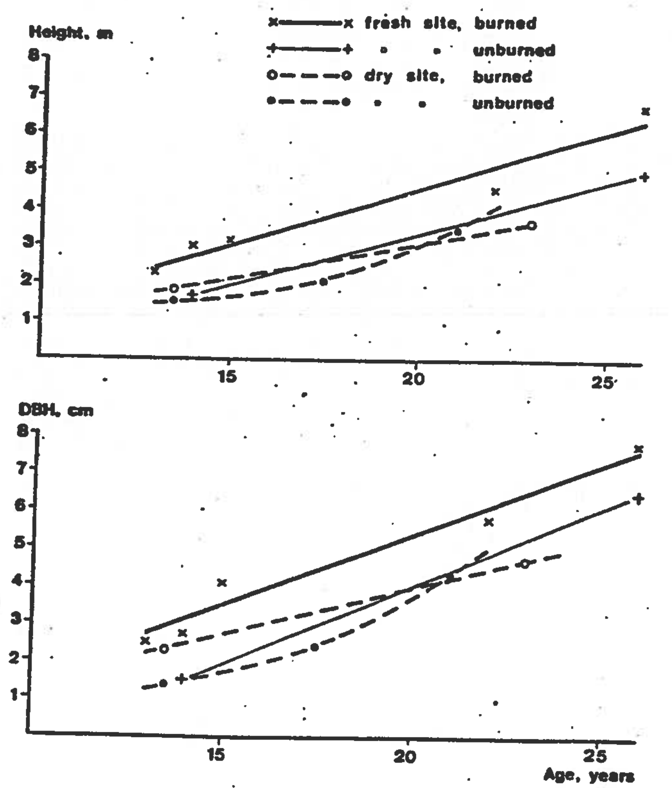

FIGURE 12. PERFORMANCE OF PINE SEEDLING STANDS ESTABLISHED DURING THE PERIOD OF 1948-59 IN SOUTHERN AND CENTRAL LAPLAND ON BURNED AND UNBURNED CLEAR CUT AREAS. THE MATERIAL CONSISTS OF SOME 80 SOWING AREAS.

- sowing as well as planting with small to tall rooted plants or bare-root plants has failed where standard patches have been prepared on fresh sites with a thick humus cover.

- on dry sites sowing has proved safer than planting, provided that leaf fall of birch has not covered the seedfurrows. Deep ploughing on sandy soil is expensive and totally useless. Above 280 m.a.s.l. all artificial afforestation efforts failed, above 260 m the result was unsatisfactory.

- of the planting methods and choices of plant materials, the tall pine plant (1+1 yr) in a large pot (>6 cm) planted on dryish sites with modern hand planting tools gave the highest survival. Expensive.

- in the humid conditions of the far North the planting depth of potted plants may vary - for survival - from two thirds of the pot height to a deep burial up to the first whirl of lateral shoots. Carelessly planted rooted plants will frequently survive but will later on succumb by instability. Planting in springtime has resulted in the highest survival.

- provenance tests have confirmed the superiority of the local pine provenances.

- the use of the mountain birch as a frost shelter seems justifiable in frost-hallows only. On slopes where sowing of pine will be used the birch storey must be removed before sowing for saving the seed from lethal burial. Experiments on reduction of sprouting have failed because of clearings for construction of electric lines just over and along the row of exptal plots. The mountain birch is an excellent fuel.

THE SEED YEAR PROBLEM

A well known fact is that the temperature is the most important ecological growth regulating factor at the northern timberline. From pine tree ring series it has been possible to track the variation of ring width. A few years of wide rings often coincide with the time of regeneration of pine (Sirén 1961). Since 1937 there has been good cone-years in 1947-49, 1961-62, 1972-73 and 1983-84. Usually these years have been preceded by 2-3 years with favourable temperature conditions. This phenomenon coincides more of less clearly with the solar activities, which varies with the same intervals of time (in average 11-12 years) as the cone years of pine. The efficient seed years do not vary with the same regularity. According to the available information on the volcanic activity the solar radiation has now and then been intercepted by volcanic dust, cloudiness etc just a year or two before the maximum period of solar activity. The consequence of this interception has so far been a temporary summer cool spell lasting for a couple of years. Thus energy requiring processes such as the development of the primordials of flowers, the flowering itself, the conception, cone and seed development, and finally the ripening of the seed have been prevented.

The connection between the solar activity cycle and the recurrence of the cone years at the northern timberline seems evident nowadays - as well as the disturbances of the seed years caused by the eruptions of the volcanos. Of the vast literature in the matter the works of Budyko 1974, Pohtila 1980, Lindblad 1980, Swedish Society of Physics 1980 and Bolin et al 1986 are of great interest.

SUMMARY

The practical consequences of the experiments carried out and of the above solar activity phenomenons are in short as follows:

- the ongoing improvement of the temperature climate in the far North has resulted in rather regular recurrence of cone years of pine since 1937 coinciding well with the maximum activity of the solar cycle. The warm spells create also conditions for application of prescribed burning as a succesful soil treatment method.

- natural regeneration of pine has been good in the years of 1937 and 1973 and excellent in the years 1947-1949 and 1961-62 provided that soil surface conditions have been favourable enough. Prescribed burning under seed tree stands have resulted in vital pine seedling stands. Seed trees have been removed from 2-year old seedling stand without fatal consequences for the young plants on dry site types.

- sowing has been a more reliable regeneration method than planting. For avoiding losses of developing 1-2 year seedlings the litter of birch leaves must be reduced to a necessary extent.

- planting of pine is seldom recommendable even on rather open birch-covered dryish or fresh sites; only after prescribed burning of the humus to a reduced thickness acceptable results have been obtained with tall potted plants of local origin.
- because of the long seed year interval natural regeneration should be promoted by applying prescribed burning over areas corresponding to the planned reforestation activities of at least 3-4 years. Local seed should be collected when abundantly available and used for sowing dry and/or dryish sites where soil preparation is unnecessary or sufficiently cheap during the seedless years.

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COMPETITION CONTROL WITH PRONONE (GRANULAR HEXAZINONE) APPLIED IN WINTER

F.W. von Althen, J.E. Wood and R.A. Campbell

Competition from herbaceous weeds and grasses is a serious problem in the reforestation of boreal mixedwood cutovers. The virgin stands of this forest type consist mainly of white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.). The soils are characterized by an organic layer, less than 30 cm deep, over well drained to moderately well drained, stone-free, fine loamy clays or silt loams. The most common method of site preparation is shearblading in winter. It consists of the removal of slash and stumps by bulldozer blade in corridors 4 m wide alternating with windrows of debris of the same width.

To determine the feasibility of winter application of herbicide, its effectiveness in competition control, and its effect on crop tree survival and growth, Pronone 5G and 10G (5 % and 10 % a.i.) was applied at 2 and 4 kg a.i./ha in February 1985 in shearbladed corridors. Black spruce 1½ + 1½ transplants and seedlings in FH508 Japanese paperpots were planted in June 1985 and 1½ + 1½ transplants and seedlings in FH408 paperpots were planted in July 1985.

Application of Pronone at both rates greatly reduced the density and vigor of the herbacous competition and had no phytotoxic effects on the planted spruce. After two growing seasons survival was 96 % or better for all planting stock except the FH408 paperpot seedlings planted in July in plots treated with 4 kg a.i./ha of Pronone 10G.

Second-year height increment of both stock types was significantly higher in the Pronone-treated plots than in the controls. The highest increment always occurred in the plots treated with 4 kg a.i./ha of Pronone. Season of planting had no effect on the height increment of the seedlings planted in paperpots, but summer planting greatly reduced the height increment of the transplants.

FIELD GUIDE TO FOREST ECOSYSTEMS OF WEST-CENTRAL ALBERTA

I.G.W. Corns

A forest-ecosystem classification for a west-central Alberta study area was designed using vegetation, soil, and forest productivity information to describe 30 ecosystem associations. Management interpretations were made for harvest season and method; site preparation intensity; soil compaction, puddling, and erosion; reforestation species, method, and limitations; frost heave; type and severity of vegetational competition; windthrow; snowshoe hare damage; and potential site productivity in site index and mean annual increment. Color photos and drawings are presented for 80 common forest plants.

THE LARCH AND THE OTHERS - A COMPARISON

Max. Hagman

Larch has been suggested as an alternative to native tree species in hard northern conditions.

Here are given some results from comparative species trials where larch has been compared to Scots pine and Norway spruce as well as to other exotics such as Lodgepole pine, White and Black spruce.

Survival is reported from 3 experimental series (373, 555 and 558) up to an age of 17 years.

In the oldest experiment 373 the survival of the Siberian larch, 40,8 %, is slighty better than that of Scots pine, 37,6 %. The best larch provenance has a survival value of 49,6 % and the best pine 52,7 %. The survival of the best origin of Lodgepole pine is 52,2 %.

In the younger trial 558 the survival percentages for Siberian larch and for Scots pine are 52,9 % and 56,1 % respectively. Lodgepole pine from Yukon has survived 74,0 % and Black spruce 73,0 %. Local Norway spruce has a survival of 73,5 %.

In the trial 555 there is only one origin of Tamarack with a survival of 39,0 % to be compared with Scots pine 33,1 %, Norway spruce 67,5 %, White spruce 41,8 % and Lodgepole pine 48,3 %.

Mean heights are reported from the same experiments.

In the trial 373 the mean for Siberian larch is 3,0 m, for Scots pine 3,1 m and for Lodgepole pine 3,4 m.

In the trial 558 the mean height of the best larch is 1,4 m and the best Scots pine 1,6 m. The best Lodgepole pine is 1,9 m and the best Norway spruce is 0,9 m. A Black spruce origin from Yukon has the good height of 1,2 m.

In the trial 555 the Tamarack has reached 1,6 m, the best pine 1,5 m and the best Lodgepole pine 1,8 m. Norway spruce and White spruce have both reached 0,9 m.

CONCLUSIONS

The promised superiority of larch is not obvious in these experiments. Great care should be taken to match species and site conditions. The importance of the right origin and provenance must be stressed. It is too early to make prognoses about total yield.
Further trials are needed with northern origins of Siberian and Dahurian larch, Tamarack, Black spruce and Alpine fir.

THE INFLUENCE FROM SCARIFICATION UPON THE INWINTERING PROCESS IN PINE

Mats Hagner

In Northern Sweden ten year old pine, planted in plowed tilts and in furrows after disc trenching, were studied. Tree heights were 1.4 m, 1.1 m respectively. The degree of inwintering was estimated using the bark colour of the terminal (August) and the colour and shape of the needle base (August).

In both scarification methods the smaller trees showed a higher degree of inwintering than the taller. In a multiple regression analysis the result showed that the genotype and the environment seemed to have an equally great impact upon the inwintering process. This indicates that the increased growth obtained by plowing delays the hardening off. This may be one reason to the large mortality among trees in the plowed plots.

The results are somewhat uncertain and the investigation should be repeated.

ESTABLISHMENT OF PINUS CONTORTA WITH FOUR SITE PREPARATION TREATMENTS ON FOUR SITES IN JÄMTLAND

James Hunt

Swedish University of Agricultural Sciences, Department of Silviculture. M. Sc. Thesis.

Establishment of Pinus contorta with 4 site preparation treatments on 4 sites in Jämtland.

INTRODUCTION

This work summarizes inventory results of the establishment phase of the project, "the future productivity of site preparation". The project aims to investigate the influence of site preparation methods on sites' long term productive capacity. Joint short term studies by a number of departments at the Swedish University of Agricultural Sciences and Umeå University (*) include seedling survival, growth and damage in relation to soil temperature, moisture and morphology as well as the breakdown of organic material and the availability of stored nutrients within the seedligs' root zone. Inventory results of survival, height and damage for the initial 5 years are presented here.

(*) Joint studies include the Departments of Silviculture, Forest Soils and Forest Site at the Swedish University of Agricultural Sciences and the Department of Forest Production at Umeå University.

METHODS

Plots were laid out in north central Sweden (see fig. 1) on four sites within a 6 km radius. Four principally different site preparation methods as illustrated in figure 2 were used at each site. Four different site types, a dry poor heath type (Bole); a fresh normal blueberry type (Rätan); a moist blueberry type (Nästelsildret), and a rich wet herb type (Östbodarna) were chosen. Site characteristics are described in table 1. The plots are 50 m² including a 10 m buffer strip with 180 to 225 seedlings per net plot depending on the site type. The experimental design is a randomized block except at Östbodarna which has a systematic layout as shown in figures 3-6.

The sites were harvested in early 1981 and site prepared in the autumn of 1981. 1-0 Kopparfors containerized seedlings of Pinus contorta, provenance Wonowon (lat. 56, long. 121, elev. 900-920 m.) were planted. Pinus sylvestris and Picea abies were included at Östbodarna, the rich, wet herb site. The untreated plots were planted in the summer of 1981 with Hagner's PUM (planting without site preparation) casings (see fig. 1). The site prepared plots were planted the following year to reduce the risk of weevil (Hylobius abietis) attack and to allow the plowed berms and mounds to settle. Damage by weevils, frost and voles necessitated supplementary planting over the 4 years following establishment. The untreated plots were inventoried in 1983 and 1985 and the site prepared plots in 1982, 1983, 1984 and 1985.

RESULTS

The results for survival and height are shown in table 2 and figures 7-10. Height increment is shown in figures 11-13.

At Böle, the site prepared plots were heavily attacked by Hylobius abietis in the initial years. Severe damage occurred on 64 to 93 % of the site prepared plots with plowed plots sustaining the least damage. No other major damage causes were recorded in 1982. The PUM casings of the untreated plots provided effective protection against weevils, however, Hagner reported about 50 % mortality due to frost in the first season. Weather continued to strongly impair seedling development such that only 14 % of the untreated seedlings were undamaged in 1985.

At Rätan, there was some severe weevil damage in 1983 and moderate vole damage in 1984 and 1985. Pinus contorta had shown a strong capability to recover from injury and plant development was not greatly impaired unless the damage was very severe.

Likewise at Nästelsildret, tehere was a heavy weevil attack (ca. 80 % site prepared seedlings severely damaged) in 1983 followed by moderate vole damage. The site prepared plots showed good recovery though the untreated plots were further impaired by weather damage (eg. frost, dessication).

Damage at Ostbodarna was initially small though in 1983, 51 % of the untreated seedlings and up to 84 % of the plowed seedlings were severely damaged, mostly by weevils or competing vegetation. Vole damage was moderate in all treatments. Later the most damage occurred in the plowed and untreated plots with heavy competing vegetation. There is a gradient in site qualities at the Östbodarna site such that the untreated plots are drier with relatively thin humus while the plowed plots are wetter and have thicker humus (see fig. 6). This site gradient combines with the systematic layout to confound the treatment effects and limit comparisons of treatments. Pairwise treatment comparisons at Östbodarna indicated that plowing and mounding had meaningfully better survival than disc trenching.

DISCUSSION

At Böle, the dry poor heath type site, plowing gave superior survival and height growth; nontreatment gave clearly inferior results while mounding and disc trenching gave similar medium results. Plowing provided a good selection of favourable planting spots with increases in soil temperature, and some retention of moisture and liberation of nutrients in the overturned humus. The high degree of bare ground exposure in the plowed plots on the poor site type may have hindered weevil attack as well. However, it is questionable if the positive effect of plowing (see fig. 11) will persist on the poor site type.

At Rätan, the site representative of the most common Swedish site type, there was little difference between treatments though survival was a little better with mounding, and height increment was poorest with nontreatment.

At Nästelsildret, the moist blueberry type site, there was almost no difference between site preparation treatments though performance of the untreated seedlings was unsatisfactory.

At Östbodarna, the richest site, with heavy competing vegetation, the best survival, height and growth were obtained with mounding and the worst results with disc trenching. The untreated plots gave relatively good results but it should be noted that these plots are one year older and are situated on the driest part of the site with less intensive vegetative competition as other plots.

CONCLUSIONS

The short term results from this experiment suggest that differences between site preparation methods (mounding, plowing & disc trenching) are fairly small on medium or good site types. Planting without site preparation gave inferiour results, except on the rich site. Differences between treatments were greatest on the poor site type. The best results were obtained in site preparation treatments with elevated planting positions. A longer time period should elapse before firm trends in treatment effects are considered.

PROPERTIES OF LARIX IN FINNISH SAWMILLING INDUSTRY

R. Juvonen

The preliminary results are included in the research "The production and use properties of larch in the mechanical wood industry". The research deals with the sawing, seasoning, planing, gluing and strength properties of larch timber, the problems in them and their reasons. The results to be presented concern the seasoning and planing properties of sawn timber of *Larix sibirica* and *Larix desidua* felled from planted stand from Southwest-Finland.

Three seasoning experiments were done, preliminary seasoning tests for larch and spruce boards and warm-air and hot-air seasoning for centre goods of larch. The planing property examined was the surface smoothness, when the variables in planing were the feed speed, working depth and moisture content.

According to the preliminary seasoning tests the drying time for larch is clearly longer than for spruce.

The most important seasoning defects of larch were the twist and other deformation defects of sawn timber. The twist was greatest in centre goods sawn from the pith. The main reason for twist is the great spiral grain of larch.

The cracking of larch was in seasoning a smaller problem than expected. The cracking was about equal in larch and spruce boards. In seasoning of centre goods especially the cracking of pith was great and in hot-air seasoning appeared inner shakes, which were long and deep.

The resinousness of larch causes most of the problems in sawing. The resin fastened on saw blades and feed rollers. In seasoning the boiling of resin, especially around dry knots was typical for larch. In hot-air seasoning the resin also got dark.

In warm-air seasoning changes in colour of larch timber were small, but in hot-air seasoning sawn timber got dark and variegated.

The surface smoothness of larch boards after planing doesn't differ much from the surface smoothness of spruce. The greatest problem in planing larch was the loosening of dry dark-edged knots, to which the feed speed and the working depth had no effect.

The research continues and a specially attention will be paid to the developing of a suitable drying schedule for larch timber.

INTRODUCTION TO KOREAN PINE FOREST IN THE NORTHEAST CHINA

Li Jing-wen

The mature korean pine forests hold a vital base in timber production and other benefits in China. They have made and will continue to hold a special place in the affections of Chinese people.

1. Habitat conditions

Korean pine (Pinus koraiensis) occurs usually with several hardwoods forming mixed stands, so generally to refer it as hardwood-korean pine forests. Their total range is limited with a narrow belt of Northeast Asia along west coast of Japan Sea with latitude 40° - 52° and longitude 126° - 140°. In Northeast China, hardwood-pine forests distribute from Changbai Mts. in south to Lesser Xing'an Mts in north, respectly ranging between 500-1000 m and 300-700 m in elevation, close to the subalpine coniferous forest upwards. The annual average temperature from 0°-8°C, annual precipitation range from 600-1000 mm, of which 70-80 % in June to August. The frost-free period average from 100-180 days, but usually between 100-130 days. Hardwood-pine forests are confined largely to dark brown forest soil, They can maintain themselves on gravelly soil where other species scarcely can survive, but they grow best on well drained loam soil.

2. Forest types and principal species

The hardwood-pine forests of China are divided into two subregions: Changbai Mts. mainly located at Jilin province and Lesser Xing'an Mts. at Heilongjiang province. In the latter subregion, there are four major climax forest types, i.e., Pinus-Quercus, Pinus-Tilia, Pinus-Betula, Pinus-Picea-Abies and others. Fig. 1 presents a simplified diagrammatic illustration of the altitudinal arrangement of these types, on which the typical soil - site relationship might generally be described. In these forests, all the principal tree species of north forest are found: Pinus koraiensis, Picea koraiensis, Picea jezoensis, Abies nephrolepis, Larix gmelini, Quercus mongolica, Tilia amurensis, Acer mono, Fraxinus mandshurica, Ulmus propinqua, Phellodendron amurense, Betula platyphylla, Betula costata and Populus davidiana etc. Shurbs usually include following genus: Corylus, Lonicera,-Ribes, Rubus, Grossularia, Rosa, Deutzia, Philadelphus, Elutherococcus, Sorbaria, Viburnum etc. Herbaceous plants are luxuriant. Hardwood-korean pine forests have many similarities with those in the Eastern United States.

3. Succession

The hardwood-pine forests have been considered as the climax communities limited by regional climate. Although climax forests are not easily displaced by other vegetation, logging and fire have played an important part in the successional status and composition of them. Compelete removal of these stands by logging or fire resulted in such drastic environmental change that korean pine and its associates were replaced by birch, aspen or shurb and grass communities. The kind of vegetation initially occupying the site will pass through different length of time to end to the corresponding climax types.

4. Reproduction

Since the early century, the hardwood-pine forests have suffered severely from overcutting and fire. The effect of which has been to substitute birch-aspen and other undesirable species for conifers on the open areas. Existing volume of mixed forests is largely in hardwood trees and many stands lightly stocked on the partial cuts. The virgin mixed forests undisturbed mainly remain in the nature reserves. Several approaches to reproduce korean pine have been used: (1) planting method for establishing pine on open land; (2) introducing pine in areas occupied by birch-aspen stand with seeding and planting beneath; (3) adopting improvement cuttings to rehabilitate the degraded forest with natural and artificial regeneration.

FIELD EXPERIMENTS ON SITE PREPARATION AT THE DEPARTMENT OF SOIL SCIENCE, FINNISH FOREST RESEARCH INSTITUTE

Kaarina Niska

An extensive series of soil tilling and fertilization experiments was started in 1975 in cooperation with the National Board of Forestry. The field experiments were established on areas with different climatic conditions, first in Northern Finland on areas difficult to reforest. The aim was to study long-term effects of tilling with treatments representing different intensity levels of timber production.

A split-plot experimental design was employed in which the main treatments are the three tilling methods, and the subtreatments fertilization at four different levels. The size of each sample plot is 50 x 50 m. There are four replications in each experiment. One experimental area is about 12 hectares.

The prescribed burning and tilling experiments which started in 1977 in southern part of Finland uses the same split-plot method. The main treatments are burned and unburned sites and the subtreatments are three soil tilling methods.

The research reports concerning seedling performance in these experiments in the following:

Levula, T. & Heikkilä, R. 1979. Rovaniemen tutk.as. tied. 18:1-12.

" 1982. Metsäntutk.lait. tied. 11:1-12.

Starr, M.; Levula, T. & Heikkilä, R. 1982. Metsäntutk.lait. tied. 51:1-11.

Mälkönen, E.; Niska, K. & Levula, T. 1987. IUFRO Working Party S 1.05-12, Grand Praire and Dawson Creek, Canada, 1986 (in prep.)

Niska, K. & Levula, T. 1987. Metsäntutk. lait. tied. 253:99-108.

SITE PREPARATION, FERTILIZATION AND DRAINING OF FOREST LAND IN FINLAND

Aulis Ritari

SITE PREPARATION

Before the 1950s site preparation, in connection with the reforestation was manual exposing of mineral soil with a hoe. This was first replaced by horse-drawn scarifiers and later by tractor-drawn versions. Prescribed burning which was taken into extensive use already in the 1920-30s was based on the positive experiences of the era of swaling. A new rise in the use of prescribed burning was seen in the 1950s after the second world war.

During the 1960s burning gave way to mechanical site preparation. Ever since there has been a continuous development of the tilling methods and tools. In recent years the main methods have been ploughing and disc tilling. During this decade prescribed burning has been favoured again especially in northern Finland.

FOREST FERTILIZATION

Forest fertilization started in Finland in the mid 1960s. On mineral soil sites fertilizers have mainly been given to forests approaching the stage of end cutting in the form of nitrogen and phosphorus. On peatland sites fertilization is normally done in connection with drainage using potassium and phosphorus fertilizers. The state supports forest fertilization according to an accepted plan up to the limit set by the temperature sum 800 d.d. -units.

Until recently, manual spreading was the most widely used method. In addition to spreading methods using aircraft, mobile machines operating on the ground have been used to a greater extent in recent years.

FOREST DRAINAGE

Forest drainage was first started in the 1910s on state land; on private land it began to get state support in 1929 when the first Forest Improvement Act was passed. Nowadays forest drainage is given support up to the temperature sum of 750 d.d. depending, however, on the peatland type.

Until the 1950s the forest ditches were dug manually. In the mid 1950s large ditch plows drawn by heavy tractors were taken into use. Since the mid 1960s hydraulic tractor diggers have been the main machines.

It is estimated that the first drainage will be finished in the 1990s; thereafter the emphasis in drainage work will be on maintenance.

LONG-TERM EFFECTS OF PRESCRIBED BURNING ON SOIL CHEMISTRY

A review of the results in P.J. Viro (1969)*

Aulis Ritari

During prescribed burning the surface vegetation, slash and part of the humus layer are burned up. This causes changes in a number of the physical and chemical properties of the soil, some lasting for decades. The present study examines the fire-induced variations in soil chemical properties in respect to time and profile depth. The material was collected from 92 burned and 92 unburned plots in southern and central Finland. The forest sites included Vaccinum-Myrtillus-type (54), Myrtillus-type (29) and Oxalis-Myrtillus-type (9). For details of the methods and material the reader is invited to see the original text.

RESULTS AND DISCUSSION

<u>Acidity</u> (humus layer)
The decrease in acidity was on the order of 2 pH-units, a.e. 100 times H^+-ion concentration (pH 4 -> pH 6). The change was still noticeable after 30 years.

<u>Organic matter</u> (humus layer)
Burning caused a decrease of 7 tons/ha (24 % of the total amount) in organic matter of the humus layer. The burned material was mostly slash and surface vegetation. The humus layer started to increase in thickness again after 10-20 years.

<u>Nitrogen</u> (humus layer)
Total nitrogen in the humus layer decreased by approximately 100 kg/ha (25 %) during burning. The recovery was very similar to that of the organic matter. In the mineral soil there was no detectable change.

Ammonium nitrogen content of the incubated samples started to decline one year after burning and the quantity was lower than on the unburned plots for 12 years. The nitrate content, however, was clearly greater on recently burned sites. This condition lasted for about 10 years.

<u>Total nutrients</u> (humus layer)
After burning the total quantities in the humus layer were higher for calcium and magnesium and lower for potassium, natrium and phosphorus. This indicates that the alkali metals and phosphorus are poorly fixed to humus material and a definite loss may result.

<u>Exchangeable and easily soluble nutrients</u> (soil profile)
With the exception of potassium and sodium the exhangeable nutrients in the humus layer in the year of burning were greater in quantity on the burned sites than on the unburned ones. Leaching attained its maximum in about 10 years. The higher concentrations in the uppermost mineral soil at the same time for potassium and phosphorus indicated that most of these elements were retained within the solum. Burning caused a redistribution of the nutrients in the soil profile without any great losses of exchangeable potassium or easily soluble phosphorus in the long run.

*Source: Viro, P.J. 1969. Prescribed burning in forestry. Comm. Inst. For.

RAIVOLA LARCH STAND

Aili Tuimala

Poster 1.

The larch stands in Raivola originate from a policy initiated by Peter the Great, the creator of the Russian navy. Forest officer Fockel, a German, was invited to establish the plantations in Tsarina Anna's time. The oldest block in Raivola, close to Kronstadt and its dockyard, was established by broadcast sowing in May, 1738. The seed was originated from Archangel. Other fields were planted in 1773 and 1821. Spacings were 3,96 x 3,96 and 4,27 x 4,27 or 625 and 549 plants per ha. The stands have never been thinned, but over the years a many severe storms have felled and damaged stems. The stands are nowadays protected as a natural monument and only a very few visitors are allowed.

Poster 2.

The first systematic forest mensuration survey in these larch stands was carried out by D. Tovstoljes in 1903 and the second one by L. Ilvessalo in 1921, when the area belonged to Finland. The area of pure stands totals 18 ha and of mixed 3 ha. Distribution of forest site types in pure larch stands: FT 2,4 %, OT 83,9 %, OMT 6,2 %, MT 7,5 %. The larch stems were very straight and clear up to a height of 60-80 feet.

Poster 3.

A small amount of pruned Larix europaea and Larix sibirica butlogs as well as unpruned Larix sibirica butlogs have been sliced into veneer. Veneers have been classified all clear after kiln dryer. The pruning of larch seemed to be very usefull.

EFFECT OF SIZE OF CLEAR-CUTTING AREA ON THE DEVELOPMENT OF SCOTS PINE CULTIVATION

Jukka Valtanen

The sample plots were established 1962 - 65 in Northern Finland (Savukoski lat. 67°25′, height 200 m, Pudasjärvi 65°50′, 225 - 280 m, Valtimo 63°45′, 185 - 235 m).

The results at the age of 20 years

SURVIVAL % - HEIGHT M

	Savukoski	Pudasjärvi	Valtimo
AREA			
> 5 ha	19 - 3.0	23 - 2.9	17 - 5.2
> 100 ha	20 - 3.2	25 - 3.2	18 - 5.0
BURNING			
No	16 - 2.8	29 - 3.8	18 - 5.0
Yes	23 - 3.3	21 - 2.6	17 - 5.2
MONTH			
V	26 - 3.3	31 - 3.3	27 - 5.5
VI	25 - 3.1	26 - 3.2	25 - 5.4
IX + X	18 - 2.9	24 - 2.9	15 - 4.8
MATERIAL			
Sowing	36 - 2.9	21 - 2.5	12 - 4.4
2 + 0	16 - 3.1	27 - 3.4	17 - 5.1
2 + 1	14 - 3.2	30 - 3.7	31 - 5.8
X	22 - 3.1	26 - 3.2	20 - 5.1

CONCLUSIONS

1. The result is very poor.
2. The result does not depend on the size of the cut-over area.
3. The burning has been usefull in Savukoski (thick humus layer) and harmfull in Pudasjärvi (thin humus).
4. Early spring just after snow melting before June is the best time for planting and for sowing, too. The autumn is unreliable time.
5. The materials are almost of equal value.

HEIGHT GROWTH OF *LARIX LARICINA* ((DU ROI) K. KOCH) ON A VARIETY OF SITES IN INTERIOR ALASKA

Trudy T. Heffernan

Tamarack (*Larix laricina*) growth was compared on a variety of sites in interior Alaska. An early growth study compared years-to-breast-height of tamarack on different site classes and compared its growth with that of its associated tree species. In a second study, height of tamarack at 25 years was compared on different site classes. In both cases, site class groupings were based primarily on soil moisture, permafrost, and landform.

The site classes demonstrated a significant effect on years-to-breast-height, but there was even more variation among sites. Growth rate of tamarack was similar to that of its broadleaf tree associates and generally faster than that of associated conifers within site classes. Site effect on height-at-25-years was significant; however, site class was not.

Multiple linear regression analysis using environmental and vegetation variables demonstrated that the latter explained more height growth variance.

SUMMARY OF RESULTS

1. Differences in tamarack early growth between site classes

   Best growth was found in the site class with:
   - no permafrost and a thin organic horizon
   - tamarack, birch, willows, horsetails, grasses and *Tomenhypnum nitans*

   Slowest growth in site class with
   - permafrost and a thick organic horizon
   - tamarack, black spruce, and white spruce, high shrub layer (*Ledum groenlandicum*, *Betula glandulosa*) and many grasses, sedges and mosses.

2. Differences in height at 25 years between site classes

   Original site classes may have been too narrow, but a regrouping into more broad classes might be more appropriate.

   Best growth was in site class with sites that were:
   - drier, with thin organic horizon
   - high in broadleaf trees, willows, *Alnus* sp., *Shepherdia canadensis*, *Hylocomium splendens*, *Stereocaulon paschale* and low in herbaceous plants

   Slowest growth was in site class with
   - peraquic to subaquic soils with permafrost and thick organic horizon
   - tamarack and black spruce, some birch, Ledum groenlandicum, *Potentilla fruticosa*, and many other shrubs.

3. Comparison of early growth of tamarack with other tree species

   Generally, tamarack growth rate was similar to broadleaf species and often faster than the other conifers. In the class where tamarack growth rate was slowest it was intermediate to the broadleaf species and the conifers.

4. Factors Influencing Growth

In both studies the plant species accounted for more variance in growth rate than did the environmental variables.

(Y=)	Regression Coefficients Years to BH		Height at 25 Years	
Soil moisture	-1.3	(+)	-0.3	(-)
Silt	-1.1	(+)	-2.6	(-)
Clay			3.8	(+)
Organic	-1.3	(+)		
Sand	2.2	(-)	-0.4	(-)
Organic horizon depth	0.7	(-)		
Permafrost	0.8	(-)		
Elevation	0.8	(-)		
Larix laricina (tree)	1.1	(-)		
Betula papyrifera (tree)			1.9	(+)
Picea glauca (tree)			3.1	(+)
Picea mariana (tree)			5.8	(+)
Populus tremuloides (sapling)	-0.9	(+)		
Alnus crispa	1.6	(-)		
Alnus tenuifolia			-6.4	(-)
Ledum groenlandicum			-5.1	(-)
Linnaea borealis			-9.6	(-)
Myrica gale	-0.7	(+)	12.0	(+)
Equisetum pratense	-0.4	(+)		
Geocaulon lividum			-19.7	(-)
Hedysarum machenzii			-12.5	(-)
Mertensia paniculata	4.4	(-)		
Pyrola secunda			38.2	(+)
Solidago sp.	-2.2	(+)		
Sphagnum sp.	0.4	(-)	-7.1	(-)

RECOMMENDATIONS FOR FURTHER STUDY

1. Improvement of classification of sites by
   - obtaining more information on the history of the site (esp. regarding fire, succession, and geologic history)
   - identification of indicator species on sites

2. The sampling of more sites (to increase the sample size) locating sites with older trees to compare growth curve shape on different types of sites and to allow the use of an older index age for comparison.

3. Controlled experiments to test effects on growth of:
   - soil temperature
   - shading
   - nutrient availability

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The Finnish Forest Research Institute
ROVANIEMI RESEARCH STATION
Eteläranta 55, 96300 Rovaniemi
Tel. (960) 15721

Founded in 1970, the Rovaniemi Research station is the largest of the eight regional research stations of the Forest Research Institute. The quarters for the station were completed in 1973. Floor space amounts to 2000 square meters, which in terms of volume represents 6400 cubimeters. Two subsidaries are located in town. Personnel at the station consists of 21 researches, district forestry officer and other staff totalling about 100. During the summer, this figure rises to about 140. The annual budget totals about 10 million FIM.

Researchers and their research topics:

S a a r e n m a a, Hannu, D.F., docent, Station head
- forest entomology
- knowledge engineering

A i r a k s i n e n, Kirsti, M.Sc. (biochem.), Forest pathology (external funding)
- biochemistry of disease and cold resistance

H e l l e, Timo, D.Sc. (Zool.), National economics of forestry
- economics of multiple-use forestry
- reindeer and moose in forestry

J a l k a n e n, Risto, D.F. (For.), Forest pathology
- fungal diseases
- damages caused by fertilization

K a i l a, Erkki, M.Sc. (ADP), ADP development
- database applications in forestry and forest research

K a i l a, Pirjo, M.Sc. (ADP), system manager
- maintenance and development of computer systems (VAX/VMS, LAN)
- consultation and training in computer use

K i n n u n e n, Hilkka, M.Sc. (Math.) Development of forestry information base (external funding)
- information service
- information systems development

M a t t i l a, Eero, D.F. (For.), Forest inventory
- national forest inventory
- forest inventory methods
- inventory of reindeer pastures

M ä k i t a l o, Kari, B.Sc. (For.), Silviculture
- regeneration of forests

N a s k a l i, Arto, M.Sc. (Econ.), Business economics of forestry
- roundwood markets

N i s k a, Kaarina, M.Sc. (Agr. and For.), Forest soil science
- soil chemistry

N o r o k o r p i, Yrjö, D.F., Research specialist, Silviculture (and forest pathology)
- methods of forest regeneration and ecology of seedlings
- treatment of sapling stands
- treatment of high land forests

P e n t t i l ä, Timo, B.Sc. (For.), Peatland forestry
- fertilization and regeneration of the northern peatland forests
- silvicultural and ecological aspects on peatlands

R i t a r i, Aulis, L.Sc. (For., Soil Sci), Forest soil science
- site preparation
- site classification
- micrometeorology

S a l m i n e n, Hannu, M.Sc. (Agr. and For.), Growth and yield studies

S e p p o n e n, Pentti, Ph.D. (Bot.), Silviculture
- forest site classification in Northern Finland
- biological aspects of multiple use of forestry

S i p p o l a, Anna-Liisa, M.Sc. National park research (external funding)

S u t i n e n, Marja-Liisa, L.Sc. (Bot.), Plant Physiology. (Academy of Finland)
- cold resistance of pine seedlings

T i k k a n e n, Eero, M.Sc. (Bot.), Silviculture
- ecophysiology of trees
- root systems

T i m o n e n, Mauri, B.Sc. (For.), Growth and yield studies
- structure, production and treatment

of the protection forests
- modelling of growth indexes and climate effects
- data prosessing methods

V a r m o l a, Martti, M.Sc. (For.), Growth and yield studies
- thinning and growth modeling of sapling stands
- quality in planted stands

H o k k a, Paavo, B.Sc. (For.), North Finland Management District of the Experimental forest office, district forest officer

KIVALO EXPERIMENTAL FOREST

Aulis Ritari

Abstract

The Kivalo Experimental Forest is located on the timber-covered hills of the Kemijoki-river (66°23'N, 26°37'E) 40 km south of the Arctic Circle. The land area of 14200 ha became part of the Finnish Forest Research Institute's experimental areas in 1924. The mean annual temperature in the region is about +0.5°C and annual precipitation 475 mm (the average for the period 1921-81). The most common soil materials are glacial till and peat which is reflected in the quality of forest sites: moist mineral soil sites occupy about 61 % and peatlands about 19 % of the area.

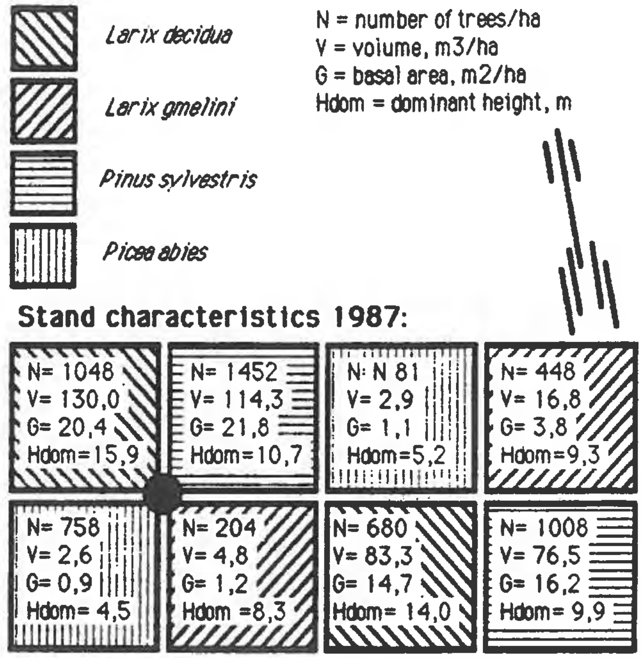
The permanent staff consists of a local forest technician, 8 other permanent workers and 12 temporarily employed. The research is conducted from both the Rovaniemi Research Station and the main office in Helsinki. They include studies on natural and artificial regeneration, ecological conditions, tree species and provenances, thinning and harvesting methods, growth and yield, peatland forestry, forest damages and multiple use. The research findings are mainly reported in the publications of the Research Institute.

TREE SPECIES TRIAL IN HÖPÖTTÄJÄ

Martti Varmola

Forest site type:	*Hylocomium-Myrtillus* -type, partly stony or paludified
Previous forest:	*Picea abies*, admixed tree species *Pinus sylvestris, Betula pubescens*
Soil type:	Sandy moraine (stony)
Clearcutting:	1947-48
Prescribed burning:	1950
Spacing:	2,5 • 2,5 m (1600 trees/ha)

Tree species:	*Larix decidua*	*Larix gmelini*	*Pinus sylvestris*	*Picea abies*
Origin	unknown	unknown	Finland	Lapland
Planting time	4.6.1952	23.6.1955	13.6.1952	29.6.1955
Age of plants	3 years	4 years	3 years	4 years
Length of plants	25 cm	12 cm	10 cm	20 cm
Quality of plants	dwarfed	dwarfed	strong	strong
Summer	rainy	dry	rainy	dry
Dominant height in 1976	9,0 m	6,8 m	5-6 m	snow limit



STAND ESTABLISHMENT PLOTS IN KEMIJÄRVI COMMON FOREST

E. Pohtila, L. Saarenmaa, H. Saarenmaa, R. Junttila & T. Mattila

Kemijärvi common forest is a cooperative of over 2000 private landowners. Its land property comprises 41000 ha, growth of the forests is 51000 m^3/year, and the yearly cutting plan 44000 m^3. Yearly budget is 6.2 million FIM, and a typical yearly profit for a member farm is 10000 FIM.

Point 1 Nuolivaaran Rakkavaara

200 m.a.s.l. Previous forest mixed spruce-pine
Clearcut in 1964
Seeding of Scots pine in 1965
Thinning in 1976
Height now 6 m

Point 2 Nälkämä pine

220 m.a.s.l. Previous forest spruce
A part of a clearcut of 3000 ha
Prescibed burning in 1973
Ploughing in 1973
Seeding of Scots pine in 1974
Herbicide treatment in 1980
Thinning in 1983

Point 3 Nälkämä larch

As point 2 except
Planting of Siberian larch (Kuusamo-Raivola origin) in 1974
No thinning
Severe Adelges laricis woolly aphid attack in 1987
Ash treatment 3000 kg/ha planned for cure

Point 4 Erkkusenselkä

240 m.a.s.l. Previous forest spruce
One of the first mechanical scalpings in 1963
Seeding of Scots pine in 1964
Thinning in 1974
Height now 5 m

Point 5 Pikku Nuolivaara

230 m.a.s.l. Seed trees on 64 ha in early '50s without success -- Ploughing in 1966
Planting with "poor quality" Scots pine in 1969
Herbicide treatment in 1974
Thinning in 1984

Point 6 Veitsiluoto Oy

210 m.a.s.l. Clearcut in 1975
Ploughing in 1975 on 47 ha
Planting of Scots pine in 1977 on 23 ha
Seeding of Scots pine in 1977 on 24 ha
Herbicide and mechanical treatment in 1984

Point 7 Tunturipalo slope

240 m.a.s.l. Previous forest spruce, 80 m^3/ha
Now a part of a clearcut of 1000 ha
Clearcut in 1976-79
Prescribed burning in 1980
Scalping in 1980
Seeding of Scots pine in 1981
Density now 1600-2500 seedling patches/ha

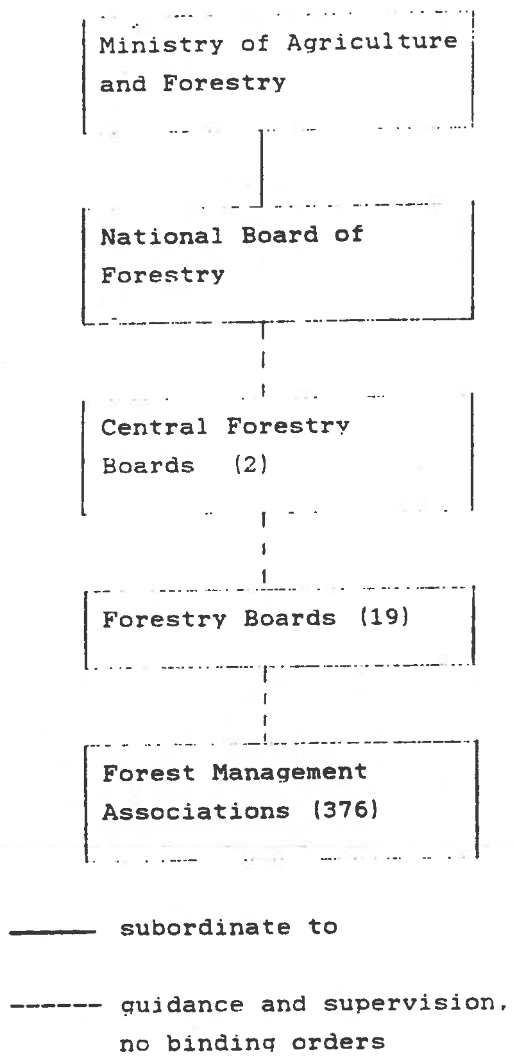
Point 8 Tuntipalo top

260 m.a.s.l. As point 7
Clearcut in 1972-75
Prescribed burning in 1976
Ploughing and scalping in 1976
Seeding of Scots pine in 1977
Density now 3700 patches/ha

FORESTRY BOARD OF LAPLAND

Jukka Ylimartimo

Administrative Organization of Private Forestry in Finland



Ministry of Agriculture and Forestry
- forestry policy-making
- preparation of statutes and supervision of their execution
- appoints the members and deputy members of the executive committees of the forestry boards as well as the chairmen of the inspection committees
- approves the plans of central and local forestry boards

National Board of Forestry
- board of appeal
- supervision of use of state funds
- approves budgets of central and local forestry boards
- appoints auditors of central and local forestry boards

Central Forestry Boards
- highest decision-making body is an 11-member executive committee comprising the director and the following:
  5 representatives of forest owners
  2 representatives of the wood industry
  2 representatives of forest workers
  1 representative of the state
- guidance and development of the activities of the local forestry boards

Forestry Boards
- highest decision-making body is the executive committee, which consists of
  4 representatives of forest owners
  2 representatives of the state
  1 representative of the wood industry
  1 representative of forest workers
- principal activities:
  1. maintenance and development of wood production
  2. development of planned forestry
  3. distribution of information on forestry
  4. forest improvement work

Forest Management Societies
- power of decision rests with forest owners
- principal activities:
  1. training and advice for forest owners
  2. provision of services needed by forest owners for improvement and use of forests

MANAGEMENT OF PRIVATE FORESTS

Mikko Hypponen

At present 63 % (12.7 mill. ha.) of the total forested area in Finland (20.1 mill. ha) is privately-owned. The state owns 24 %, companies 9 % and other owners 4 %. There are some 400 000 private forest holdings, of which 100 000 are smaller than 5 ha. Forestry boards and forest management societies provide guidance and advice to owners in management and offer professional assistance in the planning and carrying out of work.

Management of private forests is regulated by the act concerning private forests passed in 1967. The act forbids destruction of forests but it carries no obligation to manage forests nor does it require so-called sustained yield management.

The Central Forestry Board Tapio has drawn up quidelines for forest management which local forestry boards generally modify to suit the particular demands of their locality. The guidelines contain the principles for managing young of middle-aged stands as well as mature ones. Separate guidelines exist for mineral soils and peatland forests. In addition, the protection forest area of Lapland and high-elevation forests have their own set of guidelines.

In the act concerning private forests, growing and regenerating are clearly distinguished, which means that Finland uses a system of forest management by stands. The management unit is an even-aged stand, not a tree or group of trees. The smallest stand compartment is approximately half a hectare.

Although no stand management obligation exists, regeneration of a stand does require certain follow-up measures. In the case of natural regeneration, the regeneration area is always cleared at least, but generally the soil surface is also broken slightly using a disc plow. After clear cutting the regeneration area is always cleared, and soil preparation, seeding or planting are carried out. An effort is made to use natural regenera- ion wherever the soil and growing stock permit.

At present, felling and management in private forests is based for the most part on forest management plans made for individual holdings. The plans cover 50 - 80 % of the holdings depending on the forestry board. The plans are drawn up mainly by forestry boards. The planning method is survey by stands. An attempt is also made to take into account conserva- tion requirements.

During the period 1981-1986 an average of 303 000 ha of private forest were marked annually. Of this 60 % represented inter- mediate felling and 40 % regeneration felling. Of the regeneration markings, approximately 70 % were for clear felling and 30 % for natural regeneration (Fig. 1).

At the beginning of the 1980s, 102 000 ha of forest were under cultivation yearly, of which' planting comprised 85 % and seeding 15 %. Thinning and cleaning of seedling stands involved 157 000 ha, fertilization 52 000 ha and swamp drainage 65 000 ha per year (Fig. 2). Approximately 2 600 km of forest roads were constructed annually.

FIG 1

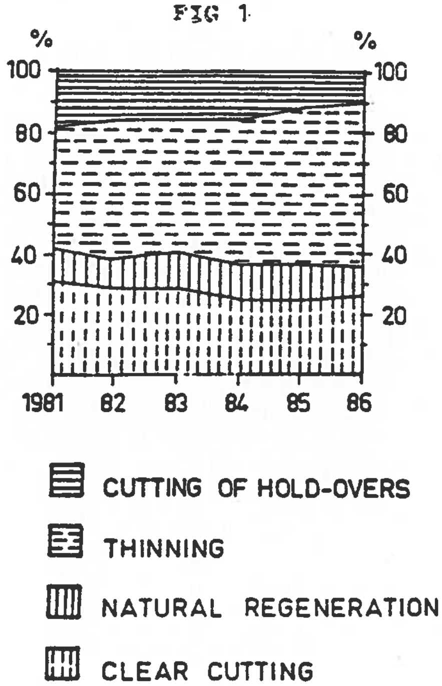
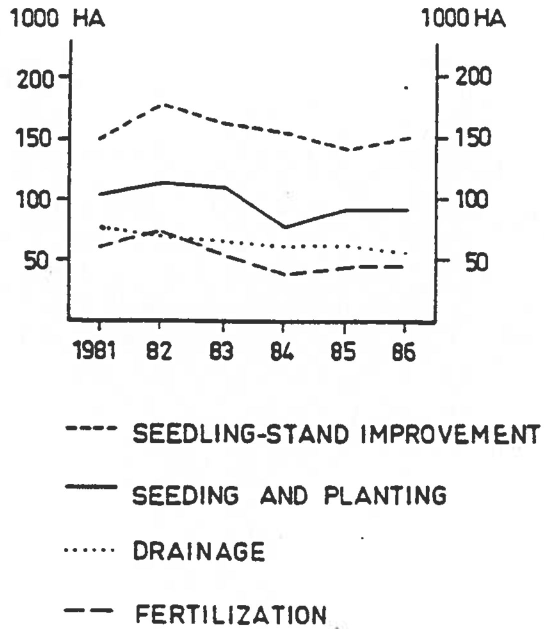

%
%
100
80
60
40
20
1981
82
83
84
85
86
CUTTING OF HOLD-OVERS
THINNING
NATURAL REGENERATION
CLEAR CUTTING

FIG 2


1000 HA
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1981
82
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86
SEEDLING-STAND IMPROVEMENT
SEEDING AND PLANTING
DRAINAGE
FERTILIZATION

STATE SUPPORT FOR OWNERS OF PRIVATE FORESTS

Mikko Hyppönen

The significance of private forests in the national economy of Finland is great. For this reason, it is looked upon as being in society's interest to undertake various measures to promote the management of private forests. The most important of these are education of forest owners and forest management plans which give the forest owners knowledge about how to produce money by forestry. In addition, under certain conditions direct loans, financial assistance and forms of tax relief is provided.

The most significant state support is based on the Forest Improvement Act. The present act, the ninth such to be passed, came into force just this past spring. According to the act, the state supports forest improvement work, which include regeneration, prescribed burning, seedling stand management, pruning of standing trees, fertilization, drainage, maintenance of drainage systems and construction of a forest road. Support is provided in the form of tree professional assistance in the planning and directing of work, free herbicides and supplies for cultivation and partial or total financing of work and other expenses through state assistance and loans.

Financial assistance is taggered geographically, with the largest appropriation being granted in Northern Finland and the smallest in the southern part of the country. There are eight assistance zones in all. In granting assistance regional development policy as well as economic, employment and environmental considerations are taken into account.

The act of regeneration of stands in unsufficient production in Lapland, the socalled Lapland Act, is as significant for the owners of private forest in the northernmost part of the country as the Forest Improvement Act is. The former guarantees 100-percent state aid for the regeneration of particularly underproductive stands and for local planning of private forests. The Act is temporary and will expire at the end of 1995.

The act aimed at reducing unemployment provides a possibility of employing jobless persons partially using state funds. The funds are available to forest management societies, forestry boards, communes, parishes and companies. In addition, an unemployed person may get funds for work carried out in his own forest without an employment contract. The assistance is intended to be used for fuelwood, pruning and various forest management measures.

A variety of tax exemptions and forms of tax relief also constitute an important form of aid. For instance, a forest regeneration area, a forest damage area, an afforested field and a drained swamp may be declared tax-exempt for a certain time. The period varies from 5 to 35 years depending upon geographical location and the basis for granting the tax-exempt status and is longer in the north than in the sout.

Forests owners may deduct the following from their taxable income from forestry: forestry fee, costs of forest management plan, fertilizer, maintenance of drainage systems and partial costs of building a forest road.

REFORESTATION EXPERIMENTS IN POKSASELKÄ

Aulis Ritari

Abstract

The reforestation experiments in Poksaselkä (67°12'N, 26°12'E) 130 km north from the Arctic Circle were started in 1972 as a joint effort by the Forest Research Institute and the National Board of Forestry. The idea was to experiment with strip cutting and various site preparation and cultivation techniques in a high-elevation (340 m asl.) Hylocomium myrtillus -type spruce forest usually difficult to regenerate.

The clearfelled strips are divided into 60 x 180 m blocks for which the treatments were randomized. The mechanical site preparation methods include: 1) scalping, 2) shoulder ploughing, 3) tilt ploughing, 4) rotary tilling and 5) mounding. One half of the clearfelled area is provided with additional drainage.

Cultivation experiments include sowing and planting trials with several tree species, provenances and seedling types. The natural regeneration is the subject of a detailed follow-up. The ecological conditions of the site are being studied as well.

Research findings have been published in the following reports:

Ritari, A. & Lähde, E. 1978. Effect of site preparation on physical properties of the soil in a thick-humus spruce stand. Seloste: Muokkauksen vaikutus paksusammalkuusikon maan fysikaalisiin ominaisuuksiin. Commun. Inst. For. Fenn. 92(7):1-37.

" 1985. Muokkauksen vaikutus paksusammalkuusikon maan ominaisuuksiin. Lic.thesis, Dept. of Silvic. Univ. of Helsinki. 104 p.

Pernu, T. & Ritari, A. 1978. Vastusluotauksia Sodankylän Poksaselässä pohjaveden esiintymisen selvittämiseksi. Groundwater prospecting in North-Finland by means of resistivity soundings. Univ. of Oulu, Dept. of Geophysics, Contrib. 96:1-15.

Norokorpi, Y. 1979. Old Norway spruce stands, amount of decay and decaying microbes in Northern Finland. Seloste: Peräpohjolan vanhat kuusikot, niiden lahoisuus ja lahottajat. Comm. Inst. For. Fenn. 97(6):1-77.

" 1973. Kuusipuuston kasvusta ja lahoamisesta Pomokairan alueella. Metsäntutkimuslaitos, Rovaniemen tutkimusaseman tiedonant. 3:16-22.

Mäkitalo, K. 1983. Koetuloksia männyn viljelyn onnistumisesta eri tavoin käsitellyllä paksusammaltyypin maalla Lapissa. Metsäntutkimuslaitoksen tiedonant. 105:98-110.

GEOLOGICAL FEATURES AND INTERGLACIAL LARCH SUBFOSSILS IN FINNISH LAPLAND

Peter Johansson

During the Quaternary period, ice sheets covered Scandinavia several times. The Precambrian bedrock in Finland was mantled with a sheet of glacial drift. The most striking present-day features are the different kinds of moraines and eskers left by the final retreat of the latest glaciation, the Weichselian glacial stage. In central Lapland, glacial erosion and deposition activity was weaker than in other parts of Finland. A cover of preglacial weathered bedrock is often found between glacial till and bedrock. Organogenic gyttja, peat, and diatomite layers have also been found intercalated between two till beds in about 80 locations. On the basis of microfossil content and radiocarbon age determinations, 49 organogenic deposits studied by various researchers can be classified as either interstadial or interglacial. The former means a short, temperate period between two cold periods with Betula-predominated pollen composition. The latter means a longer and warmer period between two glaciations with Pinus predominated pollen composition. In 1979, a Larix trunk about 8 m long and 40 cm thick was found by K. Mäkinen (1) during the excavation of the Vuotso canal. The trunk lay in the sand layer at a depth of 4.5 meters below the till layer. The pollen composition of the organogenic deposit below the trunk (Pinus 49 %, Betula 24 %, Picea 20 %, Alnus 4 %, Corylus 1.7 %, and some Carpinus, Larix and Abies) indicates that the Larix trunk grew during the interglacial period. Larix pollen has also been found in the interglacial deposits at Tepsankumpu, Härkätunturi, and Paloseljänoja in central Lapland. Correlating the stratigraphies and the pollen compositions of the interglacial deposits, it is assumed that they originate from the same interglacial period, the Lapponian interglacial period, named and studied by H. Hirvas (2). During this period, the climate was as warm as at present or even a little warmer. The age of the Lapponian Interglacial Period is invariably greater than what can be reliably determined by the radiocarbon method. This period is certainly over 50,000 years old and is possibly over 120,000 years old.

(1) Mäkinen, K., 1982. Tiedonanto Vuotson interglasiaalisesta lehtikuusen rungosta. Summary: Report on interglacial Larix trunk at Vuotso, Northern Finland. Geologi 34:9-10, 183-185.

(2) Hirvas, H., 1983. Correlation problems of interglacial deposits in Finnish Lapland. IGCP, Project 73/1/24, Glaciations quaternaires dans l'hemisphere nord. Rapport 9, 129-139, Paris.

REFORESTATION IN THE PALKISOJA FOREST FIRE AREA

Kari Pelkonen

Location 68°30'

Height above mean sea level:
road 200 m
top 320 m

Temperature sum about 690 dd°C

The area was burnt in a forest fire in July, 1960.

The burnt area is approximately 280 hectares, the majority os which comprises the jointly-owned forest of Inari. About 20 hectares are administered by the Inari Forest District of the National Board of Forestry.

The area of jointly-owned forest was reforested in 1961-1963. About 220 hectares was sowed and about 40 hectares planted.

Total amount of the seed sown was 69 kg, which originated as followes:

Pello	24.5 kg
Sodankylä	29.0 "
Inari	10.0 "
Rovaniemi	6.5 "

Supplementary planting was made in an area of 40 hectares in 1974.

In an inventory in 1984 about 8 800 plants/hectares were counted, the average height of which was 3.3 m.

In autumn 1986 a thinning was carried out in an area at 19 hectares along the road side. About 4 000 trees/hectares were cut down.

The State-owned section was planted by using pine seedlings during the summer of 1961.

The plants were two-year-old bare-root seedlings. The seed was of Kemijärvi origin, some 200 kilometres south.

The planting density was 1,600 seedlings per hectare.

Supplementary planting was carried out in 1972 with bare-root seedlings of most likely Kittilä origin. The density was 1,100 seedlings per hectare.

THE GOAL OF FOREST REGENERATION
YOUNG FOREST STAND IN KAITAVAARA

Arno Uusvaara

The systematic regeneration of state forests in Inari began in the early 1960's when markets for pulpwood opened. However, before this date occasional logging operations had been accomplished since the 1930's. They were mostly selective because these operations mainly covered only sawlogs. Another part of these forests recovered and the other part has been regenerated later.

As the overaged forests covered at the beginning of the 1960's about 75 % of the area of the state forests at Inari, the main emphasis of logging operations in Inari Forest District has been on regeneration cuttings. Since this date the total area of regenerated forests rises up to 52 000 hectares. At the same time the area of seeding and sapling areas as well as young forests has increased rapidly as the following numbers show:

Year	Forests less than 80 years
1960	20 000 hectares
1982	77 000 "
2000	110 000 "

By the year 2000 forests younger than 80 years will consist 40 % of the area of productive forest land in Inari Forest District. The situation is similar in the state forests all over Lapland.

Because in the future the young forests will form an essential part of the state forests, a special emphasis is put in the Forest Service of Finland to improve the results of regeneration and the quality of the young stands obtained in this process. The purpose is, naturally, to produce as good forests as possible. In the instructions of the treatment of state forests in the North Finland Region, given by the Forest Service of Finland 1985, the goal of forest regeneration is determined according to the following criteria:

- Suitable and valuable tree species for each site type.
- Full density of growing stock.
- Genetic value: fast growth and good quality.
- Vitality of new forest.
- Short period of reproduction.
- Good financial result.

The young stand in Kaitavaara is an example of forests we are aiming at. It meets, to a great extent, the demands described above as the data collected from the stand show.

History of the stand:

- Forest fire	1945
- Sowing on snow, pine 2 kg/ha April	1954
- Thinning	1977

Data of the stand:

- Area fo the stand		61 has
- Topographical height		140-200 m.a.s.l.
- Temperature sum		700 dd c°
- Site type		KVK (Dryish mineral soil)
- Age		33 years
- Dominant height		10 m
- Basal area		13 m^2
- Volume		60 m^3/ha
- Tree species	pine	90 %
	birch	10 %
- Increment		3 m^3/ha/year
- Density		750 stems/ha

EPIRRITA AUTUMNATA DEFOLIATION OF MOUNTAIN BIRCH

Hannu Saarenmaa

The abundance of the geometrid moth Epirrita autumnata fluctuates periodically in Northern Scandinavia. Most of the time the species is not at epidemic levels, but at about 20 year intervals, it breaks out over large areas. After a one or two year peak the population collapses again. A peak does not always translate into complete defoliation and dying of trees. However, the last large outbreak in 1964-66 resulted in total devastation on birch over an area of a half million hectares in the northern timberline. Some of this area has recovered from root saplings, but large areas became treeless tundra.

In river valleys, however, the birches were saved from extensive damage. This is accounted for deep winter frosts that kill the overwintering eggs in such places while the eggs in high mountains survived. Probably the nutritional reserves of birches were also higher in the climatically more favorable valleys than in the mountains. Just before the outbreak, the birches had been starving after two very cold summers and did not have enough reserves to replace the eaten leaves.

What is the mechanism behind the collapse and long time lag before the next outbreak of Epirrita populations? The research made by the research group of professor Erkki Haukioja at the Kevo Subarctic Research Station has shown that the quality of birch leaves as the food for Epirrita larvae gets poorer when the leaves are eaten or teared off artificially. The quality changes slightly already in a few days (short-term response), but a more severe long-term induced resistance shows not until the next and the following years. This long-term defence decreases the reproductive capacity of Epirrita at least by 70-80 %. Obviously this can call off an outbreak, but also parasites and predator play a major role.

Similar fluctuations are common in many other herbivores in the arctic. E.g. lemmings and voles occur in four-year cycles in Scandinavia. These cycles become stronger and more regular towards north. Also the well known pest of pine, Neodiprion sertifer, has a two-year epidemic cycle at the alpine timberline in Saariselkä. The common denominators of these phenomena are 1) the poor resistance of plants against herbivores under stressful conditions and 2) very simple food webs where only a few predator species regulate herbivore populations.

THE GREEN GOLD OF THE NORTHERN COUNTRIES

Markus Lassheikki

Dear friends,

On behalf of the Finnish Forestry Association I wish you all welcome to this internordic forest and forestry exhibition.

The exhibition is entitled "the Green Gold of the Northern Countries", and it is the first internordic exhibition of it's kind. All five Nordic countries: Sweden, Norway, Denmark, Iceland, and Finland have built this exhibition together. It will circulate in the Nordic countries for 3 to 4 years, telling the general public, both young and old alike, about our "Green Gold"; the forest. The exhibition is a unique proof of what the forestry peoples in different countries can bring about when they work together.

Today, when a big and growing part of the population lives in cities and suburbs, the connection with the original environment is lost, and the forest is often seen as a place only for recreation. The aim of the exhibition is to inform the public of the great importance that forests and forestry have had through the times for the Nordic peoples. The forest has meant, and still means welfare today, but it also means much more. Forest products are used in our everyday life, and the forest is the place where we northerners prefer to rest after the hard and often stressing daily work of today's modern life. The forest has always had a special place in our traditions and religions, and even today it gives us a sense of security. As peoples of the Nordic countries we had, and still have the great majority of the land around us covered with forest, and this we have been, and always will be proud of.

Most of all, however, the forest is a source of raw material for our most important export industry. Though the Nordic countries comprise of only a small percentage of the forested area of the world, the forest products, exported from these countries stand for approximately 20 % of the world forest exports. Forestry, therefore, is an extremely important employer in the Northern countries.

Nordic forestry is said to be a successful battle against a cold and severe climate. When the growing age of a stand varies between 80 and 160 years, the forestry people have to work objectively.

The fruits of our work obtained from the processes of seeding, planting, protecting and caring of young stands will not be ours to harvest, but that of our grandchildren. The growing time may seem to be an insuperable length of time but we still rely upon the forests to guarangee our well-being even after a hundred years, and it is hoped that the quality of Nordic timber will remain high, and still be greatly sought after as it is today.

The evergreen Nordic woods are a world full of beauty and possibilities, a world with space enough for everybody. Dear friends, it is a great honour to have you here, I hope you will enjoy the exhibit, and this part of the Nordic woods.

PROGRAM

Final version of August 16th.

Symposium themes:
Larix in northern boreal forests.
Site preparation in northern boreal forests.
Forest management in protection forests close to timberline.

Organizer:
The Finnish Forest Research Institute, Rovaniemi Research Station, Eteläranta 55, 96300 Rovaniemi, Finland, attn: Dr. Hannu Saarenmaa, head. tel: +358-60-15721, telex: 37004 RVNMI SF FFRIROI

Accommodations:
16-18.8. Hotel Ounasvaara in Rovaniemi tel: +358-60-23371
18-19.8. Hotel Kultakero in Pyhätunturi tel: +358-692-12081
19-22.8. Hotel Riekonlinna in Saariselkä tel: +358-679-81601

Sunday 16.8.

12:00	Registration begins at hotel Ounasvaara in Rovaniemi, setup of posters
18:00	*Welcoming address*: chair DR.H.SAARENMAA Introductions, a word from the organizer
18:10	Dinner
19:40	Opening: WP CHAIRMAN DR.E.C.PACKEE
20:00	Opening remarks from The Finnish Forest Research Institute: PROF.A.NYYSSÖNEN
20:20	Northern boreal forest resources, their utilization and ecology: PROF.K.KUUSELA
21:00	Nine thousand years of forests in Finland: DR.S.-E.APPELROTH

Monday 17.8.

	Breakfast at hotel Ounasvaara in Rovaniemi
8:00	Poster session begins
8:00	Session *Site preparation in northern boreal forests*
12:00	Lunch
13:00	Photography, interviews
13:05	Poster session showtime
13:40	Session *Larix in northern boreal forests*
15:45	Visit to The Finnish Forest Research Institute, Rovaniemi Research Station: DR.H.SAARENMAA
16:30	Sightseeing in Rovaniemi Visit at the Arctic Circle
18:00	Exhibition "The Green Gold Of The North" and reception of the city of Rovaniemi at the City Library Building: LORD MAYOR M.PELTTARI
19:00	Evening free
19:00	Poster session ends -- removing of posters

Tuesday 18.8.

	Breakfast at hotel Ounasvaara in Rovaniemi
8:00	Bus to Kivalo, presentation of the experimental forest: LIC.A.RITARI
9:30	Full-grown larch stand in Siperia: DR.E.POHTILA -- coffee
10:15	Young larch stands in Höpöttäjä: M.VARMOLA
11:00	Moose and forest management in Höpöttäjä: DR.T.HELLE
11:30	Lunch (moose stew) at Sieväkari cabin
12:20	Bus to Kemijärvi
13:30	Visit at the Veitsiluoto pulp-mill in Kemijärvi: A.EERONHEIMO

14:00 Continue
14:30 Coffee at Kummunjärvi cabin
15:00 Forest regeneration results and site preparation plots at Kemijärvi common forest (Nälkämä-Nuolivaara-Tunturipalo): DR.H.SAARENMAA, DR.E.POHTILA
17:30 Bus to Pyhätunturi
19:00 Dinner at hotel Kultakero in Pyhätunturi

Wednesday 19.8.

Breakfast at hotel Kultakero in Pyhätunturi
8:00 Bus to Sodankylä Siurunmaa
9:00 Private forestry: the farm of P.ONNELA -- coffee
Administration: J.YLIMARTIMO
Rules & regulations of forest management: M.HYPPÖNEN
Government support on forest improvement: M.HYPPÖNEN
11:00 Bus to Sodankylä
11:15 Lunch at restaurant Kantakievari
12:30 Bus to Poksaselkä, soil preparation, narrator PROF.G.SIRÉN
13:30 Site preparation field experiment: LIC.A.RITARI -- coffee
15:00 Bus to Tankavaara
16:00 Geological features of Lapland and interglacial larch subfossils: DR.P.JOHANSSON
16:30 Gold panning museum: manager I.SYRJÄNEN
17:00 Bus to hotel Riekonlinna in Saariselkä
18:00 Dinner
19:00 Business meeting at hotel Riekonlinna: Chair DR.E.C.PACKEE

Thursday 20.8.

Breakfast at hotel Riekonlinna
8:00 Session *Forest management in protection forests close to timberline*
12:00 Lunch at hotel Riekonlinna
13:00 Bus to Forest Service Inari District:
13:20 Reforestation of burned area in Palkisoja: K.PELKONEN
13:50 Continue
14:30 The goal of forest regeneration close to protection forests in Kaitavaara - a young pine stand: A.UUSVAARA
15:00 Continue
15:30 Principles of forest management when expanding into wilderness areas - logging activities in the Kessi area: P.VEIJOLA -- coffee
16:30 Bus to hotel Riekonlinna in Saariselkä
20:00 Lapland barbecue by Ohjelmapalvelu Matti Saastamoinen in Saariselkä

Friday 21.8.

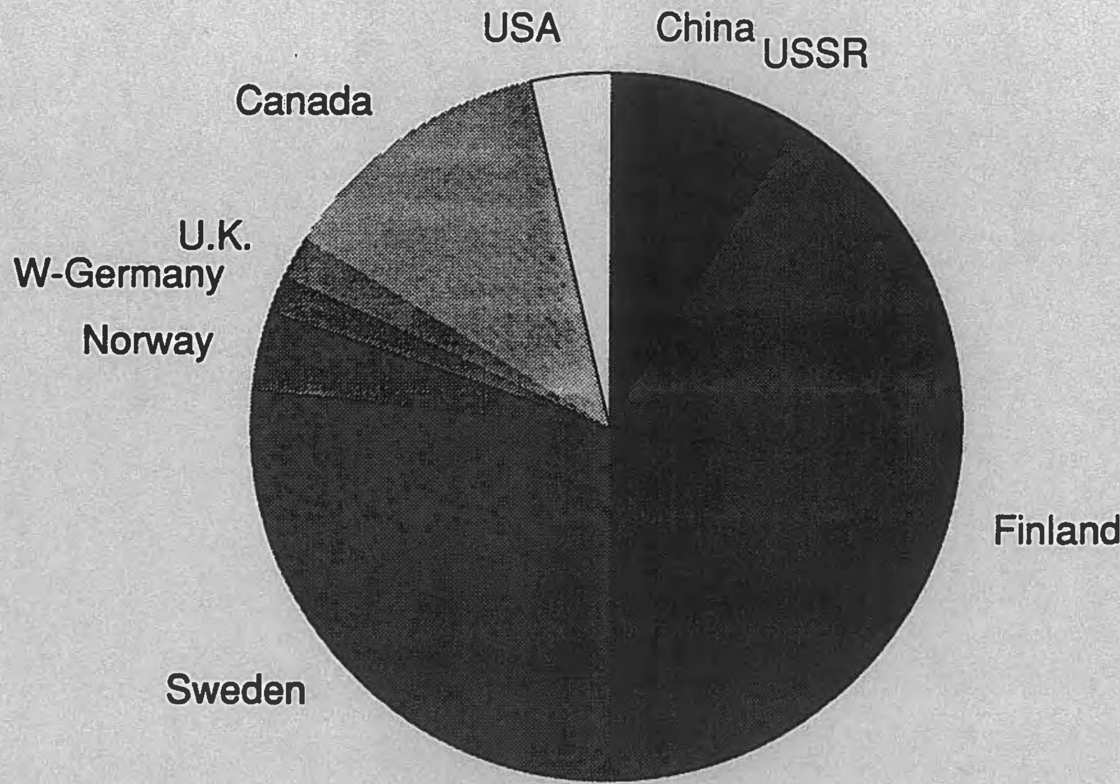
Breakfast at hotel Riekonlinna
7:30 Bus to Inari
8:30 Sámi museum in Inari
9:20 Bus to Kiellajoki
10:00 Three plantations at the timberline in Kiellajoki: PROF.G.SIRÉN -- coffee
11:30 Lunch at Kiellatupa
12:30 On the bus in Kaamasmukka *Epirrita autumnata* defoliation of birch: DR.H.SAARENMAA
13:00 Reindeer husbandry in Karigasniemi Ailigas: DR.T.HELLE
13:20 Bus to Teno valley, sightseeing, 70th latitude
15:00 The northernmost plantation of Finland in Kaava: DR.E.POHTILA -- coffee

15:30	Bus to Kevo
16:00	Kevo Subarctic Research Station and the timberline arboretum: PROF.P.KALLIO
16:45	Bus to Saariselkä -- etc.
21:00	Farewell party at hotel Riekonlinna in Saariselkä

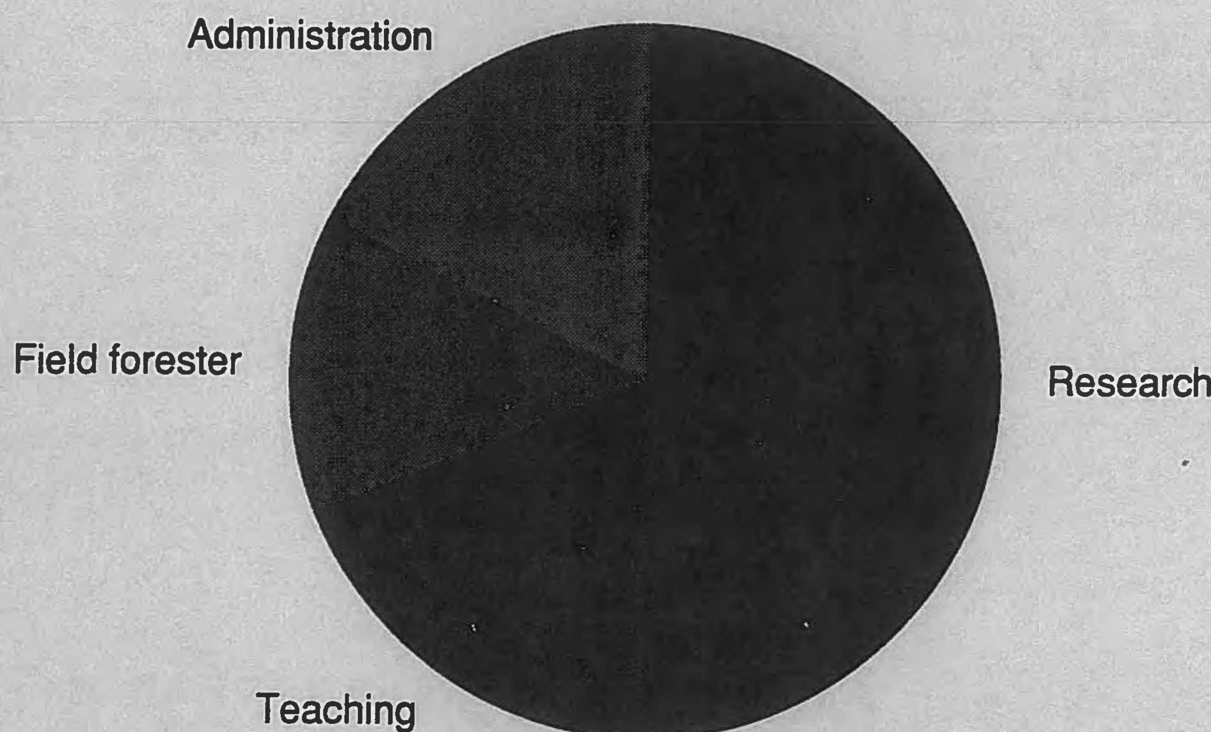
Saturday 22.8.

	Breakfast at hotel Riekonlinna
8:30	Departure to Ivalo
9:00	Shopping in Ivalo
9:40	Departure to Ivalo airport
10:30	Departure by flight to Helsinki (AY 453)
10:30	Departure by bus to Rovaniemi
12:30	Arrival by flight in Helsinki
14:00	Arrival by bus in Rovaniemi
19:00	Departure by train from Rovaniemi
21:05	Departure by train from Rovaniemi

Participants by country



Participants by field



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