F O R E S T   R E G E N E R A T I O N   I N   F I N L A N D

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Summary

The starting point for forest regeneration in Finland is flexibility and economic viability. A strong artificial regeneration period started in Finland at the end of the 1950's. The total area of forest regenerated during the past few years has been 240,000 - 250,000 ha annually. Of this total, about 40 % has been naturally regenerated and 60 % artificially. The combined forest area regenerated artificially in Finland is 3,6 million hectares (c. 18 % of the whole forested area).

The reforestation technique is mechanized. Soil tilling is a prerequisite for succesful natural regeneration. It has been estimated that the productivity of coniferous stands can be increased by 10-15 % as a result of the breeding work in establisment of seed orchards. About 60 % of the planting stock is grown in containers. A computer - aided model have been developed to assist with the choice of the most economical regeneration method.

It can generally be seen from the results of several inventories that reforestation has succeeded fairly well in Finland. About 75 % of the plantations and 60 % of the naturally regenerated young stands have a satisfactory stocking density.

In the future the extent of reforestation is likely to remain at its present level. The proportion of natural regeneration, especially with pine, will increase. As seedlings regenerate naturally in plantations, the conditions for the growing of mixed stands are favourable.

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1. Growing conditions in Finland

Despite its northern location between the 60th and 70th latitudes, the conditions for forest growth in Finland are rather favourable. Owing to the relative proximity of the warm Gulf Stream, the mean annual temperature in Finland is higher than that in other regions situated at the same latitude. The mean annual temperature ranges from $+5^{\circ}C$ in southern Finland to $+1^{\circ}C$ in northern Finland.

The length of the growing season in southern Finland is about 5 months (Fig. 1). The daily mean temperature rises above $+5^{\circ}C$ at the beginning of May, marking the start of the growing season. On the average, the growing season ceases at the end of September. The mean effective temperature sum (threshold value $5^{\circ}C$) is around 1200 - 1300 dd in southern Finland. The growing season only lasts for about 3 months in northern Finland, but the longer day lenght partly compensates for its short duration. North of the Arctic Circle the sun remains permanently above the horizon for almost one month during the growing season.

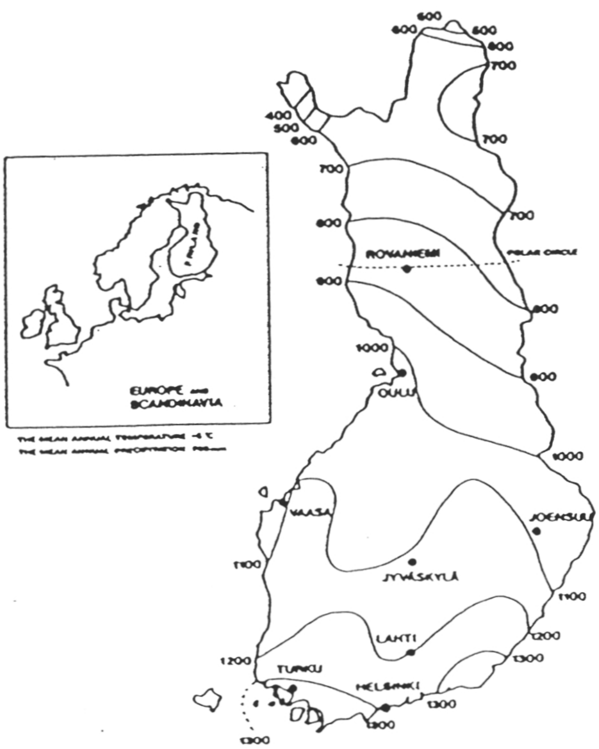

Fig. 1. The length of growing season in different parts of Finland.

The annual precipitation in southern Finland is about 700 mm, and in northern Finland 500 mm. Owing to the low evaporation, the climate is humid. At least one third of the total annual precipitation falls as snow. The permanent snow cover is formed in southern Finland in January and lasts up until April. The mean maximum thickness of the snow cover along the southern coast is c. 25 cm, in South-Finland 50-80 cm and in northern Finland 80-120 cm, depending on the terrain.

The most common types of bedrock in Finland are granite and gneiss. Their most important minerals are feldspars, micas, and quartz. The ice age has had a significant impact on both the soil in Finland and the topography. Most of the till soils, i.e. moraines, were formed as the glaciers withdrew from the southeast to the northwest. Till soils represent around 80 % of our upland soil types. Stratified sand and clay soils are only found along the coast in areas which have been under the sea for some time. The terrain in southern Finland is rather flat, although small hills are common in places.

2. Forests in Finland

About 70 % of the land area in Finland is covered with forest. The total area of forest is 20 million hectares (Fig. 2). Of this 1/3 is wetland. Forest land in Finland is classified according to a vegetation-based system of upland and peatland site types. The system was developed by the Finnish forest botanist A.K. Cajander. In southern Finland, for instance, there are five upland site types used for forestry purposes.

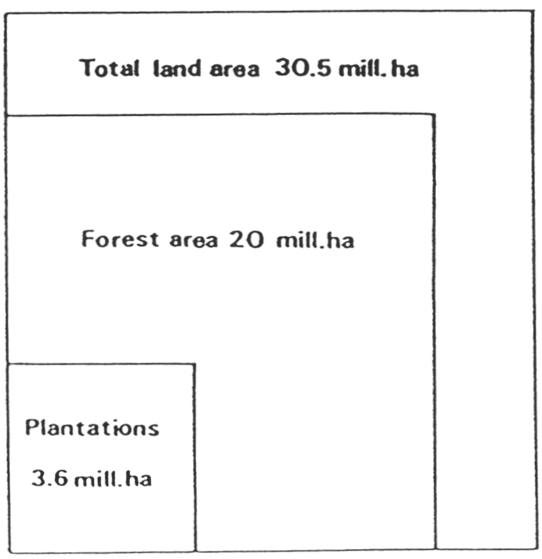

Fig. 2. Total land area, forest area and forest plantations in Finland.

The mean volume of the tree stands on forest land is 90 m^3/ha, and the mean growth in southern Finland is 4-5 m^3/ha/a. The total growing stock in Finland is 1,660 million m^3. The annual total increment is 68 million m^3.

Three commercially important tree species account for 95 % of the forest in Finland. The most common tree is Scots pine (<u>Pinus silvestris</u> L.), which forms around 50 % of all forest. The proportion of Norway spruce (<u>Picea abies</u>, Karst.) is 35 %, and that of birch (<u>Betula</u> spp.) under 10 %. The rest of the forest area is under aspen (<u>Populus tremula</u>) and other deciduous species.

Spruce and birch are the most demanding domestic tree species by soil quality. Pine grows well on the most infertile sites. At its best, the total production of all these tree species exceeds 500-600 m^3/ha. The development of birch is the fastest. The commercial rotation period for birch in southern Finland is 40-50 years, for spruce 50-60 years, and that for pine 80-100 years.

Since the growth of domestic tree species is good and all main tree species represent valuable raw-materials for the forest industries, there has been no immediate need in Finland to plant exotic tree species. Finnish pine is especially in demand as sawtimber owing to its high quality. Lodgepole pine (Pinus contorta) and larch (Larix sibirica) have, however, been cultivated to a small extent in Finland.

3. The extent of forest regeneration in Finland

Up until the 1950's most of the forests in Finland were regenerated naturally. In the early days the natural regeneration methods were, however, very rough and ready. It was believed that seedlings would become established without any special measures having to be carried out. At the beginning of the century artificial regeneration was used in Finland to a small extent only. Pine was sown and spruce planted. The artificial regeneration methods used in practice were based on those developed in Central Europe.

After the Second World War forestry in Finland began to be developed very intensively. The economic boom was based on forestry. Over 2/3 of Finland's net export income was derived from products of the forest industries. A strong artificial generation period started in Finland at the end of the 1950's. Natural regeneration started to give way to artificial regeneration. Artificial regeneration was seen as one of the most effective means of increasing Finland's wood production and, through this, the future cutting possibilities. Various funding programmes (MERA Programmes) enabled a start to be made on extensive artificial forestation. Intensive artificial regeneration has thus so far been practiced for around 30 years.

The combined forest area regenerated artificially in Finland at the present is 3.6 million hectares. This is equivalent to c. 18 % of the whole forested area.

The total area of forest regenerated during the past few years in our country has been 240,000-250,000 ha annually. Of this total, about 40 % has been naturally regenerated and 60 % artificially. In addition to the naturally regenerated areas formed as a result of cutting activities, natural regeneration has also been practised on drained peatlands, as well as in pine and birch stands where spruce undergrowth gradually forms the new stand, at an annual rate of around 50,000 hectares.

The type of regeneration technique used varies considerably from area to area. Artificial regeneration is most common in central and eastern Finland, where the proportion of natural regeneration is only slightly over 20 %. In southwestern Finland the proportions are about equal.

Pine is the most favoured tree species in both artificial and natural regeneration (Fig. 3). The proportion of pine in plantings during the first half of the 1980's has been 75-80 %. At the present time, however, the proportion of pine is clearly decreasing and that of spruce and birch correspondingly increasing. 80-90 % of the cuttings directed at natural regeneration are done in favour of pine.

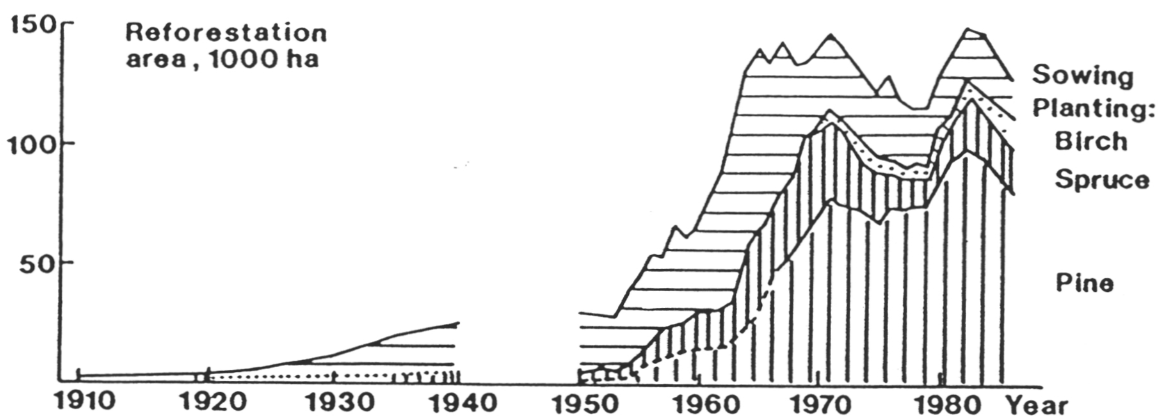

Fig. 3. The artificial reforestation in Finland in 1910-1985.

Forest tree seedlings have been produced in our country during the past few years at an annual rate of 220-240 million. The proportion of containerized seedlings out of total seedling production is around 60 %. In 1986 Finnish tree seedling production was distributed according to tree species as follows:

	Million	% of total production
Pine	176	70
Spruce	61	24
Birch	10	4
Others	5	2
Total	252	100

The role of soil tilling in the preparation of the regeneration areas has shown a continuous increase during the past few years. At the present time, about 80 % of the regeneration areas are tilled. The proportion of tilled regeneration areas in southern Finland is 40-50 %, and in Lapland almost 95 %. The area subjected to light soil tilling has increased rather recently. The most popular soil tilling device is TTS forest harrow.

4. Forest regeneration methods

4.1. Natural regeneration

The most common natural regeneration method is pine seeding felling. The natural regeneration of spruce takes place through the shelterwood felling method. Under favourable conditions the natural regeneration of pine and spruce can also be done by the strip felling method (Fig. 4). The width of the clear-cut strip must not, however, exceed 50 m. Strip felling is used especially in the natural regeneration of pine in Lapland, and in the natural regeneration of spruce on spruce swamps in southern Finland.

Fig. 4. The natural regeneration of pine with seeding felling method.

There are two key factors which determine whether natural regeneration can be used: the seed production of the seed trees, and the ability of the soil to produce viable seedlings. The pine seed crop in southern Finland does not represent an obstacle to the use of natural regeneration. Pine produces an abundant seed crop in southern Finland two or three times every 10 years. The seed trees are left on the regeneration site at a density of 50-120 trees/ha. In general, a seed crop of some sort or other is produced every year. According to measurements of the size of the seed crop, the average number of pine seeds falling on 1 m^2 of ground each year is 50-150.

The greatest obstacle to the success of natural regeneration is the capacity of the soil to produce and maintain a viable seedling stand. On the fertile sites the vigorous development of the ground vegetation does not usually favour the natural formation of a seedling stand. Soil tilling considerably improves the seedling-bearing capacity of the soil. 4-5 times more natural seedlings develop on tilled soil than on untilled soil. The broken surface remains bare in southern Finland for 3-4 years, which is usually long enough to coincide with a good seed year. Seed trees are kept on the regeneration site for 5-7 years.

The natural regeneration of spruce has proved to be clearly more uncertain than that of pine. The annual variation in the seed crop of spruce is exceedingly large. Spruce flowers abundantly in southern Finland as many as 5-6 times every 10 years, but a good seed crop can be expected perhaps only once every 10 years. Damaging agents significantly decrease the total amount of spruce seed produced.

Shelterwood felling can only be carried out in spruce stands if, owing to the presence of openings or other small groups of trees, there are clear patches of viable seedlings growing under the overwood. Experience has shown that the development of a viable seedling stand only takes place on sites where the seedling-bearing capacity of the soil is favourable. Young, naturally regenerated spruce stands easily become very patchy. Soil tilling in spruce stands is problematic owing to the risk of root damage.

So far, the natural regeneration of birch has been carried out only on a very small scale in Finland. Seed production is not a limiting factor in the natural regeneration of birch because good seed crops occur every two or three years. However, the natural regeneration of birch is not certain unless the soil surface is tilled.

4.2. Artificial regeneration

4.2.1. Seed production

The basic prerequisite for artificial regeneration is a reliable and correctly dimensioned supply of seed. On the other hand, artificial regeneration is the only technique which can be used to fully exploit the breeding gain in forest regeneration. It has been estimated that the productivity of coniferous stands in Finland can be increased by 10-15 % as a result of the breeding work carried out in establishing present-day seed orchards.

The total annual need for forest tree seed over the next few years in Finland is estimated to be 13,500 kg. This is distributed according to tree species and use as follows:

Pine stand sowing	9,000 kg
Pine seedling-nursery sowing	3,000 kg
Spruce seedling-nursery sowing	1,400 kg
Birch (B. pendula) seed	50 kg
Larch seed	100 kg

In addition, small amounts of lodgepole pine seed and the seed of a few deciduous species, e.g. alder (Alnus glutinosa), are also produced.

The seed used in artificial reforestation always has to undergo a certain degree of geographical transfer. In the case of pine seed of local origin is used as much as possible. If local seed is not available, then seed from an area with more severe climatic conditions is used. Seed transfer takes place from north to south (maximum 100 km), and from higher altitudes to lower (maximum 150 m drop).

Seed transfer from south to north (100-300 km) is possible in the case of the artificial regeneration of spruce. Some of the southernmost spruce stands in Finland have been established using seedlings grown from seed collected in the northern parts of Central Europe. Progeny transfers are done over distances of [illegible]0 km in both a north-south and south-north direction.

Forest tree seed is collected in seed orchards, seed collection stands approved by the Finnish Forest Research Institute, and in preselected, final cutting stands. There are about 5,300 ha of seed-collection pine stands, 1,200 ha of spruce stands, and about 100 ha of birch stands. The cones are collected from the standing trees in seed-collection stands.

A total of c. 3,100 ha of pine seed orchard, c. 300 ha of spruce seed orchard, and c. 50 ha of seed orchard for other tree species, have been established in Finland (Table 1). The age at which seed production starts in pine seed orchards is considered to be 15 years. By the beginning of the 1990's, all the pine seed orchards will have reached the seed-bearing age. It is assumed that the seed production in pine seed orchards will rise to about 6-7 kg seed/ha/a. At the present time, the total seed requirements of seedling nursery production in southern and central Finland are supplied by the pine seed orchards. In northern Finland, on the other hand, it will take some time before seed-orchard supply can meet demand.

Table 1. Clonal seed orchards in Finland.

Species	Number of orchards	Area, ha	Number of clones
Pinus silvestris	207	3 000	6 235
Picea abies	26	294	559
Larix sibirica	12	41	203
Betula	1	0,1	115
Other deciduous	8	10	156
Total	254	3 345	7 268

Spruce seed orchards mature considerably more slowly than pine seed orchards. Flowering starts much later in spruce seed orchards and is very irregular during the early stages. The age at which reliable seed production starts in spruce is considered to be 20 years. For the time being there is no seed-orchard seed available for artificial regeneration purposes.

Birch seed orchards have been established in Finland using the greenhouse techniques developed by the Finnish Foundation for Forest Tree Breeding. The seed obtained from these orchards already almost completely meets the practical demand for birch seed.

4.2.2. Tree seedling production

The annual production of forest tree seedlings in Finland is about 240 million, of which 60 % are containerized. The nurseries run by the private forestry sector produce the greatest amount of seedlings. The National Board of Forestry has changed over almost completely to the use of containerized seedlings. There are more than 50 seedling nurseries greater than 1,5 ha in size in Finland. The total area of these nurseries is 1,100 ha. The largest nurseries have an area of over 50 ha.

Bare-rooted seedlings

In principle, bare-rooted seedlings are produced in Finland in three different ways:

1. Broadcast sowing in the open - raising - planting
2. Broadcast sowing in the greenhouse - raising - transplanting - planting
3. Row-sowing in the open - raising - root cutting - planting

The traditional and most used method for producing bare-rooted seedlings is transplanting. This is done to all tree species. The initial raising of the seedlings is usually done on a peat substrate in the greenhouse. After the first growing season the seedlings are transplanted into the open. This is usually done in the spring but, owing to labour shortages, it also has to be done in August in late summer. Late-summer transplanting is most suited to spruce seedlings.

The transplanted seedlings produced in the greatest numbers are 2-year-old pine transplants (1+1), 4-year-old spruce transplants (2+2), and 2-year-old birch transplants (1+1). The height of the pine transplants at the time of planting usually varies from 10-15 cm, that of spruce transplants from 30-40 cm, and that of birch transplants from 40-60 cm.

The methods used for producing bare-rooted seedlings have become highly mechanized. Sowing in the open is done almost without exception by machine. The sowing machines are the same type as the drilling machines used in sowing field crops. Precision-sowing machines have been developed for row sowing which are capable of sowing the desired amount of seeds per metre. The most popular transplanting machines consist of various devices pulled by a tractor. The ploughshare of the machine cuts a furrow into which the seedlings are transplanted at distances of 5-6 cm with the aid of rubber disc, A unit capable of transplanting 15 rows at a time has been built in Finland. The output of machines of this sort is 200,000-250,000 transplants/working day.

Use of the root-cutting method presupposes row sowing. This technique has been applied to the production of pine seedlings. Cutting is done by a device pulled behind a tractor which simultaneously cuts downwards on both sides of the rows and underneath using a J-shaped cutter. While cutting, the blades of the cutter jerk backwards and forwards. Cutting is usually done in the middle of the growing season following the cessation of pine height growth.

Attempts have also been made to mechanize seedling lifting. A machine has been developed in Finland which is capable of lifting the seedlings in one bed (5 rows at a time) (HARTER). The lifting machine can lift 100,000-150,000 seedlings/day. Following lifting, the seedlings are usually packed into sacks. The plastic sacks used in Finland are white on the outside and black on the inside.

Fertilizers are spread on the seedling beds in the open in solid form - pellets or powder. The fertilizer requirements are determined on the basis of soil analyses and of practical experience. Soilanalysis-based fertilizer guidelines have been drawn up to assist the planning of fertilizer regimes. Weed control is usually done by chemical means. Under Finnish conditions, the seedlings usually have to be treated in the autumn with chemicals to protect them against pathogenic fungi during the winter. The seedlings in the nursery usually have to be irrigated during the summer using, e.g. portable irrigation piping. Up to now, mulching has not been used very much in Finland. The most common meliorating agent used in nurseries is peat.

Containerized seedlings

Containerized seedlings were first used in artificial regeneration in Finland at the beginning of the 1970's. Economical aspects have meant that the production lines for containerized seedlings have to be as rationalized, mechanized and automated as possible. The containerized seedling has become a biological conveyor-belt product.

The selection of which type of containerized seedling to use is determined by e.g. ease of handling, transport and planting, the rationalization in the nursery, the possibility of lengthening the planting season, and the price of the seedlings. There are a number of different containerized seedling methods on the market owing to the wide range of requirements and preferences.

The most popular containerized method in Finland at the present time is the paperpot. About 70 % of the containerized seedlings produced in Finland are paperpot seedlings. As the size of the pot can be varied, they are suitable for the production of pine, spruce or birch seedlings. The majority of paperpot seedlings are produced at the present time using the so-called ecopot-method. The paper, which is covered with a thin of plastic film, can be torn away from around the roots immediately prior to planting out. In this method the seedlings are planted without any container.

There is a fully automated line available for filling the paperpots, sowing and covering the seeds. The line is capable of filling and sowing over 350,000 pots/working day.

Other corresponding containerized methods include the TAKO (exploded polystyrene block), Ensopot and the peatpot (Finpot) methods. Containers of a range of different shapes and sizes are also available for these methods. The methods are suitable for the production of pine, spruce and birch seedlings. The Kombiform method, developed in Norway, is also used in the production of transplanted containerized seedlings.

The Vapo-method, which differs considerably from the traditional containerized seedling methods, is a new promising technique (Fig. 5). The method is based on the use of a block of compressed and dried peat. When moistened, the block swells up to a size ready for sowing. The seeds are sown in the block at regular intervals (e.g. 5 x 5 cm). The roots and peat block are cut on all four sides of each seedling mechanically during the raising process. This results in a self-contained container without any supporting material. Cutting interrupts root growth and initiates the formation of new root primordia. The dense root system holds the peat together to form its own small block. Very promising results have been obtained with the method and, at the moment, it is being applied to the production of small containerized seedlings in a number of nurseries. The same principle can also be used for different-sized seedling types and for different tree species.

In conclusion, it is apparent that there are a number of suitable solutions available for the production of small, one-year-old containerized seedlings. On the other hand, it has not yet been possible to develop completely satisfactory production methods for large, two-year-old containerized seedlings.

Containerized seedlings are grown, almost without exception, in plastic greenhouses. Irrigation and fertilization are fully automated, the fertilizer usually being given dissolved in the irrigation water. The watering requirements are monitored using various transducers or a solar integrator. Blinds and shades have sometimes been constructed in the plastic greenhouses so that winter hardiness can, if needed, be induced in the seedlings.

Fig. 5. In the VAPO-method, the containerized tree seedlings are produced without any container walls by cutting the roots and the peat sheet.

As the roots of the seedlings produced in most of the containerized methods grow down into the underlying soil, attempts have been made to grow the seedlings in the air on top f grids. The growth of the roots out of the bottom of the containers can also be regulated by cutting or by growing the seedlings on top of a concrete or asphalt base.

After the containerized seedlings have been growing for 2-3 months in the greenhouse, they are usually transferred outdoors in early summer in order to harden them before planting. The containerized seedlings are transported directly to the planting site in various types of container without any intermediate storage. Transportation is usually done by lorry. They can also be taken to the planting site by helicopter if the terrain is very rough.

Seedling quality

Certain quality norms are applied during seedling production in order to ensure a good result in the field. The quality norms in Finland are based on morphological parameters. Grading of the seedlings initially takes place, in connection with lifting, on the basis of their minimum height. The new norms, based on the results of extensive research work, which were formulated ten years ago, were clearly more exacting than the earlier ones.

In Finland, pine, spruce and birch bare-rooted seedlings are divided into size classes on the basis of their height. Four different size classes are used (Table 2). The whole growing lot is graded as one. The individual seedlings must meet a certain normative height and minimum root-collar diameter. Those seedlings which do not fulfil these criteria are destroyed. The seedling-quality, grading norms are reviewed each year. A considerable amount of research work has been done in recent years on seedling physiology but, for the present, it has not been possible to formulate any physiological seedling-quality norms.

Table 2. Morphological size requirements for bare-rooted Scots pine seedlings in Finland.

Scots pine (*Pinus sylvestris*)	Size class			
	I	II	III	IV
(1) The median height of the seedling lot, cm	-12	13-18	19-25	26+
(3) The minimum height, cm	6	10	15	21
(4) The minimum diameter (1-2 cm above the root collar), mm	2.5	3.0	3.5	4.0

So far, no proper quality norms or grading guidelines have been set for containerized seedlings. However, there are grading suggestions for the management of seedling production which include minimum and maximum heights and a targeted mean height (Fig. 6). The volume of the container, and indirectly the growing density of the seedlings, determine the height norms. The upper height limit avoids the production of seedlings which are too tall and slender. The aim in production is that there should only be one seedling per container. Particular attention is paid in containerized-seedling production to the formation of the root system and the condition of the roots.

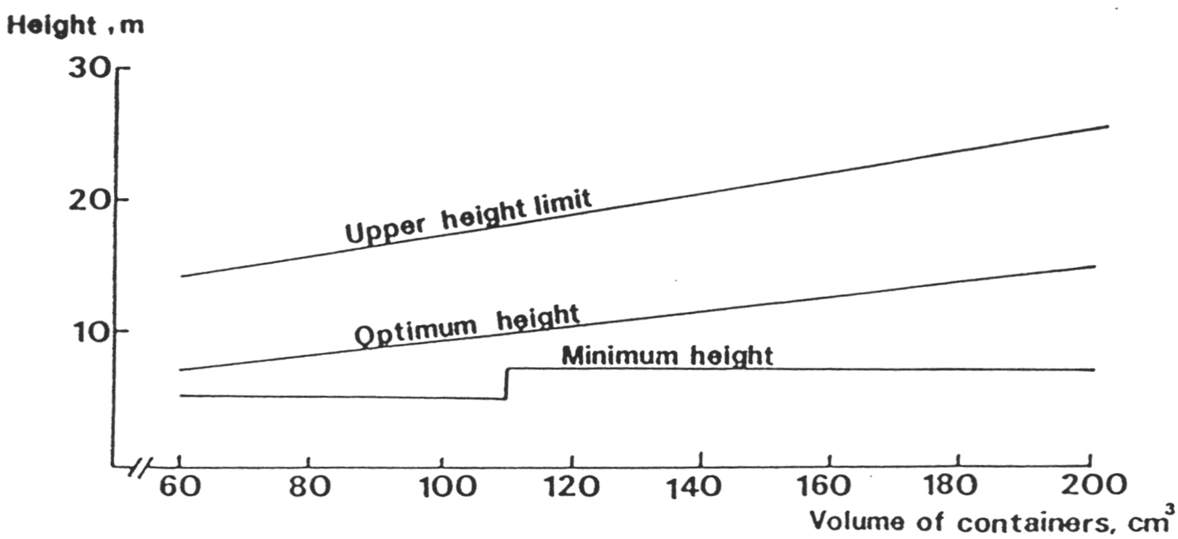

Fig. 6. Standards for grading of containerized tree seedlings.

4.3.3. Planting

Under Finnish conditions, the traditional time for planting is in the spring. As far as is possible, bare-rooted seedlings should be planted in May. The planting season for containerized seedlings can be extended up until mid June. Spruce and birch seedlings can also be planted in late summer, in August.

Bare-rooted seedlings are in most cases planted in tilled soil using a planting mattock. A pot tube is used in planting containerized seedlings. Pot-tube planting (Pottiputki) is the best method from the ergonometric point of view, and has made it possible to increase the planting output.

The possibilities of fully mechanized planting have also been investigated in Finland. The planting machine with the highest degree of mechanization was developed by Serlachius Ltd. However, the type of terrain, topography and high stoniness of the soil in Finland set insuperable obstacles on the mechanization of planting in Finland. No suitable solution has so far been found to the problem of mechanizing the planting work.

The most common planting density for pine stands has been 2,500 seedlings/ha. However, the planting density has had to be re-examined owing to doubts about the quality development of pine. At the present time, a flexible planting density range of 2,500-3,500 seedling/ha is used depending on the quality of the site. A planting density of 2,000 seedlings/ha is usually used in establishing spruce stands, and 1,600 seedlings/ha for birch.

5. The results obtained in reforestation work

Extensive reforestation means a considerable investment in forest cultivation work. It is essential that reliable information be obtained about the success and condition of the young plantations if the work is to be managed correctly. The Finnish Forest Research Institute, the universities of Helsinki and Joensuu, and certain of forest-owner organizations have carried out a large number of reforestation surveys in Finland during the past 20 years.

There is naturally a considerable amount of variation in the regeneration results since it depends on how regeneration is carried out, the tree species, the site type, the forest-ownership group and the geographical region in question.

It can generally be seen from the results of several inventories that reforestation has succeeded fairly well in Finland. About 75 % of the plantations and 60 % of the naturally regenerated young stands have a statisfactory stocking density. Most of the damage in young stands is caused by the ground vegetation, pine canker, voles and elks.

About one third of the planted seedlings have died in pine plantations. Seedling mortality has continued for at least 10-15 years after establishment. However, naturally regenerated seedlings appear in pine plantations and, through this supplementary seedling material, the plantations retain a statisfactory density. The presence of naturally regenerated seedlings means that the plantations develop into mixed stands (Fig. 7).

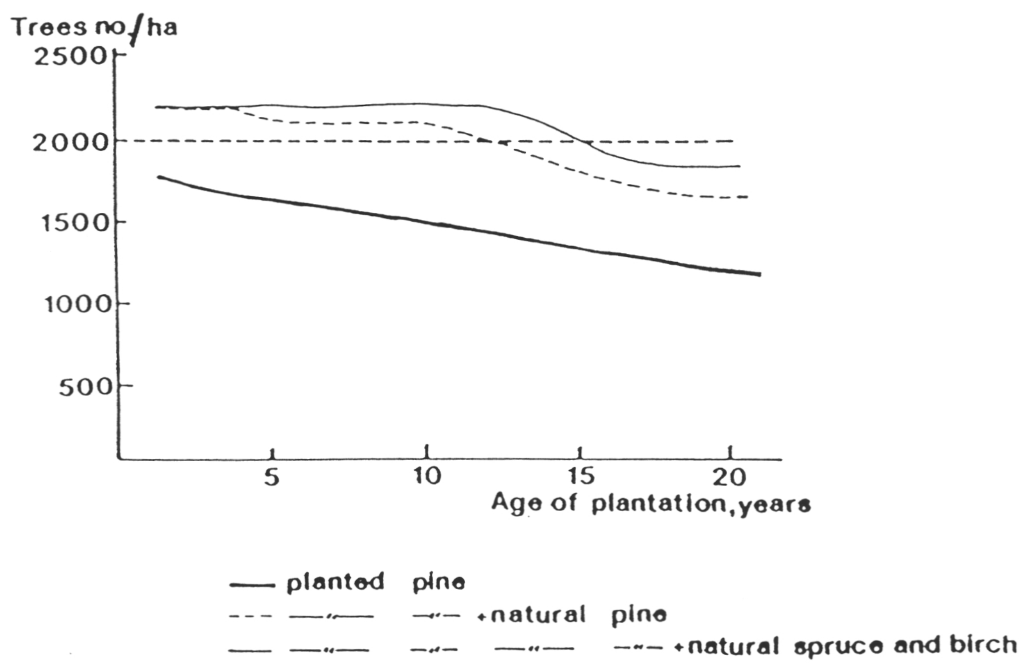

Fig. 7. The acceptable seedlings in pine plantations in South-Finland.

No decisive differences have been found between the success of artificially and naturally regenerated young stands. However, artificial regeneration is one means of obtaining a stand at a considerably faster rate than through natural regeneration. The time gained in artificial regeneration with pine, compared to natural regeneration, varies in southern Finland between 8-12 years depending on the quality of the site. The time gained in the case of spruce may be as much as 15 years on the most fertile sites. Pine plantations achieve a dominant height of 5 m 5-7 years earlier than in sown stands. The difference in height development of pine plantations between different site types is 2-3 years (Fig. 8).

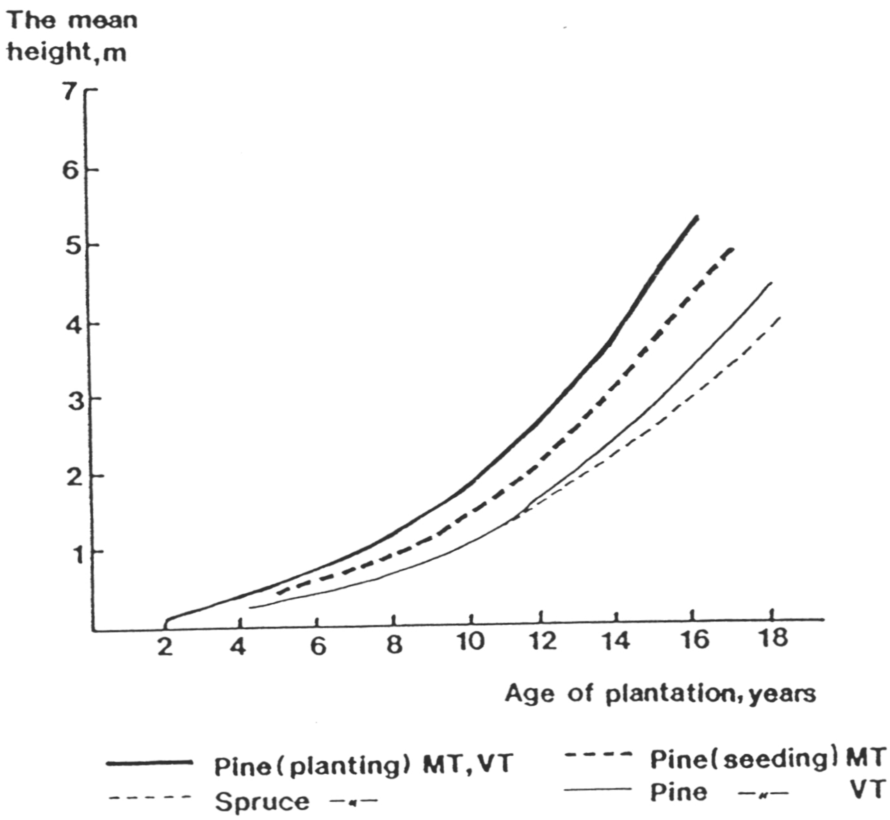

Fig. 8. The height development of plantations in South-Finland.

The surveys have brought to light two features associated with artificial reforestation: The original stocking density of plantations has often remained lower than the targeted one, and the post-treatment of those plantations which have not succeeded has not been carried out very well. Control of the ground vegetation or stump sprouts has been delayed or completely neglected. As much as one half of all the reforestation areas surveyed have been found to be in urgent need of treatment.

The mortality of the seedlings and the frequently encountered too low planting density, have resulted in failure to meet the targeted density. For this reason, an attempt is now being made to increase the original planting density in young pine stands in order to ensure a future supply of high-quality sawtimber.

The surveys of the oldest pine plantations show that root deformation is not a threat to the future development of the stand. Bare-rooted seedlings are the most susceptible to root deformation. At the most, 10 % of the trees in plantations established using bare-rooted seedlings have been found to suffer from severe butt bending caused by root deformation (Parviainen and Antola 1986). It is easy to remove such trees during the first thinning. The stem form of stands established using containerized seedlings develops almost as well as that of naturally regenerated stands. It is obvious that the container protects the roots in the planting.

6. Regeneration costs

It is the practice in Finland to examine reforestation as a chain which starts from final cutting, and finishes at the first thinning stage of the young stand. Thus reforestation costs include the costs of all the individual substages. For instance, the seedlings and planting form only one stage in the whole process of artificial reforestation.

The mean costs of artificial reforestation are, at the present time, about FIM 5,000-6,000/ha. The costs of the seedlings and planting represent about 40-50 % of the costs. Control of the ground vegetation is needed three to four times on fertile sites in order to ensure that regeneration is successful. Stump sprout control is also needed three to four times on fertile sites, depending on the method used, before the plantation reaches the 5-m dominant height stage (Fig. 9).

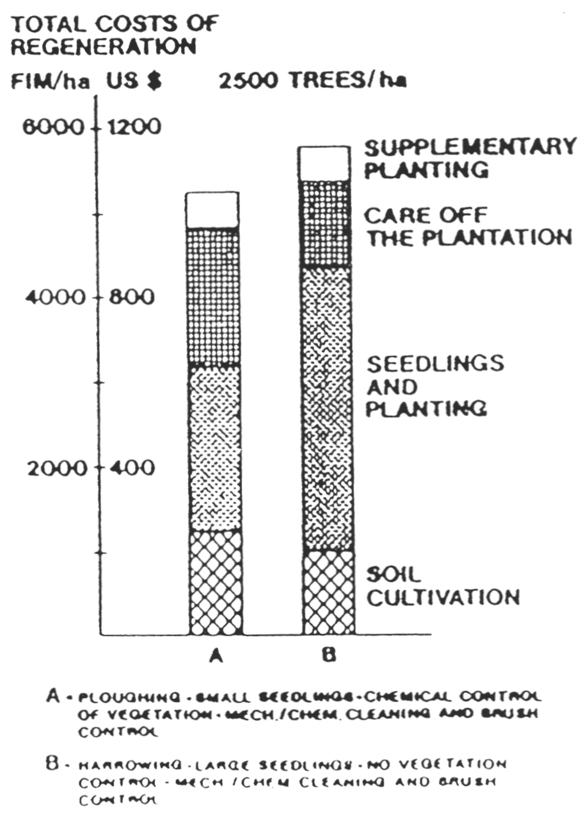

Fig. 9. The regeneration costs in two typical reforestation chains.

The costs of natural regeneration on a correctly chosen site are lower than those of artificial regeneration. The regeneration time determines whether natural regeneration is a viable option. If the regeneration time is considered an important criterion, then the total costs of natural regeneration usually approach those of artificial regeneration.

7. Choice of regeneration method

Computer-based models have been developed in Finland for comparing different regeneration alternatives. The so-called VILJO programme is being used in the private forestry sector. The aim of the VILJO programme is to make regeneration decision-making more precise by examining the whole chain using a calculation system. The aim has been to combine the biological knowledge about regeneration with the costs of the r ;eneration stage and the future timber producing capacity and value of the stand being established. The total costs of regeneration are examined with respect to the certainly of successful regeneration. The programme provides the basic information needed for selecting the most profitable regeneration chain.

The VILJO programme is, above all, a decision-making tool which those involved in regenerating stands can use to generate a large number of different regeneration alternatives in order to find out which would best suit his own situation. All the most important reforestation situations in southern Finland are depicted in the programme on the basis of the site type, previous tree generation and tree species to be established. The programme simulates the development of the young stands established using different alternatives, stretching from the regeneration stage up until the first thinning stage.

Th VILJO programme can also be used to examine a wide range of planting densities (1,600-10,000 seedlings/ha) in artificial regeneration. The programme thus permits investigation of the effects of increasing the planting density. It is also possible using the system to estimate the effects of the regeneration intensity level on the overall costs. In other words, the way n which different stump-sprout control or ground vegetation ontrol methods affect the results and costs of regeneration can e studied.

. Conclusions

he starting point for forest regeneration in Finland is lexibility and economic viability. Regeneration is seen as a omplete entity which is composed of biological, economic and echnological factors. The extent of reforestation is likely to emain at its present level. Artificial regeneration will also the main method used in reforestation work during the coming ecades. The introduction of new biotechnological methods in tificial regeneration is most likely to concern birch first. owever, the proportion of natural regeneration done in reforestation with pine, especially, will increase. As seedlings regenerate naturally in plantations, the conditions for the growing of mixed stands are favourable.

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