CONTAINERIZED FOREST TREE SEEDLING PRODUCTION AND DEVELOPMENT PROSPECTS IN FINLAND AND SCANDINAVIA

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Abstract.--Sweden, Finland and Norway produced 250, 65 and 40 million containerized seedlings, respectively, in 1980. Paperpot seedlings accounted for 210 million of the total figure. Although climate—controlled greenhouses are frequently used for crop production, maximum biological benefits have yet to be achieved. Development work aims at the integration of seedling production and planting systems, including the development of advanced planting machines. Norway is changing to containerized seedlings most rapidly, with 60% of total planting stock being containerized in 1980.

Résumé.--En 1980, la Suède, la Finlande et la Norvège ont produit respectivement 250, 65 et 40 millions de plants en mottes emballées. De ce nombre, 210 millions ont été produits dans des pots de papier. Bien qu'on emploie fréquemment des serres à climat contrôlé pour la production des cultures, on n'a pas encore réussi à obtenir le maximum d'avantages biologiques. Les travaux de développement visent à intégrer la production de semis aux systèmes de plantation et à mettre au point des machines à planter perfectionnées. La Norvège est le pays qui se convertit le plus rapidement au système des plants en mottes emballées; en 1980, 60% de son matériel de reproduction était composé de ces plants.

INTRODUCTION

Finland, Denmark, Sweden and Norway have similar forestry problems. They all have relatively important and similarly developed forest industries, and there is a great deal of mutual cooperation among the four countries. Several joint working groups have been set up in the reforestation sector, such as the Nordic Committee for Forest Seed and Seedlings (NSFP), established in 1970.

There are, however, rather considerable geographical differences both within and among these countries. Denmark, southern Sweden and Norway resemble oceanic regions of central Europe. The annual precipitation of Norway sometimes exceeds 5,000 mm, whereas that of the other Scandinavian countries ranges from 500 to 800 mm. The length of growing season ranges from 210 days in Denmark to 130 days in more northerly areas. In northern Finland, Sweden and Norway, forestry activities are carried out right up to the treeline, where conditions are extreme.

The area covered by forests in Sweden is 24 million ha, in Finland 20 million ha, in Norway 6 million ha, and in Denmark 0.5 million ha. However, forest ownership differs slightly from country to country (Table 1). Companies own a higher percentage of forest land in Sweden than elsewhere in Scandinavia. In Finland particularly, but also in Norway, the tendency for privately owned forests to be small has important consequences for those involved in reforestation planning. Besides developing different types of high-quality container-grown planting stock, the planners have to be able to promote the use of such stock by the hundreds of thousands of small landowners who, in effect, make the decisions on reforestation.

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Table 1. Forest ownership as a percentage of total forest area.

	Sweden	Finland	Norway
State	25	28	18
Company	25	7	7
Private	50	65	75

CURRENT PRODUCTION OF CONTAINER-GROWN STOCK

The combined production of forest tree seedlings in Sweden, Finland and Norway is 750 million. Seedling production in Sweden has risen steadily since the early 1970s, but in Finland and Norway it decreased for a while because of the economic recession, and has not yet returned to the level of the 1970s.

In Sweden the main increase has been in the production of container-grown stock--from 150 million in 1974 to 250 million in 1980. Relatively speaking, the most rapid change to container-grown seedlings has been in Norway --from only a small percentage in 1974 to 62% of all stock in 1980. In Finland container-grown seedling production totalled 75 million in 1974, or 34% of all stock. However, the figure later dropped to about 20%, and only recently has risen to 30% (65 million) (Table 2). The production of container-grown planting stock in Denmark is only in the experimental stage.

In Sweden and Finland the Japanese paperpot accounts for nearly 70% of all container stock production. The only other system used to any significant extent in Sweden is the Kopparfors multipot. In Finland, however, 5-8 million seedlings are produced annually in Finnpots (peat pots), Enso multipots and styroblocks. In Norway, 33 million seedlings were grown in the Kopparfors multipot in 1980, 5 million in the Kombiform (KF) container, and a further 4 million by the modified Nisula method. (This last will be replaced by the other two in 1982.)

Different cultural methods are used in each country to accommodate the various tree species. In Finland, Scots pine *(Pinus sylvestris* L.) accounts for 80% of all trees planted, and Norway spruce *(Picea abies* Karst.) for 15%. The respective figures for Sweden are 50% and 40%, while for Norway they are 11% and 80%. Two thirds of all container-grown Scots pine seedlings are planted after one growing season, and the remaining third after two seasons. Spruce seedlings are usually grown for two or more years before outplanting.

CONTAINER NURSERIES

A typical Finnish forest tree seedling nursery produces 5-10 million containerized and bare-root seedlings annually. A few large nurseries produce 20 million seedlings annually, some of these specializing in the production of container-grown stock. Greenhouses are usually used for growing containerized stock, and for the early (seedbed) stages in bare-root stock production. Irrigation and fertilization are often controlled automatically. Supplementary heating, though seldom used, and ventilation are usually controlled manually. In general, the capital outlay for buildings and extra equipment has been minimal.

In Sweden, most nurseries (bare-root or bare-root plus container) have a production capacity of 4-8 million seedlings. There are, however, more than 10 nurseries specializing in the production of container-grown tree seedlings. The largest is the Svenska Cellulosa AB (SCA) in Bogrundet, Timra, which grows about 50 million seedlings annually in Kopparfors multipots (Fahlroth and Persson 1978). This operation represents a considerable capital outlay: it has large, well-equipped greenhouses, a high level of auto-

Table 2. Planting stock production in 1980.

	Sweden	Finland	Norway	Total
		(000,000)		
Bare-root	200	160	27	387
Container-grown	250	65	42	357
Total	450	225	69	744
Percent container-grown	56	29	61	48

mation, supplementary heating and lighting, and mechanized handling and packing. The whole operation is run by a small hut highly productive labor force.

A few large nurseries in Norway specialize in containerized seedling production, although they are not nearly as well equipped as those in Sweden.

FIELD SURVIVAL AND EARLY GROWTH

The 1980 figures for survival and growth of container-grown forest tree seedlings show that, amongst the large landowners, forestry boards and companies in Sweden and Finland, results were as good as with bare-root planting stock. Survival rates 2-3 years after outplanting have averaged 85-90% although, particularly in Finland, they have been rather variable and have sometimes dropped below 80%. Nevertheless, such results show that it is possible to achieve good plantation establishment with container-grown seedlings without the necessity for infilling. However, careful attention must be given to all components of the establishment process: site preparation, seedling condition, outplanting factors, etc.

COSTS

No detailed cost/benefit statement for the various methods of container stock production is possible, since this requires information on both expenditures and income. It is difficult to place a value on stands, and only gradually are input-output data for young stands established by different container systems being gleaned from the records of the various companies and organizations involved.

Production costs (and selling prices) of one-year-old container-grown stock have generally been about double those for bare-root stock of the same size, and about the same as for transplants. Cost data for two-year-old container-grown stock are less precise, because of the smaller quantities involved, but will probably rise to double those of bare-root seedlings of the same age.

Seedling prices in Sweden are generally higher than those in Finland. Some forestry board nurseries in Finland, which have used Japanese paperpots for 10 years, produced seedlings in FH 408 paperpots at US $30-36/1000 in 1980, when the price in Finland was US $43/1000 and in Sweden US $59-79/1000.

Production costs for container-grown stock vary according to wage levels, the amount of capital tied up in production, and the interest rate. However, in considering planting stock costs it should be realized that they usually constitute a relatively minor item of the total expenditures involved in reforestation. In Table 3 reforestation costs using different types of planting stock have been calculated on the basis of information gathered by the Finnish Board of Forestry. In Sweden, SCA claims a saving in labor costs of US $100/ha by using container-grown planting stock.

The main reason that container-grown stock is cheaper to use than bare-root in Sweden, Finland and Norway is that outplanting with container stock is relatively easy. Mechanical site preparation, which has become more common in Sweden and Finland since the beginning of the 1960s, has made for easier planting of both containerized and bare-root planting stock. In addition, planter productivity with containerized seedlings has been improved by the introduction of the 'Potti-putki' planting tube, which reduces planter fatigue. However, the greater weight and volume of container-grown stock have increased the costs and logistic problems associated with the handling and transportation of planting stock. Large investments in planning and labor have been necessary to ensure that transportation distances to the planting site are kept as short as possible. Nevertheless, on the whole it has been possible to keep costs at a reasonable level.

BRIEF HISTORY OF CONTAINER PLANTING

There is nothing new in the idea of using container-grown stock for planting forests. For hundreds of years pine and spruce were planted in central Europe with their roots protected by a clump of earth. The use of bare-root seedlings, however, dates from the beginning of the 19th century, when G.L. Hartig published the results of his experiments. Interest in the use of container-grown stock arose again in the 1950s. The lessons of a hundred years of research in other biological and technical fields were applied to add new dimensions and significance to this work.

In the early 1960s several new types of container were developed for forestry use in Finland--Finnpots, Nisula rolls, Enso multi-pots, paperpots, etc. The main stimuli to this development were the rapidly increasing need for forest regeneration and the varied results obtained to that time with direct

Table 3. Calculation of reforestation costs for the northern part of Central Finland using different types of Scots pine planting stock (1981 costs).

Cost component	Reforestation function						Totals		
	Land clearance[a]	Site preparation[b]	Planting: Container[c]	Planting: 2-0[d]	Planting: 1-1[d]	Cleaning/ thinning[a]	Container	2-0	1-1
1. Labor									
day/ha	0.7		1.9	3.2	3.4	1.0	3.6	4.9	5.1
Fmk/day[e]	250		200	200	200	250			
Fmk/ha	175		380	640	680	250	805	1065	1105
2. Machinery									
hr/ha		1.8					1.8	1.8	1.8
Fmk/hr		165					165	165	165
Fmk/ha		297					297	297	297
3. Planting stock									
no./ha			2000	2000	2000		2000	2000	2000
Fmk/1000			190	110	250				
Fmk/ha			380	220	500		380	220	500

4. Transportation

	Equipment	Seedling transport: Long-haul[f] Container	Long-haul 2-0	Long-haul 1-1	Short-haul[g] Container	Short-haul 2-0	Short-haul 1-1
Mean distance(km)	200	200	200	200	2	2	2
Fmk/unit	7.33	.025	.005	.010	.04	.04	.02
Fmk/ha[h]	15	50	10	20	80	20	40

	Container	2-0	1-1
Transportation	145	45	75
Overheads and supervision - 50% of wages	403	533	553
Total cost/ha (Fmk)	2030	2160	2530

[a]Brushsaw
[b]D6 Caterpillar and Marttiini plow
[c]FH 408 paperpot, planted with Pottiputki
[d]Planted with mattock
[e]1 Fmk = US $0.21
[f]By truck
[g]By forest tractor
[h]These costs assume a total regeneration area of 100 ha.

sowing and bare-root planting. It was argued that, if production were rationalized, container-grown stock would become cheaper and more reliable than bare-root. Only later were other arguments added, such as the possibility of a longer planting season and the need for a smaller labor force with container-grown stock. Gradually, the need to create an integrated container system was recognized. Most successful was that developed by Lannen Tehtaat Dy, based on the Japanese paperpot; it eventually became the most widely used container system in Finland.

Container-grown seedlings gave good biological results in small-scale tests (e.g., Huuri 1965). However, many problems were encountered when it was first introduced on a large scale, both at the production stage and after outplanting (Kaila and Rasanen 1974, Metsämuuronen et al. 1978). Not all nurseries knew how to grow and handle containerized stock. Watering and hardening-off before outplanting were often neglected, and insufficient attention was paid to site selection. On private lands, there was hardly any mechanical site preparation. Because of the difficulties encountered and the poor results --the average failure rate was as high as 25-30%--interest in container-grown stock declined among private forest owners. Nevertheless, in state and company reforestation programs about 70% of all planting stock used is container-grown.

Inventories were conducted in Finland in 1973 and 1979 to determine the condition of stock at time of planting and the manner in which it had been grown (Kaila and Rasanen 1974, Rasanen and Kokkonen 1980). The 1973 inventory revealed that the quality of seedlings varied, growing methods were not properly established, and overall regeneration planning was often inadequate. The 1979 inventory noted a great deal of improvement, particularly in relation to use of the FH 408 paperpot. There was less variation in seedling height growth, while the number of seedlings per container and the number of empty containers had both decreased. On the other hand, it was surprising how small seedlings were when outplanted in northern Finland. The average height of 92 batches--14.8 million seedlings in all--was only 5.2 cm. The inventory revealed that container production is still being refined in Finland, 15 years after it started. Only in the production of container-grown pine has a routine methodology been established.

In Sweden there was a rapid and large-scale change to container-grown stock in the early 1970s. The changeover was evidently due to economic considerations and the labor savings realized when containerized stock was used. Wage levels in Sweden are higher than in Finland, and there is also a shortage of skilled labor. Swedish forest managers had the courage and the capital to establish large industrial-scale nurseries, even though they had little experience in growing containerized stock. Therefore, the results varied at first in Sweden just as much as in Finland (Hulten and Jansson 1974). However, intensive research and development work has brought about the automated production of container stock on an industrial scale and the introduction of fully integrated systems for handling, packing, storage and transportation.

In Norway, spruce planting predominates, and therefore the Norwegians have been less interested in the paperpot system, which is especially suitable for growing pine seedlings. Since the beginning of the 1970s they have concentrated on developing methods for growing spruce planting stock in the Kopparfors multipot and the modified Nisula roll, and conducting planting experiments. The results have been promising from both a biological and a technical viewpoint, with the result that Norway, too, has changed over to container-grown planting stock very rapidly in the last few years.

The scale of tree seedling production in Denmark is small in comparison with that of other Scandinavian countries. Moreover, many different tree species are used, while the areas involved are small. Norway spruce is the most important species planted, and successful results have been achieved with container-grown seedlings. However, it is felt that extensive economic and biological research are needed before any large-scale change to containerized stock can be made. The most important contributions made by the Danes in the field of containerized stock production are their research into seedling culture, fertilization and watering regimes in greenhouses, and in the building of advanced automated greenhouses.

In Finland, the development of containerized seedling production methods has been strongly influenced by commercial interests. This commercial orientation has had its drawbacks. Some incomplete production systems and methods have been sold without any guarantee of success. Little consideration has been given to biological factors in particular. In what have turned out to be trial-and-error methods, the trial has often been made by the producer, and the error by the customer.

On the whole, though, industrialization and commercialism have definitely proven more beneficial than detrimental to the development of container planting. Commercial projects have had specific goals in view, and the companies involved have been able to benefit from both their own and their customers' experiences, as well as from the work of other research and development agencies. A good example of the need for an interdisciplinary approach has been the development of a planting machine. The development of such a machine has proven to be very difficult, requiring the input of expertise from many fields other than forestry, and more money than is usually spent in forest regeneration research.

DEVELOPMENT PROSPECTS

The use of container-grown stock in Sweden, Norway and Finland is already quite common, and may eventually increase to become the major method of stock production. In Norway it is estimated that 80% of stock produced in 1982 will be containerized. Container-grown stock is in a favorable position in Sweden, since it is well established, and if the need for further capital investment decreases, production costs may even drop below those of bare-root stock. Finland may also need to increase container stock production, although at the moment this is hampered by a lack of capital.

It appears that in the near future production of container-grown stock will increase to some extent, strengthening its position as a regeneration option in the various Scandinavian countries. The most important reason for this likely increase is that labor costs are still rising faster than the cost of machinery and materials (Fig. 1). In addition, it appears that there will be a shortage of labor for forestry purposes, despite unemployment in industry as a whole.

Another key factor likely to influence the continued expansion of container stock production is the development of a suitable planting machine. Intensive work in this area has been carried out in both Sweden and Finland over the past 10 years. Four projects are still under way, three in Sweden and one in Finland. At present all are at the prototype stage and are undergoing large-scale testing. The Finnish prototype, designed by G.A. Serlachius Oy, is fully automatic and designed for operation by one man. This and the Swedish Dorotea prototype appear to be the most promising. Despite difficult site conditions, particularly on the stony moraine soils so common in Finland, it appears that these machines will be able to provide a viable alternative to manual planting over much of the forest area. The main concern at the moment is to improve their mechanical reliability.

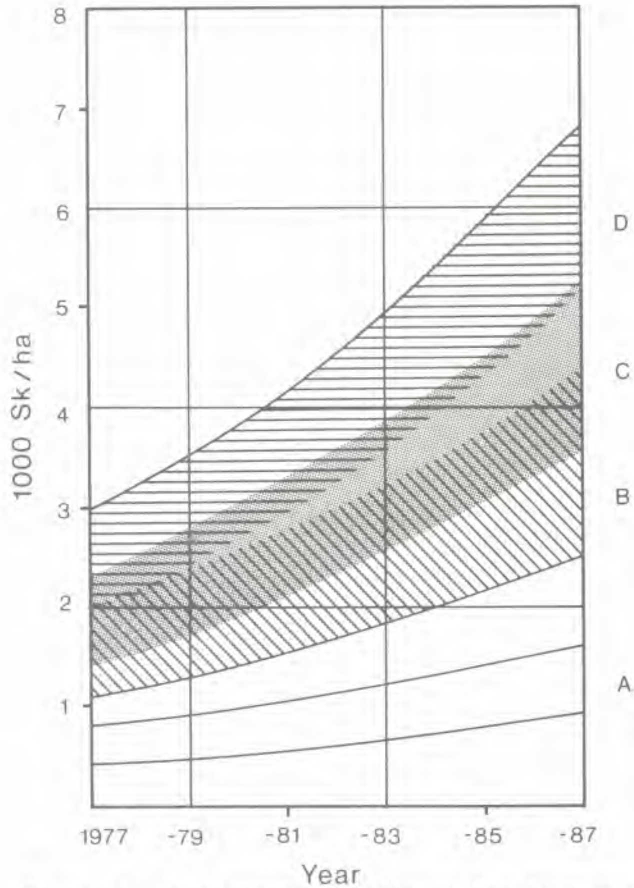

Figure 1. Estimated expenditure for four reforestation methods: (A) mechanical sowing, (B) mechanical planting of container-grown stock, (C) hand planting of container-grown stock, (D) hand planting of bare-root stock. The upper limit shows total expenditure, the lower limit expenditures less cost of seed or seedlings[a].

[a]Source - Bäckström 1977
Basis for calculation:
- area to be regenerated 16 ha
- survival rate: 2500 seedlings/ha one year after planting
- annual inflation rate
  - labor 10%
  - machinery 8%
  - planting stock 6%
- seedling cost 300 Skr/1000
- seed cost 800 Skr/kg

[b]1 Skr = US $0.20

A third problem has to do with improving the overall system of growing, transporting and planting seedlings. There are several container systems that guarantee the production of good seedlings. Nevertheless, it may take decades to weigh the thousands of factors involved in creating an effective, economically viable and integrated container planting system. New containers appear every year--a good sign in itself--but only a few are suited to forming the basis of a competitive system that produces seedlings and grows them through to healthy, free-to-grow stands. The creation of an integrated production, transportation and planting system is made easier when the whole chain is controlled by a single agency. This, of course, places the forestry boards and the large forest-owning trusts in a much better position than the small private owner.

CONTAINER SYSTEMS

In recent years Lannen Tehtaat Oy, in cooperation with its customers, has developed a new filling line on which four or five people can fill 300,000 FH 408 paperpots daily. Twenty of these new filling lines have been sold to date. New container sizes and paper qualities have also been introduced, while the basic handling unit has changed to a European-standard 40 x 60 cm plastic tray with a capacity of 192 FH 408 paperpots. Other new developments include the ribbon cell, and the so-called duracell, which has been laminated with a thin sheet of plastic. The paper and plastic are removed before outplanting. In 1982, the new 'super' filling line will be introduced, with which two or three people will be able to fill and sow 500,000 containers per day.

The Kopparfors multipot and the styroblock containers have also been further improved. A variety of sizes are now in use, and new designs and molds have been developed in an attempt to reduce root spiralling. Just as with the paperpot, these containers have formed the basis for complete systems. These systems are all similar with respect to filling and sowing equipment, the use of air-pruning pallets, and transportation trays.

New container systems already in widespread use are the Enso multipot in Finland (produced, by Enso-Gutzeit Oy, the largest forest owner after the state) and the Norwegian Kombiform (KF) version. Since 1965, Enso-Gutzeit Oy has been developing a system aimed at producing tall, hardened-off Scots pine seedlings without spiralled roots, in which the seedlings are outplanted without the container. They have produced a thin plastic multipot with 40 cavities, 250 cavities/m^2, each cavity having a teardrop cross-section. These are filled on a Lannen filling line, and the 'plug' seedlings are planted with a specially designed Pottiputki. The system has already been exported and further development is under way.

The KF system is based on a styrofoam growing and handling unit which, viewed in cross-section, has partition walls resembling a comb with some of the teeth missing. One unit contains 150 compartments, and a total of 1000 seedlings can be grown per square metre. A larger version is also used in Finland. The KF system can be used for sowing or transplanting, and special equipment has been developed for transporting and planting the containerized seedlings. The system is designed for one-way use.

Many other approaches to 'container' planting are currently under development in Finland and Sweden.

RESEARCH AND DEVELOPMENT

A great deal of biological research related to the production of container-grown stock has been carried out in all four countries. This research has been concerned mainly with improving the survival and growth performance of outplanted container-grown stock through planting experiments or assessments of operational plantings. There have also been numerous studies relating to cultural regimes--seedling nutrition, irrigation and growing schedules. In addition, the advent of containerization has raised a number of specific questions, the most important undoubtedly relating to root development in container-grown seedlings, both in the nursery and after outplanting. At present it appears that there is less root deformation in container-grown than in bare-root stock. However, such deformations may still be considerable, and may occur in 10-15% of all seedlings planted. There is joint Nordic research into this problem.

Considerable resources have already been directed toward improving the quality of container-grown stock. The work forms part of the research concerned with the basic biology of growth. Research into short-day treatments has resulted in the development of techniques, already in use in Sweden and Norway, to improve the overwinter survival of seedlings. However, there is a school of thought that considers container-grown stock to be more variable, in terms of size and physiological quality, than bare-root stock. This is one of the reasons that many countries--Finland in particular--are undertaking research to develop classifications and minimum standards for container-grown stock.

A serious economic disadvantage of many container systems is that empty cavities remain in the growing tray. At first, blank cavities were avoided by sowing several seeds per cavity, but it was often difficult to decide whether to thin or leave multiple seedlings. Nowadays the most common solution is to sow two seeds per cavity, and to thin multiples or fill blanks accordingly. More precise sowing machines are under development, as well as machines for sowing pregerminated seed and one for transplanting small containerized seedlings into blank cavities.

Correct fertilization practices, designed to provide seedling crops with the correct amount of nutrients according to their size and stage of development, can be assured by following the guidelines drawn up by Ingestad. (1974). Most nurseries adopt nutrient regimes based on his work.

The use of containers in the production of planting stock can allow us to exploit the results of tree breeding, and make the most effective use of expensive, high-quality seed. On the other hand, success in the use of container methods depends on use of the best quality seed available. Although Norway spruce has been propagated by rooting cuttings directly into containers, the results have been unsatisfactory. Attempts to grow containerized seedlings propagated by tissue culture are now under way in Norway.

For understandable reasons, container planting research has tended to concentrate upon rather narrow biological questions. The extent of multi-disciplinary research, where biological, technical and economic questions have been considered simultaneously, has been rather meagre. There is a great need for more broadly based studies, which will require further cooperation between the practising nurseryman or forester and the scientist.

CONCLUDING REMARKS

Conditions have been favorable for the development of containerized seedling production methods in Finland, Sweden and Norway. Forestry is important to the economy in each country, there are few tree species to be grown, there are evident benefits to be derived if the efficiency of planting stock production is improved in such a harsh climate, and each country is troubled by high labor costs. All three countries have played a role in the development of seedling production techniques.

Most arguments for the use of container-grown stock are accepted, although the advantages have not turned out to be as great as predicted, either in the nursery or in the field. The use of container-grown seedlings appears to require more careful planning and greater precision than is customary in reforestation. There is still a great deal of room for improvement in the implementation of available technology.

There is also a great deal to be done in developing integrated systems for container stock production. Continuous research is needed to monitor planting stock quality, field performance and the economics of containerization--factors which must always be kept in view in the course of technical development.

The aim in developing container-grown planting stock is to produce cheaper, healthier, faster-growing seedlings, in a more rational yet labor-intensive manner. In these respects, container planting can compete successfully with other methods of reforestation, such as bare-root planting, sowing and natural regeneration.

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