

Management and utilization of broadleaved tree species in Nordic and Baltic countries – Birch, aspen and alder

Proceedings of Workshop held in Vantaa, Finland, May 16 to 18, 2001





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Jari Hynynen and Anja Sanaslahti (eds.)

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Foreword

The workshop titled “Management and utilization of broadleaved tree species in Nordic and Baltic countries – Birch, aspen, and alder” was arranged in Finland in May 16–18, 2001. This interdisciplinary workshop addressed the research, management and utilization of broadleaved tree species in Nordic and Baltic countries. The purpose of the meeting was to bring together the researchers and foresters working at broadleaved tree species, change the information, and establish links between the researchers from the Nordic and the Baltic countries. Altogether, 37 researchers and foresters from Estonia, Latvia, Lithuania, Sweden and Finland attended the meeting.

These proceedings include the articles based on the presentations of the meeting. The first three articles are country reports outlining the status of broadleaved tree species in forestry and in forest research in Estonia, Finland and Sweden. The rest of the articles address recent research results, current research and management activities, and future research needs within the fields of forest tree breeding, forest management, and utilization of broadleaved tree species. We hope that this document serves as a source of background information in planning of the new joint research activities within the Nordic and the Baltic countries.

We thank all the authors of the articles for their valuable contribution. We also thank SNS for the financial support, which helped us to organize the meeting and to complete these proceedings.

Editorial remarks

The papers and abstracts presented have not been peer reviewed and each author is responsible for the scientific content and language.

Country reports

FINLAND:

Resources and utilisation of birch, aspen and alder

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Abstract

In this paper, resources and industrial uses of birch, aspen and alder species in Finland are summarised and recent trends for the management and potentials for the utilisation are evaluated and proposed under discussion. Based on the current discussions among the Finnish researchers and people working for the practical forestry and forest product industries, the currently interesting research subjects concerning birch, aspen and alder are pointed out, as well.

Key words: *Betula*, *Populus*, *Alnus*, forest management, cultivation, resources, utilisation, mechanical forest industries, chemical forest industries, research

1 Introduction

The role of broad-leaved i.e. hardwood species has been undervalued during most of the history of the Finnish forestry and forest industries. The only exception, due to the 1980's, was the management of birch for plywood industries. So far, the respect of hardwoods has grown radically, thanks to the increased use of birch and, lately, aspen for pulping and papermaking, the increased importance of all hardwoods for the ecological biodiversity, and, partly, for the resistance against forest damage and the scenic values. Simultaneously, the methods of cultivation and other measures of forest management have been developed, but only for birch and, lately, for aspen.

In this paper, resources and industrial uses of birch, aspen and alder species in Finland are summarised and recent trends for the management and utilisation are evaluated and proposed under discussion. The currently interesting subjects of research and development are pointed out, as well.

2 Resources and forest balance of hardwoods

Forests dominated by hardwood species cover 10.7 % of the forestland area in Finland, 11.4 % in the southern half and 9.5 % in the northern half of the country (Sevola 2000). Forests of white birch (*Betula pubescens*) constitute the main part, followed clearly by silver birch (*Betula pendula*) in southern Finland and with equal proportions by silver birch and European aspen (*Populus tremula*) in northern Finland. Alder forests (*Alnus glutinosa*, *A. incana*) are more abundant than aspen forest in southern Finland, whereas the relative importance of both of them is rather inferior in northern Finland. The breakdown of the forestland area by hardwood species is as follows (Kärki 1997):

	Southern Finland	Northern Finland	Whole country
Silver birch (<i>Betula pendula</i>)	3.5	0.2	2.0
White birch (<i>Betula pubescens</i>)	5.1	7.8	6.3
European aspen (<i>Populus tremula</i>)	0.4	0.2	0.3
Common and grey alder (<i>Alnus glutinosa</i> , <i>A. incana</i>)	0.6	Δ	0.3
Other hardwoods	0.1	Δ	Δ

Because more than half of the hardwood resources are growing as an admixture in the forests dominated by Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*), the proportions of hardwoods of the growing stock volume and forest growth are much larger than that of the forest area (Sevola 2000). The ditching of peatland forests, clear cuttings and tilling of soil have favoured hardwoods in mixed stands (e.g. Luostarinen and Verkasalo 2000). On the other hand, the general nature of hardwoods to grow as minority species in individual stands makes their procurement often difficult, both from the aspects of logging technology and timber marketing. Hardwoods make up 18.3 % of the growing stock of the whole country, 18.4 % in the southern half and 18.3 % in the northern half of the country, and as much as 22.5 % of the forest growth, 28.0 % in the southern half and 22.5 % in the northern half of the country (Verkasalo and Kärki 1999). These figures clearly show the relatively high level of the growth of hardwoods, indicating fertile sites and young stands, and, thus, large potential for wood production.

Of the hardwoods, birch species have a dominant role both in the growing stock and for the growth throughout the country. The proportion of birch is 81.6 % of the growing stock of hardwoods in the whole country, 78.0 % in the southern half and as much as 90.3 % in the northern half of the country (Sevola 2000). These proportions of the growth are 75.8 % in the whole country, 71.4 % in its southern half and as much as 89.4 % in its northern half. In the southern half, the diversity of hardwood species is rather large whereas white birch is absolutely the dominant and the only commercially important hardwood species in the northern half. Maybe a little unexpectedly, birch has a lower proportion of the growth than of the growing stock. This indicates on average older stands and eventually lower fertility for birch compared to other hardwoods.

In fact, the Finnish birch resources have varied surprisingly little during the period of national independence. Since the first national forest inventory in 1921–24, the growing stocks of birch between 224 and 295 million m³ were measured (e.g. Luostarinen and Verkasalo 2000). Thus, the general perception that the birch resources were destroyed during the 1950's and 1960's cannot be justified. Considering the forest areas lost to Soviet Union after World War II, there are currently larger volumes of birch in the Finnish forests than right after the period of burn-beating ended in the 1920's.

The Finnish birch resources concentrated to eastern Finland's formerly burn-beaten silver birch lands still in the 1940's. Now, increasing amounts of white birch grow in western Finland on drained peatlands and paludified mineral lands. Accordingly, the proportion of white birch of the growing stock has grown from 50 % in Southern Finland and 80 % in Northern Finland during the 1950's to the corresponding 70 % and 90 % during the 1990's (Verkasalo 1997). Of the growing stock, the proportion of silver birch is the largest in the southern parts of Eastern Finland, 7–8 %, and the smallest in Ostrobothnia and Northern Finland, 1–2 %. The proportion of white birch is the largest in Ostrobothnia, 12–20 %, and the smallest in the most southern districts, 4–6 %.

Of the minor hardwood species, aspen and grey alder constitute the main part. Their total proportion of the growing stock is the largest in the southern coastal areas and in some restricted parts of Eastern Finland, 4–5 %, and the smallest in Ostrobothnia and Northern Finland, 1–2 % (Kärki 1997). Common alder is dominant in the southern coast. In the other parts of the country, aspen is clearly more common in Western and Northern Finland, and grey alder in Eastern Finland's former burn-beaten areas.

In the southern half of the country, which is the main production area of hardwoods in Finland, breakdown of the growing stock according to the 8th National Forest Inventory (1986–94) is as follows (Kärki 1997, completed by the data from Sevola 2000).

	1000 m ³	%
Silver birch (<i>Betula pendula</i>)	63 900	27.8
White birch (<i>Betula pubescens</i>)	130 900	56.8
European aspen (<i>Populus tremula</i>)	18 400	8.0
Common alder (<i>Alnus glutinosa</i>)	4 100	1.8
Grey alder (<i>Alnus incana</i>)	18 900	8.2
Other hardwoods	14 100	6.1
Total	230 300	100.0

The forest balance of hardwood species, as a result of annual growth and drain, is shown in five-year periods in Table 1. Until the beginning of the 1970's the growth of hardwoods remained almost constant in Southern Finland and decreased in Northern Finland. This was evidently due to the previous conscious reduction of hardwoods, although this reduction was decreased when forest improvement gained momentum in the 1960's. Forest improvement is also the most important reason for the increase in growth after that; the cutting potential for birch increased by 3.4 and 1.4 million m³ per year in Southern and Northern Finland, respectively. The increase in growth

occurred nation-wide mainly in the 1970's but continued in Southern Finland for the following 15 years. In Northern Finland it has remained constant for the last 15 years, which is due mainly to the ageing of birch stands and reduction in forest improvement (Luostarinen and Verkasalo 2000).

The proportion of birch of the total drain of hardwoods is estimated to be 90–95 % in Finland (Louna and Valkonen 1995, Luostarinen and Verkasalo 2000). In Southern Finland, the drain of hardwoods increased until the end of the 1960's, but during the next 10 years it decreased markedly, by 7 million m³ per year. The reason for this was the significant decrease in the demand of firewood for heating urban dwellings at that time since the 1960's; the firewood was largely made of hardwoods and small-diameter trees. After that the drain increased further because the demand for pulpwood increased by 0.5 million m³ per year for ten years, but that demand decreased during the depression at the beginning of the 1990's. The drain of birch increased slightly until the middle of the 1970's, then decreased markedly and started to increase again at the beginning of the 1980's (Luostarinen and Verkasalo 2000).

Table 1. Growth, drain and forest balance of hardwood species in Southern and Northern Finland during the five-year periods 1950–93. Reproduced from the data of Sevola (2000) and METINFO (2001).

Period	Southern Finland			Northern Finland			All Finland		
	Growth	Drain	Bal.	Growth	Drain	Bal.	Growth	Drain	Bal.
	Million m ³ per year								
1950–54	10.0	3.0	13.0	12.9	+0.1
1955–59	9.6	12.5	-2.9	2.8	2.5	+0.3	12.4	15.0	-2.6
1960–64	9.6	13.4	-3.8	2.6	2.6	+0	12.2	15.9	-2.7
1965–69	9.6	15.1	-5.5	2.4	2.9	-0.5	12.0	18.0	-6.0
1970–74	9.8	12.3	-2.5	2.6	3.0	-0.4	12.4	15.3	-2.9
1975–79	12.2	8.1	+4.1	3.2	2.2	+1.0	15.4	10.3	+5.1
1980–84	12.4	8.9	+3.5	3.8	2.2	+1.6	16.2	11.1	+5.1
1985–89	12.7	9.4	+3.3	3.8	2.7	+0.9	16.5	12.1	+3.4
1990–94	13.0	8.6	+4.4	3.8	2.4	+1.4	16.8	11.0	+5.8
1995–99	13.2	10.0	+3.2	3.8	2.5	+1.3	17.0	12.5	+5.5

Until the middle of the 1970's, the timber balance in the hardwood forests of Finland was clearly negative and after that was even more clearly positive. During those periods, the volume of hardwoods decreased by 3.7 million m³ and by 0.2 million m³ per year, on average, in Southern and in Northern Finland, respectively. Since then the resources of hardwoods have grown by 3.9 million m³ per year in Southern Finland and by 1.2 million m³ per year in Northern Finland per year. From this we can conclude that the cutting possibilities for hardwoods are clearly improving.

During the last 25 years, the hardwood balance has been clearly positive, tracing to the highly increased growth and the simultaneously still lower level of drain. Purposeful management of birch was implemented again in the 1970's when planting silver birch was started and new perspectives could be seen for the utilisation of birch in pulp and

paper industries. Mixed stands of birch and softwoods and vast areas on drained sites forested by white birch entered the stage of their most rapid growth, as well. Meanwhile, import of birch pulpwood was started in a large scale, which partly inhibited the utilisation of domestic birch potential.

Thus, according to the estimates by the MELA group of the Finnish Forest Research Institute (pers. comm.) during the 50-year prediction period, cuttings of saw and veneer logs of birch can be increased from the level at the beginning of the 1990's according to a cutting potential by 0.7 million m³ per year and according to a maximum sustained yield by 0.9 million m³ per year, respectively, when the cutting possibilities are compared to the situation in which there is no import, only domestic wood. The average cutting possibilities per year for saw and veneer logs during the same period are, according the cutting potential, 1.9 million m³ and, according to the maximum sustained yield, 2.1 million m³ per year. The most extensive cuttings during the first 10-year period, 2.4 million m³ per year, would first lead to halving of the cutting possibilities, but during the last 10-year period they would increase to the level that existed at the beginning of the first 10-year period. On the other hand, if the cutting were done reasonably during the first 10-year period, i.e. 2.0 million m³ per year, the cutting possibilities would be greater than the cutting potential during each of the following 10-year periods.

3 Timber assortments of hardwoods

The most valuable part of the timber stock are traditionally the logs for mechanical wood processing, i.e. saw, veneer and plywood milling and further processing of the primary mechanical products. The breakdown of the standing hardwood timber by species and main timber assortments according to the 8th National Forest Inventory (1986–94) is shown for southern half of Finland in Table 2.

The volume of log-size hardwood trees and the log percentage of the standing timber are markedly smaller than those of softwood trees (conifers), because the wood resources are of younger age and smaller dimensions and the common minimum requirements for dimensions are more strict. In addition, the proportion of the trunk that is not of high quality enough for saw or veneer logs is larger in hardwoods than in conifers, 40–60 % and 5–20 %, respectively. In this respect, significant differences occur between the Finnish hardwood species.

For the first hardwood for veneer, plywood and saw logs in Finland, silver birch, the log percentage is 30, and for the second hardwood, white birch, 10 %. Generally, the proportion of large birches has not diminished; on the contrary, the birch standing crop of over 30 cm diameter at breast height is at present even larger than in the 1930's and double the amount at the beginning of the 1950. About 80 % of the total 13 million m³ of white birch logs in southern half of Finland are smaller than 30 cm in diameter. Logs of silver birch (total of 21 million m³) are distributed more evenly by diameter class; e.g. the proportion of logs with a diameter over 30 cm is 40 %. In this

case the proportion of saw timber of the whole log-size crop is, on average, only 38 % for white birch but 54 % for silver birch, and for larger diameter classes the difference increases. See figure 1 for the diameter class distribution of saw log trees of birch.

Aspen has a relatively high log percentage, 15. This is due to the large proportion of large-dimensioned trees in the stock; e.g. there is a larger proportion of aspen in the diameter classes over 30 cm than of birch (Fig. 1). However, the large occurrence of decay limits the potential of aspen for mechanical wood processing as well for paper industries. In this respect, the newly introduced hybrid aspen planted on fertile forest sites and abandoned agricultural lands has raised positive expectations for paper industries, in the first hand.

The log percentages and volumes of alder species, especially grey alder, are generally small. They provide only a limited potential for special products of mechanical wood processing for small and medium-scale enterprises. However, improved utilization of the existing resources of these poorly used species should and is targeted for. If small and short logs are accepted, some potential can be seen. In the final felling of alders stands (age 40–60 years), the log percentage may then vary 40–70 % (Verkasalo and Kärki 1999).

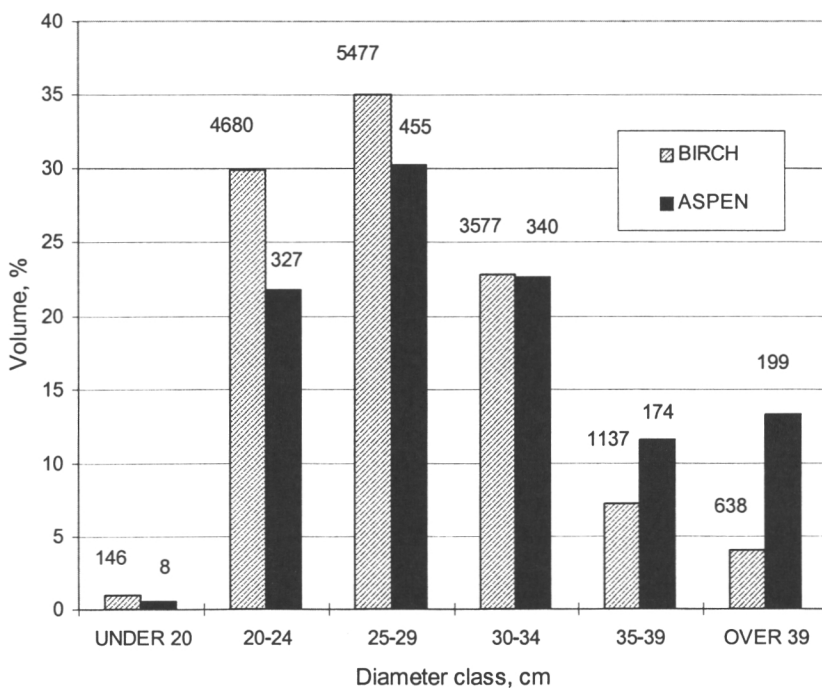


Figure 1. Volumetric distribution of the standing stock of saw log trees and log volume of birch and aspen in Southern Finland by the 8th National Forest Inventory (1986–1994).

Table 2. Growing stock of hardwoods by species and timber assortments in Southern Finland by the 8th National Forest Inventory (1986–94).

Species	Logs		Pulpwood		Total
	1000 m ³	%	1000 m ³	%	1000 m ³
Silver birch (<i>Betula pendula</i>)	15 828	30.0	36 877	70.0	52 705
White birch (<i>Betula pubescens</i>)	11 193	10.4	96 731	89.6	107 924
European aspen (<i>Populus tremula</i>)	2 348	15.0	13 266	85.0	15 614
Common alder (<i>Alnus glutinosa</i>)	245	6.8	3 362	93.2	3 607
Grey alder (<i>Alnus incana</i>)	69	0.6	11 457	99.4	11 526
Other hardwoods	67	1.8	3 713	98.2	3 780
Total	29 750	15.2	165 406	84.8	195156

The current trend in mechanical wood processing is toward decreasing the minimum log diameters and lengths, along with the predicted decrease in the dimensions of the standing stock available for industrial utilisation. For birch, the traditional minimum diameter and length for veneer, plywood and saw logs have been 18 cm (over bark) and 3.1–4.3 m. The newly introduced assortment, small-diameter saw log of birch allows top diameters as low as 10–12 cm and lengths as short as 2.2–3.4 m. This enables the utilisation of timber in pulpwood dimensions for saw milling and further processing as long as the minimum log grades are met. As it was indicated before, aspen and alder logs have traditionally been used in small dimensions for mechanical wood processing for special products of furniture, interior panelling and packaging. Pulpwood of hardwoods is utilised down to the diameter of 7 cm and using the approximate bolt lengths of 3.0 m and 4–5 m.

4 Present and potential uses of hardwoods

4.1 Birch (*Luostarinen and Verkasalo 2000*)

In Finland, sawing of birch probably started during the 1850's. The production increased rapidly until the 1920's, but since then the amounts of sawn birch have remained stable; the largest amount of logs, ca. 0.6 million m³ per year, was sawn in the middle of the 1960's. The amount of sawn birch logs is presently 0.15–0.2 million m³ per year, e.g. 0.18 million m³ in 1993, while at the same time their main user, plywood industry, used 0.87 million m³ of birch (Fig. 2).

Sawing of hardwoods is carried out by some specialised family enterprises, which are registered and monitored by the Finnish Industrial Statistics, and a heterogeneous group of small non-industrial sawmills. Their proportions of the production of hardwood lumber were 37 % and 63 % in 1993, for example. At present, small sawmills carry out more than half of the birch sawing in Finland. However, the proportion of birch of the total timber used by the small sawmills was only 6 % in 1990 (comp. other hardwoods 1 %). – The Finnish Industrial Statistics covers the sawmills with five

employees or annual turnover of more than FIM 3.5 million, at their minimums. Their use of roundwood is more than 10 000 m³ per year.

Birch wood has been used in Finland for industrial products since the middle of the 19th century. The first industrial use was manufacturing reels of thread, which began in 1873. In the 1920's and 1930's about 80 % of the demand for reels of thread for whole the world was supplied by Finland.

The development of the plywood industry significantly increased the use of birch wood. Wiikari Oy, Karkku in westcentral Finland, started rotary-cutting of veneer in 1894 by producing birch plywood and from this plywood e.g. chairs and chests of drawers. Wilhelm Schauman Ltd. founded the first large plywood factory in 1912 in Jyväskylä, and since 1918 the amount of birch used in the plywood industry has been larger than in sawing. After that the industry developed considerably and Finnish plywood dominated in the global markets for plywood made of deciduous trees. World War II and the loss of four plywood factories to the Soviet Union caused a temporary decline in the Finnish plywood industry.

In the 1990's the use of birch wood in the plywood industry has been, on average, 1–1.5 million m³ per year (Fig. 2). The peak use, 2 million m³ per year, was reached in the middle of the 1960's, as was in sawing. After that the lack of birch raw material and competition from the new plywood producers in southeastern Asia caused a crisis in veneer and plywood manufacture in Finland. As a result, the Finnish plywood industry had to specialise in expensive special products and also start to use large amounts of spruce as inner veneers in plywoods, where the outer birch veneers determined the properties and price of the product. Importation of birch from Russia and Baltic countries for veneer cutting has increased during recent years. Recently, new investments in the domestic birch plywood production were announced meaning increase in the use of plywood logs.

According to information provided by the plywood industries, 15–20 % of all the birch used in Finland (ca. 0.15 million m³ per year) is imported (Fig. 3). This amount is obviously rising. Also large birch logs were imported earlier, mostly from Russia and Sweden, several tens of thousands of cubic metres per year, e.g. 75 100 m³ in 1993. At the same time, large, special-quality birch logs were exported, mostly into Germany, e.g. 7 400 m³ in 1993. Import of birch for sawing from the east and south is also increasing continuously.

In addition to sawing and veneer and plywood manufacture, there are many special uses for log-size birch. The most valuable raw materials for those logs are the special forms of *B. pendula*, curly-grained and flamy-grained birch. They are used for furniture and interior decoration as well as for decorative items. Normal birch wood is widely used for these purposes if it is of good quality, but it is also used for ice-cream sticks, ice-hockey sticks and musical instruments. Matchboxes, skis, javelins, plywood for railway carriages, trams and aeroplanes as well as many utility articles have previously been manufactured from birch.

The traditional use of small dimensional birch has been as firewood. Its significance started to decrease rapidly during the 1950's, which caused problems in the demand for birch timber from thinnings (Fig. 2). The present use of birch as firewood is

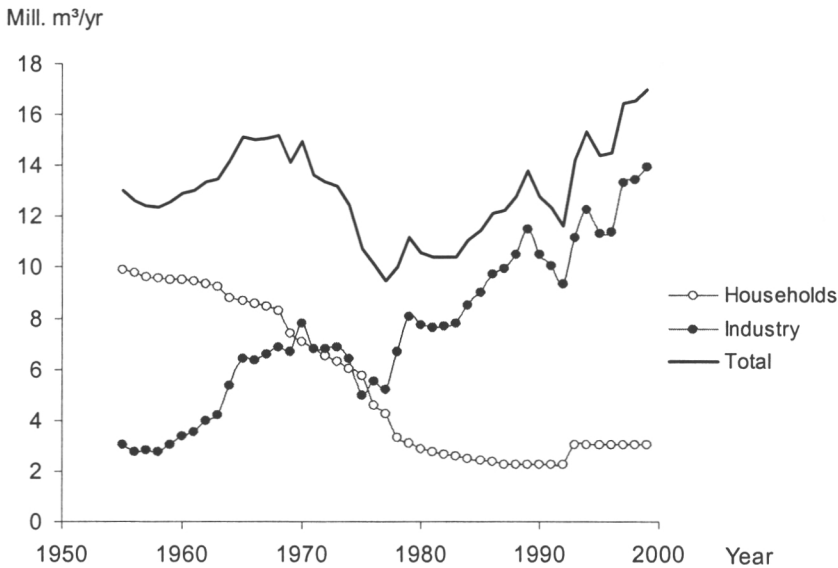
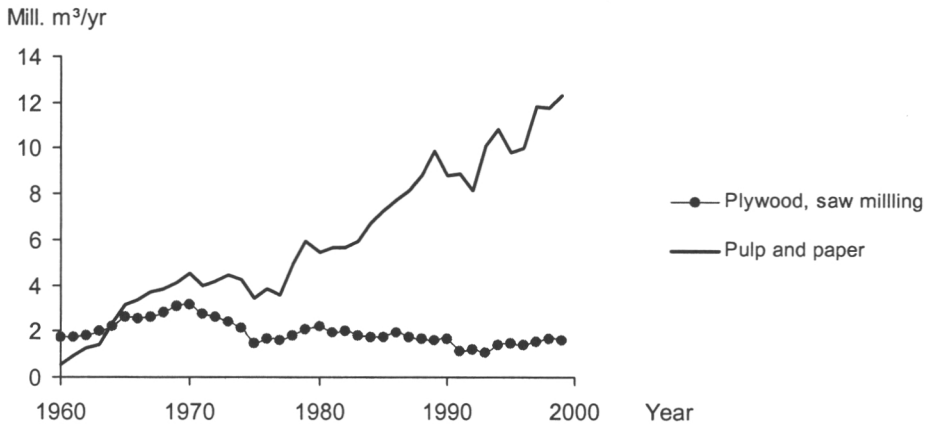


Figure 2. Use of hardwood timber for the main industrial processes 1960–1999 (above) and in forest industry and households 1955–1999 (below) in Finland (Sevola 2000).

estimated for ca. 2–4 million m³ per year. Small-dimensioned birch has also been used in the fibreboard and particleboard industries. At present, however, the raw material of these industries is almost totally waste wood from saw mills and plywood factories.

Currently, the main use for small birch timber is in pulping (Fig. 2). As early as the 1920's attempts were made to use it for pulp, but not until the 1950's was a kraft pulping method for birch invented. After that in the middle of the 1970's, the use of birch in the pulp industry steadily increased to 4 million m³ per year. The ability to use significant amounts of birch in the manufacturing of printing and writing papers has markedly increased the demand for birch pulpwood since the end of the 1980's. Thus, at present the pulp industry is the most important consumer of birch in Finland, as it uses more than 10 million m³ per year. More than half of this birch is imported (Fig. 3).

4.2 Aspen and alder (*Verkasalo and Kärki 2001*)

Typical wood products from aspen and alder are aimed for special end-use purposes, whose amounts sold are relatively small. Louna and Valkonen (1995) estimated the use of aspen and alder in the beginning of 1990's as follows:

Aspen: Logs: 10 000–15 000 m³ per year; Pulpwood: 150 000–200 000 m³ per year
Alder: Logs: 20 000 m³ per year; Pulpwood: 30 000 m³ per year

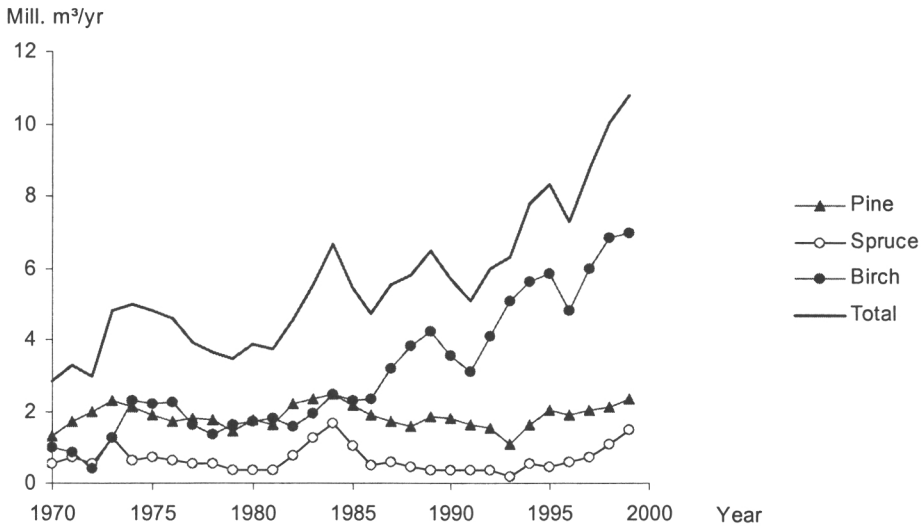


Figure 3. Import of roundwood by species to Finland 1970–1999 (Sevola 2000).

These figures may be somewhat vague, because they are based on inquiries to larger forest industry enterprises employing more than 20 people with a sample of 10 % of the smaller enterprises. Accordingly, the wood consumption of smaller enterprises is obviously underestimated. These are the main users of aspen and alder logs, as well. In contrast to the before-mentioned data, Kärki (1997) estimated the use of aspen logs for 20 000–30 000 m³ per year; the current use might be somewhat larger. The volume of aspen used for plywood production is less than 20 000 m³ a year, owing to the poor log supply.

For mechanical wood products, aspen is mostly used for benches and panels in saunas and other wet interiors, and to a small extent for ice hockey clubs, packaging, pallets and boats. Heat-treated aspen is predicted to rise to a wanted customer product for a variety of interior and exterior uses. Common and grey alder are mainly used for panels in saunas and interiors; other uses include furniture and a variety of household and decorative items. In the German furniture industries, common alder is used as a substitute of walnut, cherry and mahogany; grey alder is used mainly for the same purposes (Kärki 2000).

5 Major research subjects in the fields of silviculture, growth and yield and wood quality and utilisation of hardwoods in Finland

Based on the current discussions among the Finnish researchers and people working in the practical forestry and forest product industries, the currently interesting research subjects concerning birch, aspen and alder may be summarised as follows:

1. Tree breeding of birch (esp. silver birch) for rapid growth, superior wood and timber quality and improved biotic resistance
2. Mixed stands of birch-spruce (and birch-pine) – growth and yield, spatial management, harvesting operations and technology, total production economy
3. Birch plantations on abandoned agricultural lands – initial stand development, growth and yield, wood properties, alternatives of wood utilisation, fungal and insect damage and their economic importance
4. Breeding of aspen for timber production with short rotations for paper industries
5. Adding biodiversity with hardwoods – many aspects
6. Import of birch and aspen timber – many aspects
7. Quality and utilisation of birch (aspen and alder, in addition) for mechanical wood processing, esp. in the small and medium-scale forest industries – saw milling, billet and component manufacture, modified wood products (heat treatment, pressing, press-drying), engineered wood products (OSB, PSL, LSL, LVL) – many aspects
8. First thinnings of birch (as well as pine and spruce): strategy of treatments, harvesting schedules, logistics of harvesting, transport, production and distribution, quality and uses of wood (pulping, energy, mechanical further processing)
9. Small lots of hardwood timber: harvesting, transport, logistics, management within the timber flow.

References

- Kärki, T. 1997. Markets, harvesting costs and quality of aspen and alder logs. University of Joensuu, Faculty of Forestry. Research Notes 53. 78 p. [In Finnish].
- , T. 2000. Grey alder (*Alnus incana*) as a raw material for mechanical wood processing in Finland. Finnish Forest Research Institute, Research Papers 764. 48 p. + 5 sub-publications.
- Louna, T. & Valkonen, S. 1995. Status of domestic wood raw materials in the industrial use of broadleaved trees. Finnish Forest Research Institute, Research Papers 553. 38 p. [In Finnish].
- Luostarinen, K. & Verkasalo, E. 2000. Birch as sawn timber and in mechanical further processing in Finland. A literature study. *Silva Fennica Monographs* 1. 40 p.
- Sevola, Y. (ed.). 2000. Finnish statistical yearbook of forestry. SVT Agriculture, forestry and fishery. 366 p.

- Verkasalo, E. 1997. Hieskoivun laatu vaneripuuna. Abstract: Quality of European white birch (*Betula pubescens* Ehrh.) for veneer and plywood. Finnish Forest Research Institute, Research Papers 632. 483 p. + App. 59 p.
- , E. & Kärki, T. 1999. Further Processing with Nordic Hardwoods. An Inter-Nordic Research Project 1998–99. Country Report Finland. Mimeograph. Finnish Forest Research Institute, Joensuu Research Station. 32 p. [In Finnish].

ESTONIA:

Forest resources and research status of broadleaved tree species in Estonia

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Abstract

Until 1992 ocular estimation of all stands was used for inventory of Estonian forest resources. The regular inventory of state forests (818 thousand ha) with 10-year period continues. About 400 thousand ha of potential private forests (1432 thousand ha) have inventoried recently, but there is still 1 million ha of forest land with limited information. To provide statistics about the conditions and utilization of forest resources on a national level, the National Forest Inventory (NFI) was conducted in 1999 and 2000. The following figures are based on NFI results.

Total area of Estonia (without Peipsi lake)	4 369 803 ha
Area of forest land	2 249 400 ha (51.5 %)
Area of forest stands	2 114 759 ha
Growing stock	409 366 thous. m ³
Gross annual increment	11 594 thous. m ³
Mean volume per ha	194 m ³ /ha
Mean volume increment per year	5.48 m ³ /ha
Mean age	56 years
Mean relative density (according to Tretyakov)	0.82
Mean site index (according to Orlov)	2.3

Majority of the Estonian deciduous forests are formed of birch stands. According to the data of the Estonian Forest Survey Centre the share of birch stands in all stands is 30 %, while this is made up of two different birch species: silver birch and downy birch. Silver birch is of greater forestry and economic importance and is also the best studied birch species in Estonia.

Aspen is an extremely fast growing and highly productive tree species in Estonia. According to the data of the Estonian Forest Survey Centre, aspen occupies the second place with respect to the mean annual increment of stands. Although the standing stock of aspen is appreciable, its extensive cultivation has not been undertaken because of the lack of the market for its wood and because of the damage inflicted to a large part of matured aspen stands by heart rot. However, despite the present low management and economic importance, aspen is a relatively well studied tree species in Estonia.

Two alder species grow naturally in Estonia: common alder and grey alder. Grey alder stands make up 7.6 % and black alder stands 2.8 % of the forest area. Alders are nitrogen fixing species and are capable of improving soil properties. The economic importance and popularity of black alder as well as of birch have increased in recent years. However, since matured trees are often damaged by heart rot, there has arisen the problem of the paucity of high quality black alder wood. The share of grey alder stands in Estonian state forests is relatively small (0.9 % of the forest area), whereas their proportion much larger in private forests (11.4 %). During last decade the three main directions of the research have been developed: (1) natural riparian grey alder stands as buffer zones, (2) production and caloric value of natural grey alder stands and (3) biomass and production of grey alder and hybrid alder stands growing on former agricultural land.

1 Introduction

For this paper three main sources were used to get information about forest resources in Estonia: (1) National Forest Inventory data (Eesti metsad... 2001), (2) forestry statistics issued by the Ministry of Environment (Aastaraamat... 2000), and (3) the current database of Estonian state forests stands.

The National Forest Inventory (NFI) carried out by the Estonian Forest Survey Centre was started in 1999. The statistical design and methods for Estonian NFI were adapted from the Swedish NFI. In this paper summary statistics based on two years' measurements are used as the most objective information about Estonian forest resources at the moment. However, detailed information like distributions by age classes of broadleaved species calculated from the NFI data, due to limited number of plots, may contain considerable errors.

Forestry statistics relying on updated total forest inventory data (ocularly estimated compartmentwise) are also prepared by Estonian Forest Survey Centre (Aastaraamat... 2000). In state forests inventory is made continuously (at least once in 10 years), but on large area of nonstate forests inventory has not been made since 1990, and we do not have sufficient information about forests on 800 thousand hectares.

As a rule, forestry statistics do not provide sufficient information about broadleaved species in stand composition. That is why several queries from state forest database were generated to get more detailed information about the broadleaved tree species at least in state forests.

The research status of broadleaved tree species in Estonia has been summarized on the basis of a comprehensive paper (Kurm and Tamm 2000) by V. Uri.

2 Forest resources of broadleaved tree species in Estonia

According to NFI data, the area of forest land in Estonia is 2 249 (\pm 56) thousand hectares, which is 51.5 % of total area of Estonia. The area of forest stands is estimated to be 2 115 thousand hectares. After the World War II the forest area in Estonia has been increasing about 20 thousand hectares per year. Table 1 shows that the area under all main tree species except spruce has been increasing during that period. Table 1 also shows that the share of broadleaved species (especially grey alder in the last 25 years) has been increasing and the share of pine and spruce stands has been decreasing.

These trends are expected to continue because of forestation of abandoned agricultural lands and of low interest by new private owners in planting and precommercial thinnings. The area of forest land is expected to reach 2.4 million ha (55 %) in the near future (Eesti metsad... 2001).

Table 1. Changes in forest area in Estonia after the World War II (Aastaraamat... 2000)

Dominant tree species	1958		1975		2000	
	1000 ha	%	1000 ha	%	1000 ha	%
Pine	532.7	41.9	670.7	40.6	724.3	34.3
Spruce	288.0	22.7	380.3	23.0	370.5	17.5
Birch	345.6	27.2	471.2	28.5	649.4	30.7
Aspen	28.7	2.3	27.2	1.6	114.0	5.4
Common alder	19.9	1.6	25.4	1.5	61.6	2.9
Grey alder	47.2	3.7	65.5	4.0	164.0	7.8
Other	9.0	0.7	11.9	0.7	30.9	1.5
Total	1271.1		1652.3		2114.8	

According to the Estonian Forest Survey Centre data (Aastaraamat ... 2000), 802 thousand ha (36 % of forest area) are state forests managed by the State Forest Management Centre and 363 thousand ha (16 %) belong to private owners who have forest management plans. Almost 800 thousand ha of the area of forest land are still out of management because of land reform. Fig. 1 shows that the share of broadleaved tree species is greater in nonstate forests. The difference is the greatest for the area of grey alder, which covers only 7.3 thousand ha of state forests and 163.7 thousand ha of forests of other owners.

Table 2 shows the distribution of stands area by age classes and by dominant species. Old broadleaved forests cover a rather big area in Estonia. The same can be more clearly seen in Fig. 2 which presents the distribution of stands area by development classes and by dominant species. The figure shows cumulation of mature aspen and alder forests which have not found utilization due to a lack of interest on the markets.

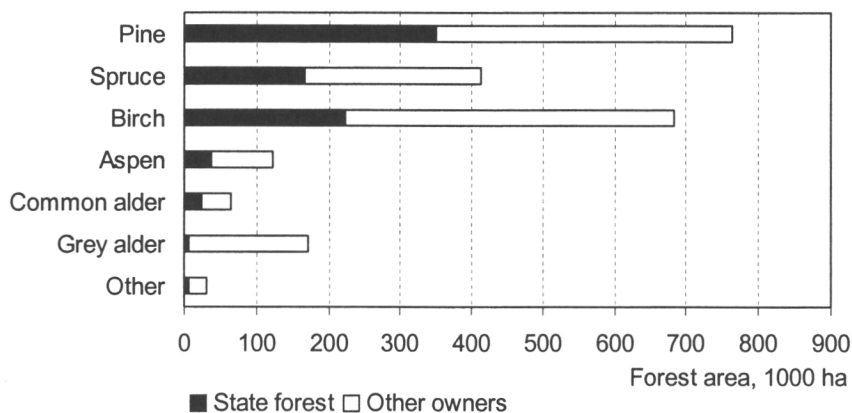


Figure 1. Distribution of Estonian forest area by dominant species and by ownership according to NFI data.

Table 2. Distribution of stands area (thousand ha) by age classes and by dominant species according to NFI data.

Age class	Pine	Spruce	Birch	Aspen	C.alder	G.alder	Other	Total	%
1–10	7.5	5.3	49.5	13.0	1.6	14.8	2.5	94.2	4.5
11–20	30.0	27.8	50.0	4.9	4.2	25.4	2.1	144.4	6.8
21–30	30.0	36.9	57.1	5.1	4.2	45.5	3.5	182.3	8.6
31–40	57.0	40.2	107.4	8.5	9.4	52.7	6.0	281.2	13.3
41–50	95.0	33.9	130.2	27.9	17.5	21.9	2.0	328.4	15.5
51–60	93.2	49.9	122.0	29.4	12.9	3.7	5.9	317.0	15.0
61–70	105.0	52.6	80.4	14.2	7.1		4.1	263.4	12.5
71–80	96.4	50.2	31.3	7.2	2.9		4.1	192.1	9.1
81–90	78.7	33.1	13.7	1.9	0.7			128.1	6.1
91–100	52.9	21.8	5.6	1.1			0.8	82.2	3.9
101–110	20.9	8.0	2.2		0.4			31.5	1.5
111–120	26.7	8.5		0.7	0.7			36.6	1.7
121–	31.0	2.2						33.2	1.6
Total	724.3	370.4	649.4	113.9	61.6	164.0	31.0	2114.6	
%	34.3	17.5	30.7	5.4	2.9	7.8	1.5		

According to calculations from NFI data performed by Estonian Forest Survey Centre, the volume of growing stock on Estonian forest land is 411 (± 13.5) million cubic metres and has been increasing from year to year since World War II. Table 3 presents the distribution of volume of Estonian forest stands by dominant tree species. The table shows the great share of nonstate ownership in broadleaved forests. Table 4 presents the distribution of volume on Estonian forest land by tree species. In this table, volumes of trees in stand composition were taken into account.

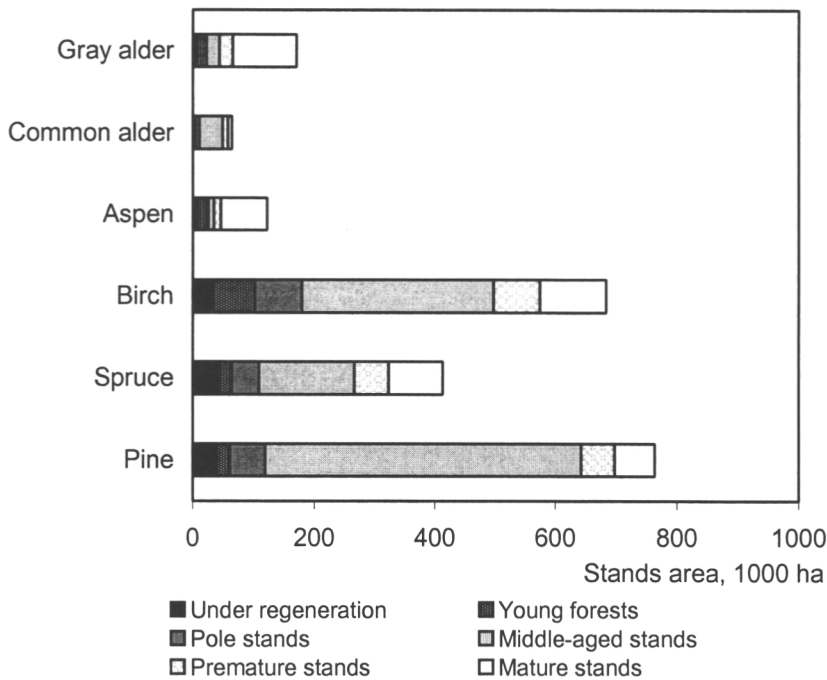


Figure 2. Distribution of stands area by development classes and by dominant species according to NFI data.

Table 3. Distribution of volume (million m³) on Estonian forest land by dominant tree species and by ownership according to NFI data

Dominant tree species	State forest	Other owners	Total
Pine	67.7	78.0	145.7
Spruce	27.4	53.1	80.5
Birch	38.4	70.7	109.1
Aspen	9.1	17.0	26.1
Common alder	4.2	7.7	11.9
Grey alder	2.0	30.8	32.8
Other	1.3	3.5	4.8
Total	150.1	260.8	410.9
%	36.5	63.5	

Tables 3 and 4 show the difference in volume distribution by tree species. This means that, for example, pine stands include in their composition a considerable share of other tree species and, on the other hand, for example, common alder grows mainly in combination with other tree species in Estonia and there are not many pure common alder stands.

Estonian state forest database was analysed to get more detailed distribution of broadleaved species volume. Fig. 3 shows the volume of birch on Estonian state forest land by age and its share in stand composition. According to Fig. 3 most birch volume comes from birch dominated stands. Another type of distributions was obtained for

aspen (Fig. 4), common alder (Fig. 5) and grey alder (Fig. 6) volume on state forest land. A great portion of volume of those species in state forest comes from stands dominated by another species. Due to the longer rotation period of other dominant species, felled aspen and alder timber is overmature and of poor quality. This situation has been created by state silvicultural policy that prefers pine and spruce to the broadleaved tree species. However, there are many more broadleaved dominated forests on privately owned forest lands, which enables the owners to get better yields of those species during a shorter rotation period.

Table 4. Distribution of volume (million m³) on Estonian forest land by tree species according to NFI data.

Tree species	Growing stock	Standing dead trees	Broken and fallen trees
Pine	118.82	6.26	1.69
Spruce	106.25	3.40	3.49
Birch	92.75	1.95	1.41
Aspen	29.78	0.17	0.61
Common alder	17.46	0.44	0.15
Grey alder	31.86	1.69	1.13
Oak	2.49	0.22	0.00
Ash	4.85	0.04	0.11
Goat willow	3.35	0.12	0.43
Other	3.30	0.08	0.08
Total	410.91	14.37	9.10

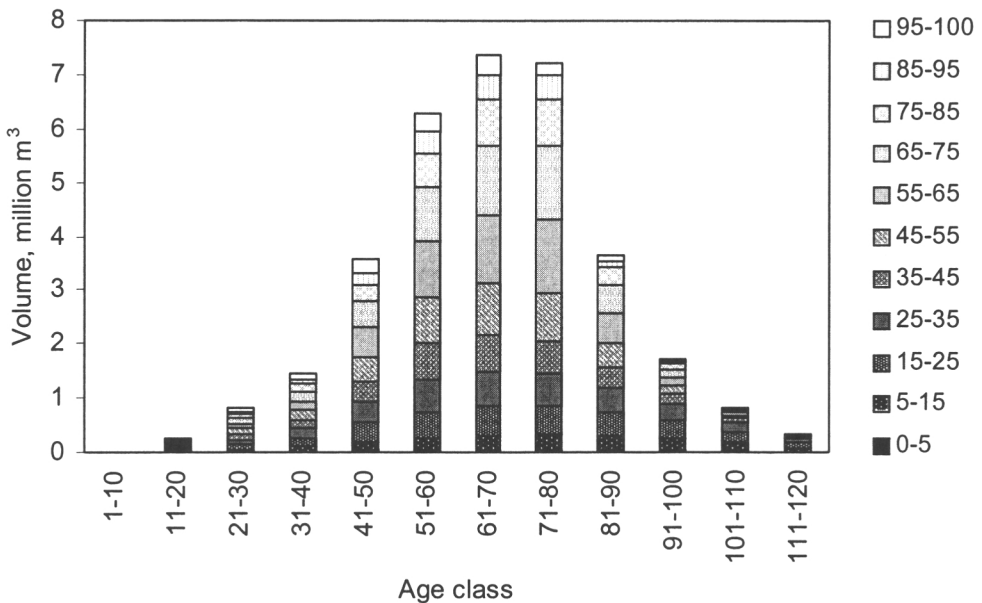


Figure 3. Birch volume on Estonian state forest land by age and its share in stand composition calculated from the state forest database.

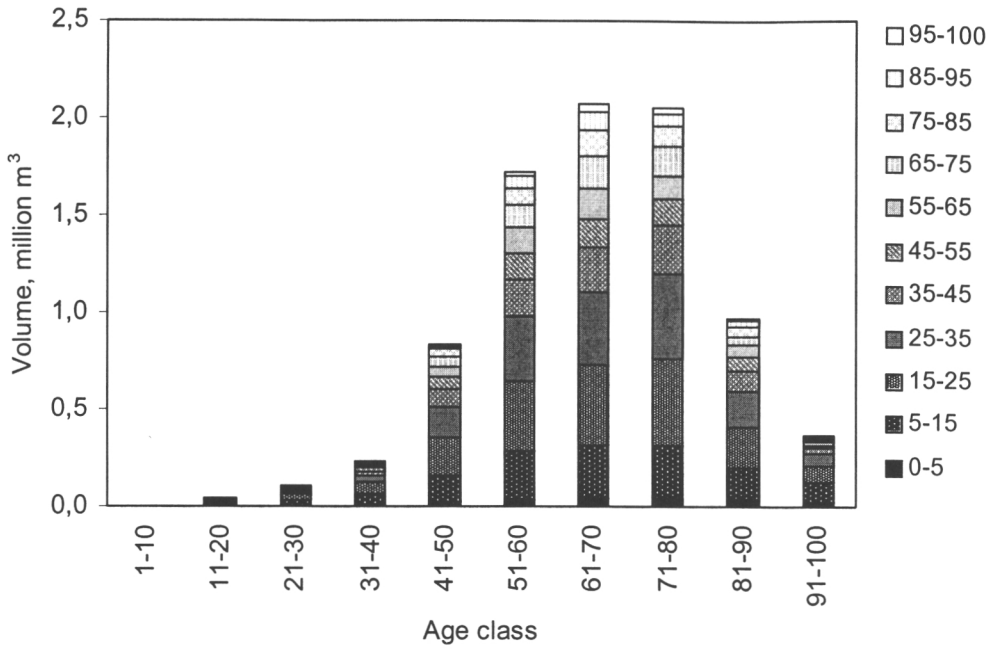


Figure 4. Aspen volume on Estonian state forest land by age and its share in stand composition calculated from the state forest database.

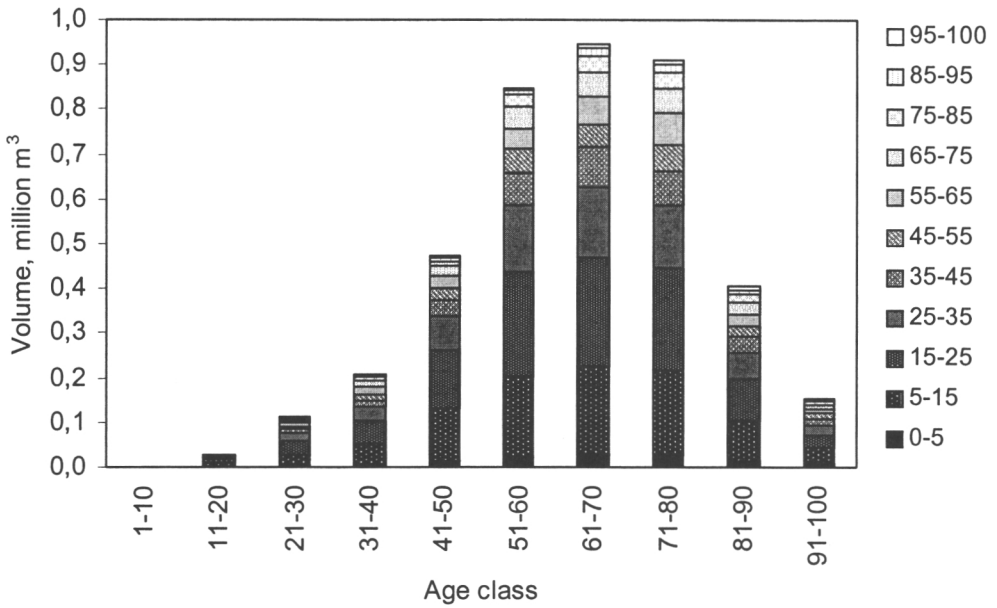


Figure 5. Common alder volume on Estonian state forest land by age and its share in stand composition calculated from the state forest database.

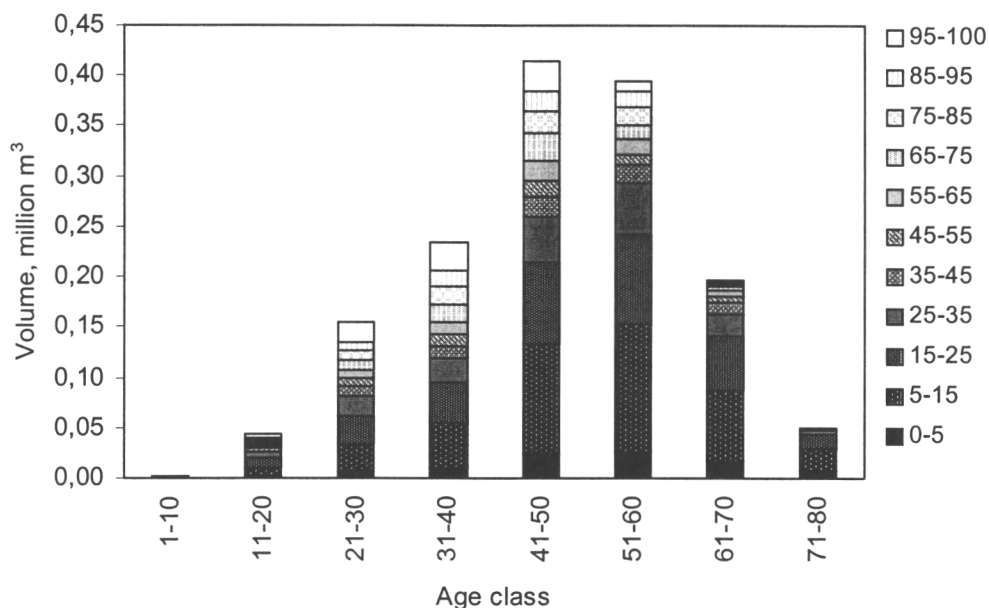


Figure 6. Grey alder volume on Estonian state forest land by age and its share in stand composition calculated from the state forest database

Table 5. Standing and felled volume (thousand m³) on forest land according to NFI data.

Tree species	Growing stock and standing dead trees	Felled trees in 1999/2000 season	Felled % of standing volume
Pine	125 084	2 317	1.85
Spruce	109 650	5 513	5.03
Birch	94 692	1 720	1.82
Aspen	29 955	328	1.09
Common alder	17 898	448	2.50
Grey alder	33 553	313	0.93
Oak	2 712	54	1.99
Ash	4 891	56	1.14
Goat willow	3 466	8	0.23
Other	3 378	73	2.16
Total	425 279	10 830	2.55

Table 5 shows felled volume during the last felling season. According to NFI data a total of 10.8 (\pm 2.3) million m³ was felled in 1999/2000 season. This is a remarkably greater amount of timber than 6.7 million m³ that has been published as the official data of the Ministry of Environment (Aastaraamat... 2000). The official amount of felled timber is calculated by summarising of felling permits data which due to low administrative ability of Estonian authorities is evidently lower than the real amount of cuttings. The increment of Estonian forests according to NFI data is 11.5 (\pm 0.4) million cubic meters. Thus, the amount of felled timber is quite close to the current

increment of Estonian forests. The full utilization of the volume increment is justified because of the high average age of stands. However, more than half of the felled timber is spruce, which is the most valuable tree species in Estonia at the moment. Unfortunately, it has been difficult to find utilization for mature aspen and gray alder stands.

3 The research status of birches, aspen and alders in Estonia

3.1 Birches

Majority of the Estonian deciduous forests are formed of birch stands. According to the data of the Estonian Forest Survey the share of birch stands in all stands is 30 %, while this is made up of two different birch species: silver birch (*Betula pendula*) and downy birch (*Betula pubescens*). Silver birch is of greater forestry and economic importance and is also the best studied birch species in Estonia.

Owing to the need to draw up yield tables for birch, suitable for Estonia, the study of the growth dynamics and production of birch stands was undertaken already in the early 20th century (Mathiesen 1926). An essentially similar activity was continued later by O. Henno, who studied also the differences in the form factor and standing stock between birch stands and birch-spruce mixed stands (Henno 1959, 1960, 1962, 1963b, 1965, 1969, 1980). On the basis of this research stem volume tables and stem volume tables of standing trees were drawn up. O. Henno dealt also with determination of optimal density at the thinning of silver birch stands. It appeared that heavy thinning in silver birch stands of a fertile site type exerts an accelerating effect on the diameter increment of trees (Henno 1978). The technical characteristics and quality of birch wood (Henno 1963a, Kasesalu 1963, 1965a, 1965b, 1968, 1969) as well as the caloric value of the stem wood of downy and silver birch (Löhmus et al. 2000) have been investigated relatively thoroughly.

Curly birch (*Betula pendula* var. *carelica*), a form of silver birch, deserves a separate treatment. Cultivation of this valuable form has aroused more interest in recent years. The study of curly birch has quite a long history, it was first described from Estonia in 1937 (Aun 1937). This form grows naturally in western, northwestern and northern Estonia with up to 620 finding places (Ott 1980). Several experimental plantations of curly birch have been established on former agricultural land. A recently published study gives a survey of the existing research results as well as of the cultivation and management of curly birch in Estonia (Sibul 2000).

At present, the cultivation and research of silver birch is largely related to the issue of the growing over of agricultural land with forest, emerging in the 1990s. The area of arable land left out of agricultural use is now no less than 228 000 hectares (Meiner 1999) plus a few hundred thousand hectares of natural grasslands overgrown with shrubbery. Fallowed agricultural lands are grown over mainly with pioneer tree species,

among them dominating are birches (silver birch and downy birch). One of the causes of the spread of birches is certainly their intensive seed bearing: mast years recur every other year but often even each year. Seed bearing capacity and seed quality have been studied more in detail by P. Ott (Ott 1968, 1973).

Silver birches are and will evidently be one of the most perspective tree species in afforestation of non-forest lands, including recultivation of exhausted oil shale quarries where, according to the existing research results, they have proved to be highly suitable species (Kaar and Raid 1991). The advantages of cultivation of birches on abandoned agricultural land is their rapid growth and the relatively high price of birch wood. Birches growing on agricultural land are not endangered by fungal diseases or by deterioration of wood quality; the economic profit can be gained already after two-three decades when thinning is started. In Estonia, primarily coniferous trees have been exploited in the afforestation of agricultural land, while the use of fast growing deciduous trees for this purpose has been poorly studied. At present, the research of natural sapling stage birch stands with support from the Estonian Science Foundation has been carried out by a work group led by H. Tullus. The aim of these investigations was to estimate the biomass and production of stands growing in such regions, as well as the development of an ecosystem of agricultural land into a forest ecosystem. Also, a study is made of various cultivation methods and the suitability of the planting stock. Different silvicultural possibilities are analysed with the aim to turn such natural areas into high quality class stands.

In connection with the growth of the popularity of birch as a managed tree species, tree breeding activity has also made progress: 38 plus trees have been selected on the basis of which it is planned to establish a vegetative seed orchard. The first attempts of reproduction with tissue culture method have been successful.

3.2 Aspen

Aspen (*Populus tremula*) is an extremely fast growing and highly productive tree species in Estonia. According to the data of the Estonian Forest Survey, aspen occupies the second place with respect to the mean annual increment of stands ($6.4 \text{ m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$) (Viilup 1999). Although the standing stock of aspen is appreciable, its extensive cultivation has not been undertaken because of the lack of the market for its wood and because of the damage inflicted to a large part of matured aspen stands by heart rot (*Phellinus tremulae*). However, despite the present low management and economic importance, aspen is a relatively well studied tree species in Estonia.

Recently, a monograph was published in which one of the most outstanding Estonian aspen researchers Prof. Ü. Tamm summarizes the existing investigation results (Tamm 2000). He has specified aspen phenotypes and has studied the variability of the aspen genome, including triploid aspen (*Populus tremula* f. *gigas*), in Estonia as well as the importance of triploid aspen in forest management and aspen breeding. Among the studied issues are also the growth dynamics, above-ground biomass allocation and management of aspen stands; wood properties and application of aspen wood; diseases and pests of aspen.

Due to the circumstance that in recent years aspen wood has been used in paper production, the first hybrid aspen plantations have been set up in Estonia. The forest company AS Metsind started with plantations in 1999. A total of 162 080 seedlings were planted in 14 areas with different soils and soil preparation (Reisner 2001). Owing to relatively good preliminary results and the necessity for establishment of permanent experimental plantations, the estimated area of hybrid aspen plantations is up to 1 400 ha at present and it is expected to amount to 3 000 ha in ten years time (Reisner 2001).

3.3 Common alder (*Alnus glutinosa*)

Two alder species grow naturally in Estonia: common alder (*Alnus glutinosa*) and grey alder (*Alnus incana*). Alders are nitrogen-fixing species and are capable of improving soil properties. The economic importance and popularity of common alder as well as of birch have increased in recent years. However, since matured trees are often damaged by heart rot (*Phellinus igniarius*), there has arisen the problem of the paucity of high quality black alder wood.

A study has been made of the dependence of the growth of common alder stands on the intensity of drainage (Hainla 1959, 1968). The author has investigated also the impact of meteorological conditions on the stem diameter increment of black alder (Hainla 1969, 1989). B. Haller has studied the growth dynamics of common alder stands (1932).

The soil improving properties of common alder have been studied as well. Namely, common alder with silver birch and hybrid alder have been successfully used for the afforestation of exhausted oil shale quarries; the stands are characterized by high productivity and soil formation is intensive (Kaar 1997, Vares 1999, 2000). Another good example is the Luidja common alder stand which was cultivated about a hundred years ago in Hiiumaa Island for fixing moist sand dunes and for preventing erosion (Tiismann 1924). More recently, the growth of common alder stands and the development of the forest ecosystem have been studied by several researchers (Gael et al. 1977, Pärt 1987, Hainla 1988).

The breeding of common alder has been practised in Estonia since 1973. The main aim has been to establish differences in growth between progenies and mother trees and the dependence of growth on the characteristics of the mother tree (Hainla 1985, 1996).

In recent years, issues related to common alder stands have been investigated mainly by A. Vares, who has published papers on common alder cultivation, biomass and production as well as on crown structure and allocation of the main nutrients (NPK) (Vares 1999, 2000a, 2000b, 2000c, Vares and Tullus 2001).

3.4 Grey alder (*Alnus incana*)

Since grey alder is of relatively low economic importance, the level of its management and research in the earlier period was quite low in Estonia; only a few studies date from that time (Schabak 1931, Auksmann 1936, Daniel 1936).

Research into grey alder has been intensified during the last ten years in connection with the growing over of agricultural lands with forest and the increasing actuality of the problem of cultivation and utilization of renewable energy forests. The three main directions of the research conducted in this period are the following:

1. The work group of the University of Tartu under the guidance of Prof. Ü. Mander has studied natural riparian grey alder stands as buffer zones. The results of this research have been published in numerous papers (Mander et al. 1995, Mander et al. 1997a, Mander et al. 1997b, Lõhmus et al. 1996, Tullus et al. 1996, Tullus et al. 1997, Tullus et al. 1998a).
2. Researchers of the Agricultural University under the leadership of Prof. H. Tullus have investigated the production and caloric value of natural grey alder stands and the possibilities of application of such stands as a source of renewable energy (Keedus 1995, Keedus 1997, Keedus and Uri 1997, Lõhmus et al. 1996, Muiste et al. 1996, Tullus et al. 1996, Tullus et al. 1997, Tullus et al. 1998a, Tullus et al. 1998b, Tullus and Uri 1998).
3. The latter work group has recently focused their activities on the research of the biomass and production of grey alder and hybrid alder stands growing on former agricultural land, as well as the allocation of the main nutrients (NPK) and nitrogen cycling in such stands. Methods of cultivation of grey alder and its vegetative reproduction and seed quality have been discussed as well (Tullus et al. 1998b, Uri 1997, Uri and Tullus 1999, Uri 2000, Uri et al. 2001, Uri 2001).

References

- Aastaraamat Mets 2000. Yearbook forest 2000. 2000. Tartu. 141 p. [In Estonian].
- Auksmann, A. 1936. Valge lepp. Eesti mets 2: 45–46. [In Estonian].
- Aun, K. 1937. Imelik kask. Eesti Mets 17 (8/9): 297–298. [In Estonian].
- Daniel, O. 1936. Valgelepp (*Alnus incana* DC.). Eesti Mets 12: 401–404. [In Estonian].
- Eesti metsad 2000. Metsavarude hinnang statistilisel valikmeetodil. 2001. Tallinn. 44 p. [In Estonian].
- Gael, A.G., Smirnova, L.F. & Tälli, P.G. 1977. Opõt oblesenija tšernoï olhoi peskov strova Hiiumaa na Estonskom poberežje. Metsanduslikud Uurimused XIII. Tallinn. p. 104–117. [In Russian].
- Hainla, V. 1959. Sanglepikute kuivendamisest. Sotsialistlik Põllumajandus 24. 1152 p. [In Estonian].
- , V. 1968. Sanglepikutest ja nende kuivendamise tulemustest. Metsanduslikud Uurimused VI. Tallinn. p. 49–56. [In Estonian].
- , V. 1969. Karmide talvede ja kuivade suvede mõjust sanglepa diameetri juurdekasvule. Metsanduslikud Uurimused VII. Tallinn, p. 144–150. [In Estonian].

- , V. 1985. Sanglepa järglaskatsekultuurid. Metsanduslikud Uurimused XX. Tallinn. p. 50–65. [In Estonian].
- , V. 1988. Luidja leplik. Eesti Loodusuurijate Seltsi Aastaraamat 72. Tallinn. p. 24–28. [In Estonian].
- , V. 1989. Ilmastikutingimuste mõjust sanglepa aastarõngaste laiusele. Eesti Loodusuurijate Seltsi Aastaraamat 71. Tallinn. p. 26–38. [In Estonian].
- , V. 1996. Lepad. Metsaselektioon Eestis. Tartu. p. 26–29. [In Estonian].
- Haller, B. 1932. Uurimusi mustlepa (*Alnus glutinosa* Gaertn.) kasvukäigust. Tartu. 57 p. [In Estonian].
- Henno, O. 1959. Paremaboniteediliste kaasikute kasvukäik Eesti ENS-s. EPA teaduslike tööde kogumik 11. Tartu. p. 50–57. [In Estonian].
- , O. 1960. Kase-kuuse segapuistute ökonoomne koosseis. EPA teaduslike tööde kogumik 17. Tartu. p. 45–51. [In Estonian].
- , O. 1962. Kasvava metsa mahutabelid. Metsamajandus. Tallinn. p. 15–20. [In Estonian].
- , O. 1963a. Kasepuidu tehnilistest omadustest. EPA teaduslike tööde kogumik 33. Tartu. p. 180–189. [In Estonian].
- , O. 1963b. Kasetüvede mahutabel. EPA teaduslike tööde kogumik 29. Tartu. p. 49–53. [In Estonian].
- , O. 1965. Kase standardtabel. EPA teaduslike tööde kogumik 41. Tartu. p. 114–119. [In Estonian].
- , O. 1969. Puude arvu ja läbilõikepindalade jaotumuse seaduspärasusi jämedusastmete järgi paremaboniteedilistes kaasikutes. EPA teaduslike tööde kogumik 60. Tartu. p. 57–62. [In Estonian].
- , O. 1978. Harvendus- ja põimendusraiate vajalikkusest naadi-arukaasikute kasvatamisel. Metsamajandus. Tallinn. p. 97–103. [In Estonian].
- , O. 1980. Arukaasikute kasvukäik põhilistes kasvukohatüüpides. EPA teaduslike tööde kogumik 128. Tartu. p. 80–89. [In Estonian].
- Kaar, E. 1997. Tööstusmaastike metsandusliku rekultiveerimise tulemusi, Akadeemilise metsaseltsi toimetised IX. Metsaparanduse minevik ja tänapäev Eestis. p. 30–36. [In Estonian].
- , E. & Raid, L. 1991. Millist puuliiki eelistada tasandatud põlevkivikarjääride metsastamisel. Eesti Mets 2: 34–38. [In Estonian].
- Kasesalu, A. 1963. Kasepuidu riketest. EPA teaduslike tööde kogumik 33. Tartu. p. 190–195. [In Estonian].
- , A. 1965a. Kasepuidu füüsikalise-mehaanilistest omadustest erinevates kasvukohatüüpides. Metsanduslikud Uurimused IV. Tallinn. p. 149–157. [In Estonian].
- , A. 1965b. Aru- ja sookase puidu tehniliste omaduste võrdlevaid andmeid. EPA teaduslike tööde kogumik 41. Tartu. p. 149–157. [In Estonian].
- , A. 1963. Kasepuidu anatoomilisest ehitusest. EPA teaduslike tööde kogumik 50. Tartu. p. 210–223. [In Estonian].
- , A. 1969. Kasepuidu füüsikalise-mehaaniliste omaduste ja anatoomilise ehituse vahelistest seostest. EPA teaduslike tööde kogumik 60. Tartu. p. 104–117. [In Estonian].
- Keedus, K. 1995. Hall lepp energiaressursina. EPMÜ teadustööde kogumik 181. Tartu. p. 200–204. [In Estonian].
- , K. 1997. Angervaksa KKT hall-lepikutest Põhja-Eestis. EPMÜ teadustööde kogumik 193. Tartu. p. 106–110. [In Estonian].
- , K. & Uri, V. 1997. Biomassi produktsioon naadi hall-lepikus. EPMÜ teadustööde kogumik 189. Tartu. p. 223–228. [In Estonian].

- Kurm, M. & Tamm, Ü. 2001. Lehtpuude uuritusest Eestis. Akadeemilise Metsaseltsi toimetised 14. Tartu. p. 24–67. [In Estonian].
- Lõhmus, K., Mander, Ü., Tullus, H. & Keedus, K. 1996. Productivity, buffering capacity and resources of grey alder forests in Estonia. In: Perttu, K., Koppel, A. (Eds.). Short rotation willow coppice for renewable energy and improved environment. Uppsala. p. 95–105.
- , K., Ivask, M., Tamm, Ü., Vares, A. & Tamm, U. 2000. Arukase (*Betula pendula* Roth.), sookase (*Betula pubescens* Ehrh.), sanglepa (*Alnus glutinosa* (L.) Gaertn.) ja haava (*Populus tremula* L.) tüve kalorsus Eestis. Metsanduslikud uurimused XXXII. Tartu. p. 113–120. [In Estonian].
- Mander, Ü., Kuusemets, V. & Ivask, M. 1995. Nutrient dynamics of riparian ecotones: A case study from the Porijõgi River catchment, Estonia. *Landscape and Urban Planning* 31: 333–348.
- , Ü., Kuusemets, V., Lõhmus, K. & Muring, T. 1997a. Efficiency and dimensioning of riparian buffer zones in agricultural catchments. *Ecological Engineering* 8: 299–234.
- , Ü., Lõhmus, K., Kuusemets, V. & Ivask, M. 1997b. The potential role of wet meadows and grey alder forests as buffer zones. In: N. Haycock, T. P. Burt, K.W.T. Goulding and G. Pinay (Eds.). *Buffer Zones, Their Processes and Potential in Water Protection*. Oxford. Quest Environmental, Foundation for Water Research. p. 35–46.
- Mathiesen, A. 1926. Kastre-Peravalla kase puiestikkudest. (Kokkuvõte). Eesti metsanduse Aastaraamat I. Tartu. p. 42–53. [In Estonian].
- Meiner, A. (ed.) 1999. Eesti maakate. - CORINE Land Cover projekti täitmine Eestis. Land Cover of Estonia. Implementation of CORINE Land Cover project in Estonia. Tallinn. 132 p.
- Muiste, P., Tullus, H. & Uri, V. 1996. Utilization of Estonian Energy Wood Resources. In: Power Production from Biomass II With special emphasis on gasification and pyrolysis R&DD. Kai Sipilä and Maija Korhonen (eds.). Technical Research Centre of Finland. Espoo. p. 283–287.
- Ott, P. 1968. Arukase seemnekandvusest ja seemnete kvaliteedist. EPA teaduslike tööde kogumik 50. Tartu. p. 130–150. [In Estonian].
- , P. 1973. Kase seemnete kogumisest ja säilitamisest. EPA teaduslike tööde kogumik 89. Tartu. p. 28–35. [In Estonian].
- , P. 1980. Maarjakask Eesti NSV-s. EPA teaduslike tööde kogumik 128. Tartu. p. 28–35. [In Estonian].
- Pärt, E. 1987. Luidja leppik. *Mets. Puit*. Paber 29: 19–21. [In Estonian].
- Reisner, Ü. 2001. Hübriidhaavast ning tema istandustest Eestis – minevik, hetkeseis ja perspektiivid. Lehtpuupuistute kasvatamine Eestis. Akadeemilise Metsaseltsi Toimetised XIV. p. 115–122. [In Estonian].
- Schabak, O. 1931. Valge lepp (*Alnus incana*). *Eesti Mets* 11: 329–331. [In Estonian].
- Sibul, I. 2000. Maarjakask ja tema kasvatamine. Tartu. 24 p. [In Estonian].
- Tiismann, B. 1924. Hiiusaare rannikuluited, nende kinnitamine ja metsastamine. Ülikooli Õppemetskonna väljaanne. Tartu. 96 p. [In Estonian].
- Tamm, Ü. 2000. Haab Eestis. Tartu. 257 p. [In Estonian].
- Tullus, H., Uri, V. & Keedus, K. 1995. Grey alder as an energy resource on abandoned agricultural lands. Proc. Intl. Conference: Land use changes and nature conservation in Central and Eastern Europe. Palanga. p. 55–56.
- , H., Mander, Ü., Lõhmus, K., Keedus, K. & Uri, V. 1996. Sustainable Forests Management in Estonia. In: Blinn, R. C. and Thompson A. M. (Eds.). Proc. of the Meeting on Planning and Implementing Forest Operations to Achieve Sustainable Forests. Michigan, USA July 29 – August 1, 1996. p. 99–101.

- , H., Mander, Ü., Lõhmus, K., Keedus, K., Uri, V. & Ivask, M. 1997. Grey alder (*Alnus incana*) stands as energy and buffer forests in Estonia. Proceedings of the XI World Forestry Congress. 13–22 October, Vol. 3. Antalya, Turkey. 312 p.
- , H., Mander, Ü., Lõhmus, K. & Uri, V. 1998a. Sustainable use and management of abandoned farm lands for energy forestry. Proceedings of International Symposium on Global Concerns for Forest Resource Utilization. Miyazaki, Japan. Vol. 1: 398–407.
- , H., Uri, V., Lõhmus, K., Mander, Ü. & Keedus, K. 1998b. Halli lepa majandamine ja ökoloogia. Tartu. 36 p. [In Estonian].
- , H. & Uri, V. 1998. Grey alder (*Alnus incana*) as energy forests in Estonia. Proc. Intl. Conference: Biomass for Energy and Industry. Würzburg. p. 919–921.
- , H. & Uri, V. 2000. Sustainable Management of Abandoned Farm Lands for energy Forestry. H.E.L.P. Project. Book Abstracts. Rural Development: Contents, Models and Policies in the E.U., towards the 21th Century. S. Pietro-Perugia. Faculty of Agriculture 2000. p. 258–267.
- Uri, V. 1997. Halli lepa kultuuri kasv esimesel istutusjärgsel aastal. EPMÜ teadustööde kogumik 189. Tartu. p. 265–270. [In Estonian].
- , V. & Tullus, H. 1999. Grey alder and hybrid alder as short-rotation forestry species. In: Biomass: a growth opportunity in green energy and value-added products. Proceedings of the 4th Biomass Conference of Americas. Oakland, California, USA, August 29 – September 2, 1999. Ralph P. Overend and Esteban Chornet (eds.). Vol. 1: 167–173.
- , V. 2000. Halli ja hübriidlepa kultuurid endisel põllumaal ja nende biomassi tootmine. Metsanduslikud Uurimused XXXII. Tartu. p. 78–89. [In Estonian].
- , V., Tullus, H. & Lõhmus, K. 2001. Biomass production and nutrient accumulation in short-rotation grey alder (*Alnus incana* (L.) Moench) plantation on abandoned agricultural land. For. Ecol. Manage. 12 p. (in press).
- , V. 2001. Halli lepa kultiveerimisest ja seemnete kvaliteedist. Akadeemilise Metsaseltsi Toimetised XIV. Lehtpuude kasvatamine Eestis. Tartu. p. 131–139. [In Estonian].
- Vares, A. 1999. Peamised toitained (NPK) ja biomass 20 aastases sanglepa-katsekultuuris. Metsanduslikud Uurimused XXXI. Tartu. p. 90–97. [In Estonian].
- , A. 2000a. Biomass, nitrogen and phosphorus allocation in above-ground parts of black alder (*Alnus glutinosa* (L.) Gaertn.) plantations. Baltic Forestry 1: 47–52.
- , A. 2000b. Lehe suuruse ja pindtiheduse vertikaalne varieeruvus 21 aasta vanustes sanglepakultuurides. Metsanduslikud Uurimused XXXII. Tartu. p. 73–77. [In Estonian].
- , A. 2000c. Sanglepa (*Alnus glutinosa* (L.) Gaertn.) kultiveerimise võimalused Eestis. EPMÜ Metsandusteaduskonna magistrantide ja doktorantide teaduslike tööde kogumik. EPMÜ Metsandusteaduskonna toimetised 34: 5–13. [In Estonian].
- , A. & Tullus H. 2001. Sanglepa kultiveerimine ja kasvatamine. Akadeemilise Metsaseltsi Toimetised XIV. Lehtpuude kasvatamine Eestis. Tartu. p. 123–130. [In Estonian].
- Viiilup, Ü. 1999. Metsaressursid. Aastaraamat METS'99. Tartu. p. 1–33.

SWEDEN:

The role of broad-leaved tree species in Swedish forestry

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Abstract

In Sweden the total growing stock for conifers and broadleaves was 2.8 bill. m³ in the survey period 1993–1997. The percentage broadleaves of total growing stock was 16 % or 0.441 bill. m³.

Among broadleaved species, birch is the main species in Sweden. Pendula and pubescent birch include 68 % of total growing stock of broadleaves. Pubescent birch, which covers most of Sweden, is the main birch species. Pubescent birch has its widest distribution in northern Sweden. Pendula birch is more evenly spread over Sweden with the main coverage in southern Sweden. European aspen, which is growing in total Sweden, is the second most frequent broadleaved species with 9 % of the growing stock.

In Sweden there are two main noble tree species, oak and beech, which are growing mostly in southern Sweden. The wood production in 1998 was 50.7 mill. m³ and 7 % (3.6 mill. m³) of the production was produced by broadleaved species. Only parts of percentage were utilised for broadleaved sawtimber. The consumption of broadleaved wood and sawtimber from hardwood has also increased in 1995 compared with the amount in 1984.

Then in 1985 there became a commercial value on pulpwood of birch. The prize for birch pulpwood is as high as for spruce pulpwood. Today there is a lack of birch for pulpwood in Sweden. The timber prize for birch is higher than for conifer timber. Small quantities of veneer are also produced. Oak and beech timber is used for making floors and furniture.

During the last 20 years research on broadleaved trees has changed from studying methods for cleaning conifer stands with the aim to reduce or completely remove the broadleaves to studying broadleaved species as a challenge.

Some implications on future research activities are given.

1 Background

Historically, broadleaved trees have been utilised as a producer of pulpwood and timber, for medical purpose, as fodder for cattle, for making potash, for pollarding, coppice etc.

Potash production was very important for the export market in Sweden during 1700. However, the procedure demanded high quantities of birch trees and locally there became a deficit of birches (Tirén 1987).

During centuries until middle of the 1900s broadleaved trees were used as fodder for cattle. Mostly European aspen (*Populus tremula* L.), common ash (*Fraxinus excelsior* L.), rowan (*Sorbus aucuparia* L.) and birch were used. There were two main ways of utilisation. One way was to use leaves and finer twigs, another way was to fell the trees and the cattle browsed the tree, gnawed the bark, and sometimes browsed parts of the wood.

In Sweden pollarded trees mostly are found in southern and middle Sweden. Lime tree (*Tilia cordata* L.), willow (*Salix* spp.) and sometimes birch are the broadleaved tree species, which frequently have been pollarded. Pollarding was used for creating an aesthetic landscape view but also as fodder supply for the cattle.

Noble species such as common oak (*Quercus robur* L.) and European beech (*Fagus sylvatica* L.) have been managed for timber production the last 500–600 years. Most of noble tree species are growing in Southern Sweden. Among Nordic countries the largest oak plantings is localised on an island “Visingsö” (Fig. 1). This plantation was established in 1830 for production of oak timber for the navy (war ships). But when the forest owner in 1985 presented these oak stands ready for clear felling and further building of war ships the marine stab was not interested. The area of the plantation is 375 ha. On 50 % of the area oaks were planted and on the other half oaks were seeded. Totally 260 000 plants were planted but on some areas the plantings was supplied with new plants when older died. Today these stands are managed and some of the oaks are used for building new ships with older original ships as a prototype. Oak timber from this plantation has been used for repairing the old war ship “Wasa”.

As the number of oak and beech stands decreased during 1960–1970 the authorities made a special law concerning management of beech. This law stated that if an owner clear-cut a beech stand he must plant beech on the area. In the forest law there also was stated that oak stands must be reforested by oak to avoid decreasing areas of oak stands.

On the contrary, the forest laws 1948 and 1979 stated that primarily conifers should be favoured on clear-cut areas. Only birches, mainly pendula birch (*Betula pendula* Roth), could be accepted as a main plant. Cleanings of young stands should be focussed on reducing or complete removal of broadleaved trees. Large clear cut or reforested areas were treated by herbicides during the 1960s and 1970s. Then in 1985 there became a commercial value on pulpwood of birch. Today, the prize for birch pulpwood is as high as for spruce pulpwood. Nowadays there is a lack of birch for pulpwood in Sweden.

The actual forest law 1993 states as a compulsory aim that forest yield and biodiversity have equal dignity when managing forest land. In practise some broadleaved stands such as common alders (*Alnus glutinosa* (L.) Gaertn) growing on wet rich sites with a high quality of rare species could not be commercially managed.



Figure 1. Map of geographical localisation for oak plantation at Visingsö.

2 Forest statistics today

The total growing stock for conifers and broadleaves was 2.8 bill. m³ in the survey period 1993–1997 (Anon. 2000). The percentage hardwood by total growing stock was 16 % or 0.441 bill. m³. In Table 1 an overview is made for growing stock by different survey periods for some species. The percentage broadleaves by total growing stock differ only by parts of a percentage unit.

Table 1. Growing stock, mill. m³, by different survey periods (Anon, 2000).

Period	Pine	Spruce	Birch	Others	Total	% hard-woods
1923-29	702	715	258	85	1 760	19.5
1952-62	897	991	252	83	2 223	15.1
1958-67	906	1 027	247	97	2 276	15.1
1968-72	915	1 108	243	105	2 372	14.7
1973-77	915	1 115	259	114	2 403	15.5
1978-82	973	1 142	275	128	2 517	16.0
1983-87	965	1 208	261	125	2 559	15.1
1988-92	1 078	1 244	285	143	2 750	15.6
1993-97	1 149	1 283	313	147	2 892	15.9

Among broadleaved species, birch is the main species in Sweden. Pendula and pubescent birch (*Betula pubescent* Ehrh.) include 68 % of total growing stock of broadleaves (Table 2). Pubescent birch, which covers most of Sweden, is the main birch species (Fig. 2). Pubescent birch has its widest distribution in Northern Sweden (Table 2). Pendula birch is more evenly spread over Sweden with the main coverage in Southern Sweden. European aspen growing in total Sweden is the second most frequent broadleaved species with 9 % of the growing stock (Fig. 2 and Table 2).

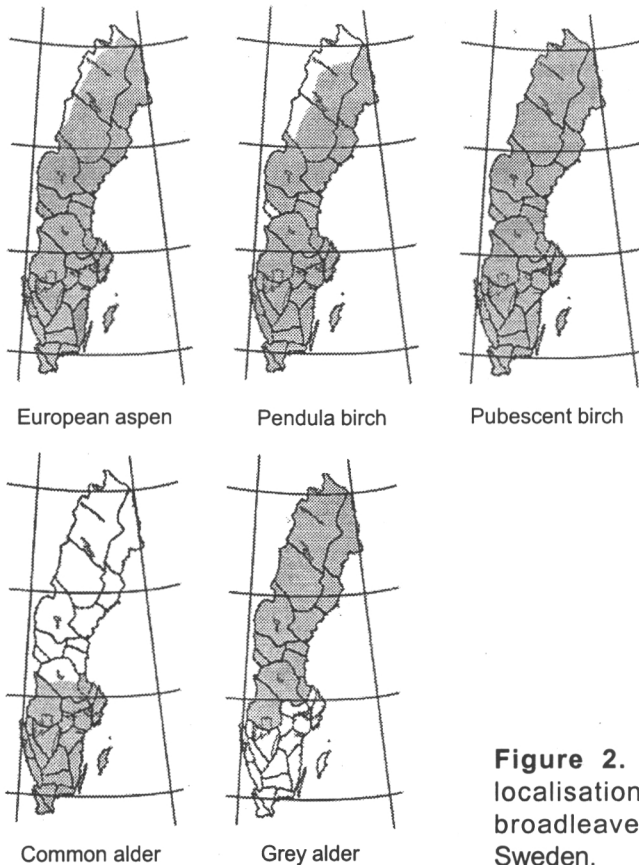


Figure 2. Geographical localisation of main broadleaved species in Sweden.

Table 2. Growing stock by species, mill. m³, by regions in Sweden ,1995-99 (Anon, 2001)

Species	Northern Sweden	Central Sweden	Southern Sweden	Total	%
Scots pine	549	306	245	1100	39.4
Norway spruce	510	313	428	1251	44.8
Pendula birch	14	24	36	74	2.7
Pubescent birch	144	40	39	223	8.0
Common alder	1	7	16	24	0.9
Grey alder	6	3	1	10	0.4
Aspen	13	14	13	40	1.4
Sallow	7	2	3	12	0.4
Rowan	1	1	3	5	0.2
Other hardwoods	1	1	2	4	0.1
Beech	-	-	17	17	0.6
Oak	-	2	24	26	0.9
Ash	-	-	3	3	0.1
Maple	-	-	1	1	0.03
Elm	-	-	1	1	0.03
Lime	-	-	1	1	0.03
Total	1246	713	833	2792	100

The two alder species have different geographical distribution. Common alder grows in southern and middle Sweden (Table 2 and Fig. 2). On the other hand grey alder (*Alnus incana* (L.) Moench.) grows in northern and middle Sweden.

In Sweden there are two main noble tree species, oak and beech, which are growing mostly in Southern Sweden (Table 2 and Fig. 3). Oaks growing in the most northern part of its distribution area mostly are short and the tree is more or less a “bush”. The timber quality is low. Common ash (*Fraxinus excelsior* L.) is an important species. Generally, common ash grows in small grows mixed with common alders.

Most of the broadleaved stems are thinner than 30 cm at breast height (Table 3). It is only European aspen and common alder stands, which have more than 20 % of the stems thicker than 30 cm. Among noble species all species have >30 % of the stems with breast height diameter >30 cm (Table 3). Noble trees are more often managed by cleanings and thinning than other broadleaved species.

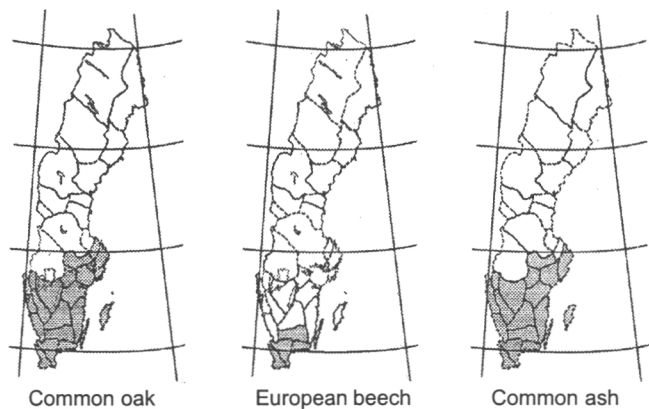


Figure 3. Geographical localisation of main noble species in Sweden.

Table 3. Percentage growing stock by diameter classes, %.

Species	Diameter class, cm					Growing stock	
	0-10	10-20	20-30	30-45	45+	Mill. m ³	%
Aspen	8	27	34	25	6	35	1.3
Birch	21	46	24	9	-	270	67.5
Grey alder	42	43	13	2	-	9	2.3
Common alder	9	33	38	20	-	22	5.4
Rowan	58	30	8	3	1	4	1.1
Sallow	21	35	27	12	5	10	2.4
Other species	35	33	16	7	9	3	0.7
Elm	16	16	20	17	31	1	0.2
Ash	14	21	26	28	11	3	0.8
Beech	3	9	19	40	29	16	4.0
Oak	7	16	21	30	26	25	4.0
Lime		14	15	14	57	1	0.2
Maple	14	35	19	23	9	1	0.2

3 Industrial production

The wood production in 1998 was 50.7 mill. m³ and 7 % (3.6 mill. m³) of the production was produced by broadleaved species. Only parts of percentage was utilised for broadleaved sawtimber (Table 4). Most of harvest broadleaved stems are used as pulp wood and biofuel. Production of saw timber of birch, alder and aspen is low, 3.1 % by total broadleaved cuttings (Table 4).

The consumption of broadleaved wood in 1995 has increased since 1984 (Table 5). The consumption of sawtimber from broadleaved species has also increased in 1995 compared with the amount in 1984 (Table 5).

Table 4. Wood production of soft- and hardwoods in Sweden (1998).

Totally		Softwood		Hardwood	
Mill, m ³	%	Mill, m ³	%	Mill, m ³	%
50.7	100	47.1	93	3,6	7
		Saw timber 31.5 (63%)		Saw timber 0.1 (3.1%)	
		Pulpwood 18.8 (37%)		Pulpwood 3.1 (96.9%)	

Table 5. Consumption and production of hardwood saw timber, 1000 m³, for years 1984, 1990 and 1995. (Saw mills with a production > 1 000 m³).

Consumption of saw timber, 1000 m ³			Production of saw timber, 1000 m ³		
1984	1990	1995	1984	1990	1995
346	340	374	192	182	207

4 Wood prices

The timber prices for birch are higher than for conifer timber. Small quantities of veneer are also produced. Oak and beech timber is used for making floors and furniture.

5 Research status in Sweden

During the last 20 years research on broadleaved trees has changed from studying methods for cleaning conifer stands with the aim to reduce or completely remove the broadleaves to studying broadleaved species as a challenge.

Reports dealing with site index are presented for birch (Eriksson et. al. 1997, Karlsson et. al. 1997), European aspen (Johansson 1996), common and grey alders (Johansson 1999a).

Yield and management studies of mixed stands of Norway spruce and birch have been presented by among others Tham (1989), Mård (1996), Bergqvist (1999), Klang and Ekö (1999) and Johansson (2000a, 2001).

During the last ten years efforts have been made to construct functions for predictions of biomass yield for broadleaved species. Biomass functions for young birches, aspens and alders have been presented by Johansson (1999b,c and 2000b). Older grey and common alders have been studied and functions for prediction of biomass have been presented by Johansson (1999d).

Karlsson (1996) studied growth and survival of natural seeded birches growing abandoned farmland area.

Trials with planting on abandoned farmland started in 1988. The main species was birch but also alder, hybrid aspen, balsam poplar and wild cherry have been approved. Oak plantation mostly by seeding has been established. Results from some experiments on birch and alder plantings have been published (Johansson 1999e, 2000c).

Some studies on wood quality have been made (Johansson 2000d,e).

6 Further research activities

Still there is a need for more knowledge about:

- Methods for managing mixed stands of Norway spruce/alder, Norway spruce/aspen and Norway spruce/birch
- Methods for managing pure stands of alders or aspens but also birches with according to biodiversity and sustainability
- Improving wood quality of broadleaved species
- Methods for harvesting small quantities of broadleaved stems
- Logistic solutions of transporting small quantities to sawmills or other manufactories
- Establishing network between forest owners and the industry (sawmills and joineries)

References

- Anon. 2000. Statistical yearbook of forestry 2000. Official statistics of Sweden. National Board of Forestry. Jönköping. 345 p.
- , 2001. Statistical yearbook of forestry 2001. Official statistics of Sweden. National Board of Forestry. Jönköping. 337 p.
- Berqvist, G. 1999. Wood volume yield and stand structure in Norway spruce understorey depending on birch shelterwood density. *Forest Ecology and Management* 122: 221–229.
- Eriksson, H., Johansson, U. & Kivistie, A. 1997. A site-index model for pure and mixed stands of *Betula pendula* and *Betula pubescens* in Sweden. *Scandinavian Journal of Forest Research* 12: 149–156.
- Hazell, P. 1999. Conservation and yield aspects of old European aspen *Populus tremula* L. in Swedish forestry. SLU, *Studia Forestalia Sueciæ*. *Silvestria* 102. 34 p.
- Johansson, T. 1996. Site index curves for European aspen (*Populus tremula* L.) growing on forest land of different soils in Sweden. *Silva Fennica* 30(4): 437–458.
- , T. 1996. Management of birch forest. In: J. Dietrichson (ed). *Silviculture for fuel wood*. IEA Bioenergy Task XII Activity on "Forest management" Workshop. *Norwegian Journal of Agricultural Sciences*. Suppl. No 24: 7–20.
- , T. 1998. Biomass utilization in mixed stands of birch – Norway spruce, aspen – Norway spruce, and alder – Norway spruce in Sweden. In: J. Richardson (ed.) *Bioenergy and boreal forest management*. IEA Bioenergy. Scientific and Technical Publications, Science Branch Canadian Forest Service, National Resources Canada Ottawa. p. 25–31.
- , T. 1999a. Site index curves for common alder and grey alder growing on different types of forest soils in Sweden. *Scandinavian Journal of Forest Research* 14: 441–453.
- , T. 1999b. Biomass equations for determining fractions of pendula and pubescent birches growing on abandoned farmland and some practical implications. *Biomass & Bioenergy* 16: 223–238.
- , T. 1999c. Biomass equations for determining fractions of European aspen growing on abandoned farmland and some practical implications. *Biomass & Bioenergy* 17: 471–480.
- , T. 1999d. Biomass equations for determining fractions of 21–91-year-old common alder and grey alder growing on forest land and farmland and some practical implications. *Canadian Journal of Forest Research* 29: 1679–1690.
- , T. 1999e. Förekomst av självföryngrade lövträd på nedlagd jordbruksmark. Summary: Presence of self-regenerated broad-leaved trees growing on abandoned farmland. SLU. Department of Forest Management and Products. Report 2. 83 p.
- , T. 2000a. Regenerating Norway spruce under the shelter of birch on good sites might increase biofuel supply in Sweden. *New Zealand Journal of Forestry Science* 30: 16–28.
- , T. 2000b. Biomass equations for determining fractions of common and grey alders growing on abandoned farmland and some practical implications. *Biomass & Bioenergy* 18: 147–159.
- , T. 2000c. Överlevnad och tillväxt hos glasbjörk, vårtbjörk och klibbal planterade på åkermark. Summary: Survival and growth for pubescent birch, pendula birch and common alder growing on farmland areas. SLU, Department of Forest Management and Products. Report 13. 35 p.
- , T. 2000d. Grå- och klibbalens virkeskvalitet. Summary: Timber quality in stands of grey- and common alders. SLU, Department of Forest Management and Products. Report 8. 66 p.
- , T. 2000e. Röta i stubbskott av björk. Summary: Rot in sprouts of birch. SLU, Department of Forest Management and Products. Report 11. 35 p.

- , T. 2001. Björkskärm över gran. Summary: Birch shelter and Norway spruce. SLU, Department of Forest Management and Products. Report 16. 29 p.
- Karlsson, A. 1996. Initial seedling emergence of hairy birch and silver birch on abandoned fields following different site preparation regimes. *New Forests* 11: 93–123.
- , A., Albrektsson, A. & Sonesson, J. 1997. Site index and productivity of artificially regenerated *Betula pendula* and *Betula pubescens* stands on former farmland in southern and central Sweden. *Scandinavian Journal of Forest Research* 12: 256–263.
- Klang, F. & Ekö, P.-M. 1999. Tree properties and yield of *Picea abies* planted in shelterwoods. *Scandinavian Journal of Forest Research* 14: 262–269.
- Mård, H. 1996. The influence of a birch shelter (*Betula* spp.) on the growth of young stands of *Picea abies*. *Scandinavian Journal of Forest Research* 11: 343–350.
- Tham, Å. 1989. Prediction of individual tree growth in managed stands of mixed *Picea abies* (L.) Karst. and *Betula pendula* Roth and *Betula pubescens* Ehrh. *Scandinavian Journal of Forest Research* 4: 491–512.
- Tirén, L. 1937. Skogshistoriska studier i trakten av Degerfors i Västerbotten. Reports from the Swedish Institute of Experimental Forestry 30: 67–314. [In Swedish].

Voluntary papers

Broad-leaved breeding in Sweden

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1 Introduction

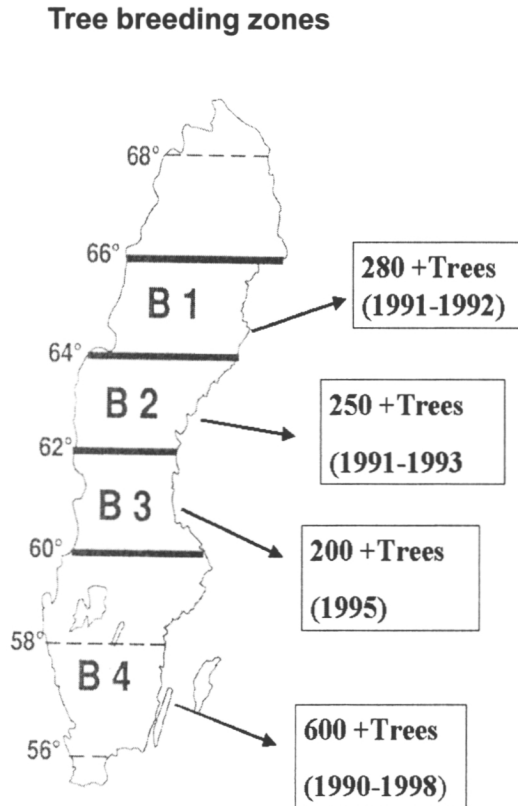
During the recent years approximately 300 million conifer seedlings have annually been planted in Sweden compared to the roughly 2–3 million broad-leaved seedlings (mainly birch). These small quantities explain why the financial resources for breeding broadleaved species are quite limited and why the intensity in breeding varies for different species. Long-term breeding is for instance only carried out for silver birch. For other broadleaved species it is a question of intermittent short-term activities mainly financed by external fundings.

2 Birch

Birch is the only deciduous species that is bred following a long-term breeding strategy. The breeding is carried out following a strategy which combines long-term adaptation and genetic improvement with the preservation of genetic diversity. Breeding material is kept separate in several unrelated populations of trees (breeding populations). The main operations in the breeding work are selection, crossing and testing, and these are carried out in each of these populations. The different populations are bred for adaptation to different combinations of latitude and temperature climate. When producing bred seed for commercial use, parent trees can be taken from more than one population in order to reduce coancestry between trees and increase gain.

Practical work in the breeding of birch started in the 1940s, but true breeding with the aim of improving climatic adaptation, growth and quality throughout the country didn't start until 1988. A total of 1300 plus trees of silver birch and 200 of downy birch have been selected in Sweden, Finland, the Baltic states, Poland and Germany for possible use in Sweden. The major part of the material is currently out in field trials. Reliable results from all plus trees will be obtained not later than year 2005, making it possible to select the best plus trees to be used in long-term breeding and new seed orchards.

Figure 1. Number of plus-trees selected and year of field test establishment in various regions.



3 Hybrid aspen

A lot of intensive breeding work with hybrid aspen (*P. tremula* x *P. tremuloides*) was done during 1940–1960's by the Swedish Match Company. Since it became cheaper to buy raw material elsewhere the company lost interest and the improvement work was ended. However, the interest in hybrid aspen was increased once more, when the discussions about alternative use of the surplus of agriculture land started in the middle of the 1980's. Thus in order to improve the reforestation material of hybrid aspen, SkogForsk selected 300 plus-tree clones in the old trials and in commercial stands south of latitude 60°. All 300 clones were copied as root cuttings and established in clonal tests in south Sweden during 1986–1991. Today all 11 clonal tests have been evaluated, i.e. we have genotypic values for all 300 tested clones. Production in the oldest trials indicates that the yield will be at least 20 m³ sk/ha, year at a rotation time of 20–25 years when the 15 % best clones are used.

Height by age. Clonal test S1055

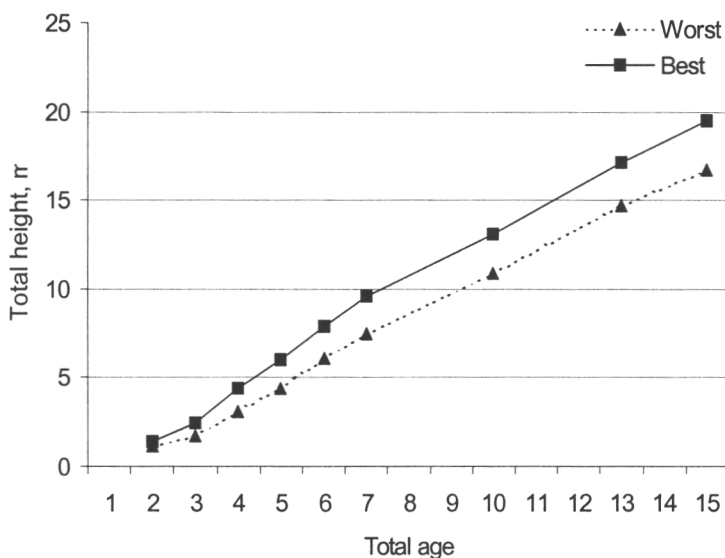


Figure 2. Height growth over age for the 5 best and 5 worst clones out of totally 55 clones tested in the trial at Bulstofta, latitude 55° 59'.

By fertilisation and watering the yield can of course be much higher. However, the interest from the forest owners is today almost zero. Since stem canker (*Hypoxyylon mammatum*) can be a very serious pathogen on hybrid aspen future research will be focused on this problem.

4 Alder

Practical breeding work with alder began in the 1940s. Work to cross different species (grey alder, black alder and red alder) was fairly intense during the 1950s. One result from these activities are the seed orchards at Ignaberga and Kollberg (in Skåne), which contain untested plus trees of black alder.

The current level of activity with alder is rather low. However, during the 1990s a minor improvement project started for black alder in cooperation with Lithuanian breeders. Approximately 150 new plus trees were selected in Götaland, Svealand and in Lithuania. Progeny tests were established in southern Sweden and in Lithuania in 1998. In the Swedish trials, species hybrids between black and red alder are included, since they have shown very high yields in previous trials.

Breeding activities with the grey alder are neither in progress or planned.

Long-term tree breeding strategy in Finland, with special emphasis on broadleaved species

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Summary

First-generation seed orchards of phenotypically selected plustrees of Scots pine and Norway spruce, established mainly between years 1965 and 1975, are now in full production in Finland. The economically productive stage of these orchards is expected to last 40–50 years. The establishment of second phase seed orchards (mainly so-called 1,5-generation orchards) has been started, and will be carried out through the whole country within next 10–15 years. Seed orchard management of birch species has been practised in polythene greenhouses since the 1970s, with production periods of 5 to 10 years. Also a few clonal orchards of “noble hardwoods” and some minor broad-leaved species were established in the late 1970’s.

Establishment and juvenile-stage management of seed orchards as well as long-term forest tree breeding have always been completely state funded in Finland. The latter was formerly organised as a co-operation of several forestry institutions. Since the beginning of year 2000, tree breeding at the national level has been centralised as the responsibility of the Finnish Forest Research Institute.

Finnish tree breeding strategy was reformulated in the late 1990s. The present strategy is based on the idea of open nucleus breeding system in which the breeding material in each breeding zone is organised into a main breeding population of about 300 progeny-tested plus trees, and a nucleus population of 50–70 best ranked genotypes. The new strategy is closely linked to the planning of the 1,5-generation seed orchards. Simultaneously with the selection of about 50 best-ranking mother trees for new seed orchard units, roughly the same sets of individuals are adopted as the nucleus populations of the respective species and zones. The second cycle of breeding begins with controlled crosses in the nucleus populations to produce progeny for forward selection. In the main populations, breeding is planned to be continued mainly with phenotypic selection of second generation candidates in existing 10–20 years old progeny tests. Several alternatives are open for the procedures of testing and forward

selection (e.g., generative or vegetative progeny, phenotypic or genotypic selection). The final choices in different species naturally depend, first of all, on the availability of economic resources for tree breeding in the coming years.

The basic principle of present Finnish tree breeding strategy is its integration to the seed orchard programme, which again is based on predicted needs of reforestation seed in practical forestry. The second cycle of breeding must be carried out in such a way that new selections are available at the right time to serve the establishment of third phase of seed orchards (mainly 2nd generation orchards). In Scots pine and Norway spruce this would require the breeding cycle to be limited to 40–50 years. In birch species the breeding cycle maybe must be adjusted to 20 years, although seed orchard rotation is only 10 years at maximum. For aspen, a small breeding program based on selection and controlled crossing followed with clonal testing and propagation has been formulated. In other broadleaved species, there are no decisive plans how to continue breeding in the second cycle.

The present long-term breeding strategy is strongly based on the idea that seed orchards continue to be the main method of commercial mass production of genetically improved reforestation material also in the future. However, the strategy seems be quite efficient to serve more immediate needs and production alternatives as well. It should be able to offer genetically well-known individuals and families for commercial multiplication, short-term breeding operations and biotechnical manipulations almost continuously.

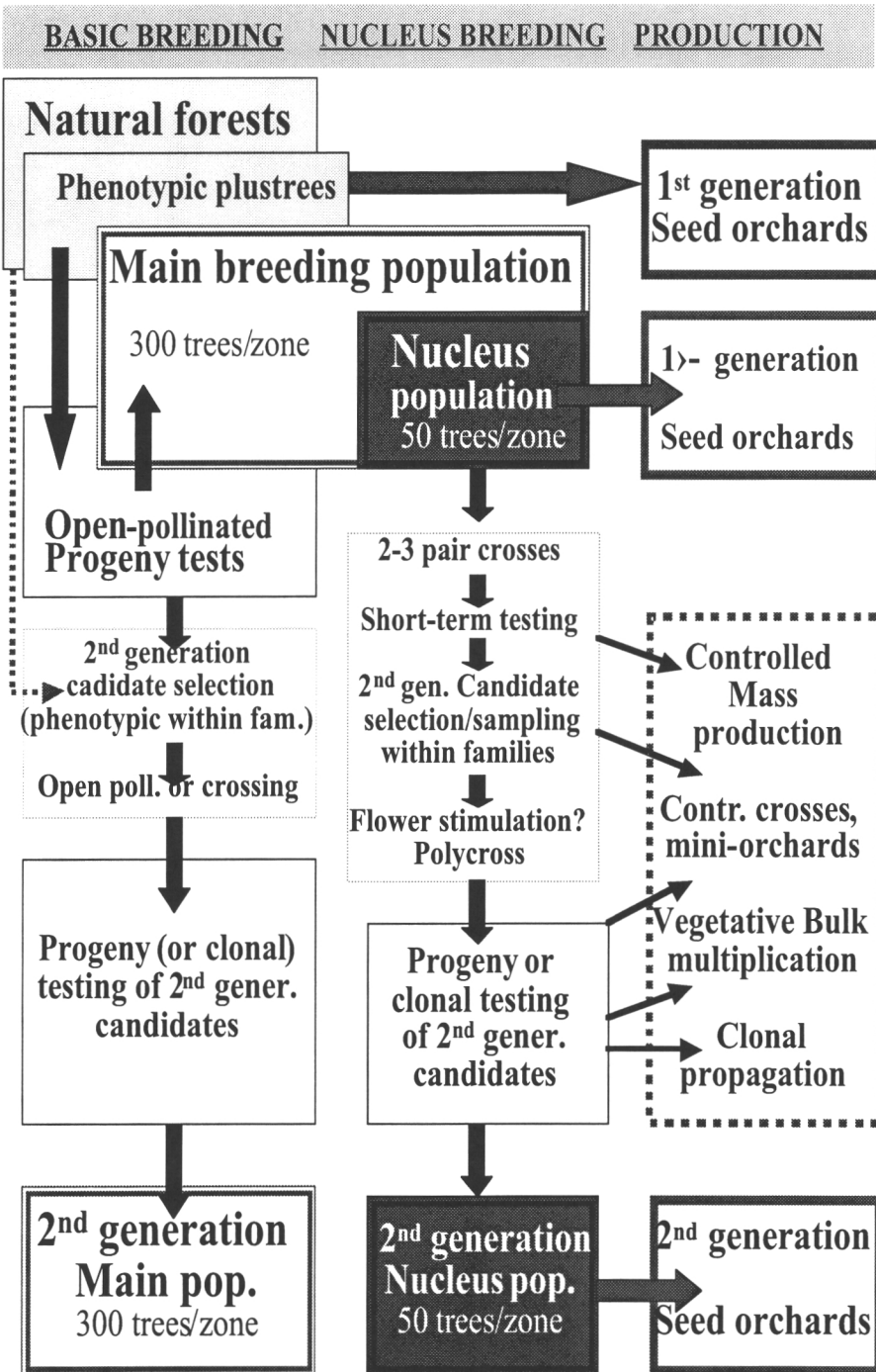


Figure 1. Long-term breeding plan for the main tree species in Finland. The time scale for the progress from 1st to 2nd generation breeding populations (and from 1½ to 2nd generation seed orchards) is 40 to 50 years for *Pinus sylvestris* and *Picea abies*, and about 20 years for *Betula pendula*.

Possibilities of controlling the wood properties of hybrid aspen

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Abstract

The use of hybrid aspen (*Populus tremula* x *P. tremuloides*) as raw material for making high quality printing papers is not only dependent on the wood quality or growth traits themselves, but also on the possibilities of multiplying trees with the desired fibre and growth characteristics.

The fibre length in the 162 trees studied varied between 0.7 mm and 1.1 mm, and the dissolved lignin content between 8–15 %. The fibre length seems to be not only under genetical control, but the size of the tree also appears to correlate with fibre length. The 24 hybrid aspen clones studied differed considerably with respect to their multiplication efficiencies when produced by means of micropropagation. However, there were no significant correlations between multiplication efficiency and fibre length, or between multiplication efficiency and lignin content.

Key words: fibre length, lignin content, vegetative production, aspen clones

1 Introduction

Wood properties are not only important in paper production processes, but they may also have a considerable impact on the consumption of energy and production of waste, and subsequently on the use of environmental resources.

It has been suggested that an efficient, sustainable production chain could be constructed using aspen (*Populus tremula* L.) or the more rapidly growing hybrid aspen, *Populus tremula* x *P. tremuloides*. These tree species seem to have certain characteristics that make suitable for sustainable production combined with high-quality paper making (Dhak et al. 1997, Karl 1998, Tarvainen 1999). According to Ranua

(1996), by selecting short fibre material among aspens it is possible to produce high quality printing papers with high opacity levels and rigidity with considerably low weight.

Aspens and hybrid aspens have a considerably high variation in wood and growth properties (Pulkkinen et al. 1999, Tarvainen 1999, Rautio et al. 2001, Yu et al. 2001b) and, moreover, these characteristics seem to be under at least moderate genetical control (Yu et al. 2001b). However, the only way to utilise these desired characteristics efficiently is via vegetative propagation (cloning). This means that we have an opportunity to utilise the total genetic variation, and the desired wood and fibre characteristics will then be included in all the planting material produced.

2 Material and methods

Height and diameter at breast height were measured on 162 hybrid aspen trees located in several stands around Southern Finland. The age of the trees was calculated from increment core samples. The amount of dissolved lignin and fibre length in the wood of the trees were also measured in the Department of Chemistry, University of Jyväskylä. All the analyses were carried out on 2 core samples taken at breast height from each tree with a 5-mm increment borer. For more detailed information, see Tarvainen (1999).

The production method used in the study was micropropagation in which the shoot cultures were grown on a modified WP medium containing an increased concentration of calcium nitrate (Lloyd and McCown 1980). The laboratory techniques have been described in more detail in Lepistö et al. (1998). The rooting percentage was calculated from plantlets transferred unrooted from the laboratory into fertilised peat in the greenhouse. The clonal values in rooting were averaged over 1997 and 1998. The multiplication rate (MR) was taken as the number of plantlets obtained per jar, and was also averaged over two years. The multiplication results presented here are based on the 24 clones.

3 Results and conclusions

There was considerable variation in the lignin content and fibre length between the trees (= clones). The clonal means of dissolved lignin varied from 8 to 15 %, and the fibre length from 0.7 to 1.1 mm. The mean dissolved lignin content was 11 % and fibre length 0.9 mm.

Although we already know that these fibre traits are under genetical control (Yu et al. 2001), it seems that the age and height of the tree also have a considerable impact on fibre length at least (Fig. 1). It has earlier been reported that the age of the cambium and the growth rate affect the fibre traits in several tree species (see e.g. Kennedy 1957, Yanchuk et al. 1984). Thus, even though there is no clear evidence from poplar trials, perhaps due to their young age, it may be possible to control the fibre length by means of planting density and rotation times.

The multiplication possibilities also varied considerably between the 24 clones. The multiplication rate ranged from 11 up to 27 shoots per jar, and the rooting percentages from 42 to 91 (Fig. 2). The clones with high multiplication rates tended also to have also a high rooting ability. However, the most interesting finding is that there were no strong correlations between the fibre traits and micropropagation rates (see Table 1).

Based on the results presented here and in other recent publications (see Yu 2001), aspen and hybrid aspen seem to have certain characteristics which may allow relatively efficient control of these fibre traits. First of all, there is high variation between clones, and secondly, part of the variation is under genetical control and a considerable portion of the environmental variation is probably due to ageing and growth.

A method for producing the desired fibre material (e.g. short fibres) could consist of:

1. preselection of the candidate clones on the basis of phenotypical fibre characteristics
2. selection of clones on the basis of the propagation efficiencies
3. final selection of the clones on the basis of the growth and resistance values
4. efficient multiplication of the clones using e.g. pieces of root (Pulkkinen and Herrala 2000) or micropropagation
5. short-rotation and high-density production stands.

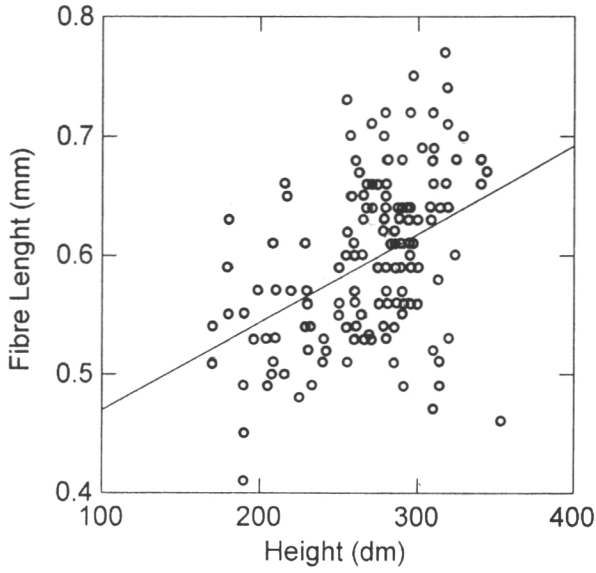


Figure 1. Relationship between height and fibre length in the hybrid aspens.

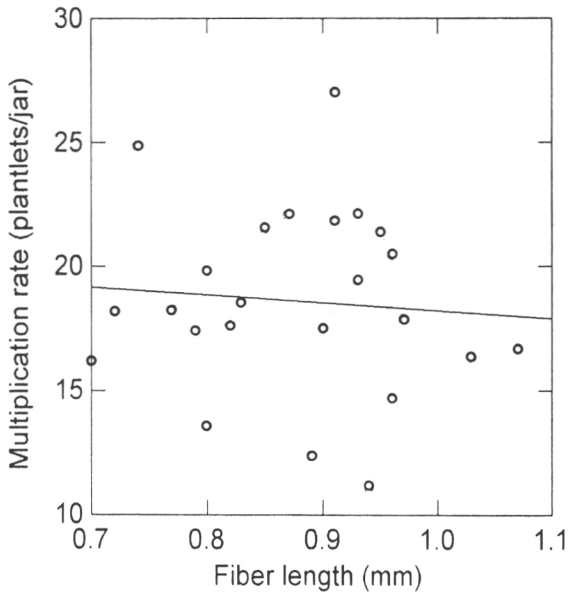


Figure 2. Relationship between fibre length and multiplication rates of micropropagation in the hybrid aspen clones.

Table 1. Pearson's correlation coefficients (*r*) among the micropropagation traits and wood properties in 24 aspen hybrid clones.

Characteristics	Multiplication rate	Rooting %	Figre length mm
Rooting, %	0.55**		
Figre length, mm	-0.11	0.11	
Lignin, %	0.02	-0.02	0.02

From Pulkkinen (2001)

References

- Kennedy, R.W. 1957, Fibre length of fast- and slower-grown black cottonwood. *For. Chron.* 33: 46–50.
- Dhak, J., Pitz, M. & Crossley, B.R. 1997. Refining characteristics of aspen. TAPPI proceedings. Engineer and papermakers Conference. p. 347–352.
- Karl, W. 1998. Aspen: quickly becoming today's preferred wood species for pulp. *Pulp and Paper Journal* 41: 119–123.
- Lepistö, M., Salonen, M. & Salonen, S. 1998. Haavan jalostus- ja lisäystekniikka. Hankkeen toisen vaiheen loppuraportti tilaajalle. Metsänjalostussäätiö. 17 p.
- Levlin, J.E. and Söderhjelm, L. 1999. *Pulp and Paper Testing*. Fapet Oy. Helsinki, Finland. 287 p.
- Lloyd, G. & McCown, B. 1980. Commercially-feasible micropropagation of Mountain laurel, *Kalmia latifolia*, by use of shoot-tip culture. *The International Plant Propagators' Society. Combined Proceedings* 30: 421–427.
- Pulkkinen, P. 2001. The effect of wood properties on the possibilities of vegetative propagation of hybrid aspen. In: Pulkkinen, P., Tigerstedt, P.M.A. & Viirros, R. (eds). "Aspen in Papermaking" seminar in Espoo, Finland 20–21.11.2000. University of Helsinki, Department of Applied Biology, Publications 5: 34–39.
- , & Herrala, K. 2000. Esiraportti juuripistokaskokeen tuloksista. Report to Metsämannut Corp. 7 p.
- , Lepistö, M. & Tarvainen, N. 1999. Properties of the woody tissue of aspen as the subject of genetic improvement. In: Napola, J. (ed.). *Annual Report of Foundation for Forest Tree Breeding in Finland 1998*. Auranen, Forssa. p. 34–35. ISSN-0355-1024.
- Ranua, J. 1996. Miksi haapa kiinnostaa metsäteollisuutta? Why is the Finnish forest industry interested in Aspen, in Finnish with English summary. *Sorbifolia* 27: 178–180.
- Rautio, M., Kangas, T., Auterinen, T., Álen, R. & Pulkkinen, P. 2001. Wood quality components for paper making in hybrid aspen. In: Pulkkinen, P., Tigerstedt, P.M.A. & Viirros, R. (eds). "Aspen in Papermaking" seminar in Espoo, Finland 20–21.11.2000. p. 19–26. University of Helsinki, Department of Applied Biology, Publications 5: 19–26.
- Tarvainen, N. 1999. Haapapuun kuitudimensooiden ja ligniinipitoisuuden vaihtelusta paperiteknisen potentiaalinal kannalta. Lisensaatintutkimus. Kemian laitos. Jyväskylän Yliopisto. 90 p.
- Yanchuk, A.D., Dancik, B.P. & Micko, Y.Y. 1984. Variation and heritability of wood density and fibre length of trembling aspen in Alberta, Canada. *Silvae Genet.* 33: 11–16.

- Yu, Q. 2001. Selection and propagation of hybrid aspen clones for growth and fibre quality. University of Helsinki, Department of Applied Biology, Publications 6. 41 p.
- , Mäntylä, N. & Salonen, M. 2001a. Rooting of hybrid clones of *Populus tremula* L. x *P. tremuloides* Michx. By stem cuttings derived from micropropagated plants. *Scan. J. For. Res.* 16: 238–245.
- , Pulkkinen, P., Rautio, M., Haapanen, M., Alen, R., Stener, L.G., Beuker, E. & Tigerstedt, P.M.A. 2001b. Genetic control of wood physiochemical properties, growth and phenology in hybrid aspen clones, *Can. J. For. Res.* 31: 1–9.

The above-ground biomass and production of alders (*Alnus incana* (L.) Moench, *Alnus glutinosa*, (L.) Gaertn. *Alnus hybrida* A. Br.) on abandoned agricultural lands in Estonia

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Abstract

The above-ground biomass and production were evaluated in a grey alder plantation during six years after establishment, in a hybrid alder plantation during five years after establishment and in a 21-year-old black alder plantation. The plantations were set up on abandoned agricultural land. The above-ground biomass of grey alder plantations after six years was 25.3 t DM ha⁻¹ and annual current production was 11.5 t DM ha⁻¹. The respective figures were for the hybrid alder plantation in the fifth year after establishment 10.1 t DM ha⁻¹ and 5.6 t DM ha⁻¹. Above-ground biomass in the 21-year-old black alder stand was 88.8 t DM ha⁻¹ and mean annual production, 17.1 t DM ha⁻¹.

Key words: *Alnus incana*, *Alnus glutinosa*, *Alnus hybrida*, above-ground biomass, production, abandoned agricultural land

1 Introduction

During the last decade the economic situation has changed drastically in Estonia. Agricultural production declined, as a result of which 228 000 ha of abandoned agricultural land have come into existence (Meiner 1999), ensuring availability of necessary land resources for afforestation in Estonia. Such lands are afforested naturally with broadleaved pioneer tree species: alders, birches, aspen and willows. Owing to the extensive area of uncultivated land and considering the fact that the economic importance of deciduous trees has grown with each year, interest in establishment and cultivation of various deciduous stands has lately aroused general interest in Estonia. Of the greatest economic importance in afforestation of agricultural

land and in cultivation of deciduous in the conditions of Estonia is silver birch (*Betula pendula* Roth). Cultivation of hybrid aspen (*Populus tremula* L. x *Populus tremuloides* Michx.) has become a matter of consideration in recent years as well. Namely alders, primarily grey alder, form the first forest generation on former agricultural land. Still, considerably little attention has so far been paid to the research and cultivation of alders in Estonia. Only in the last decade was there undertaken more thorough study of issues related to alders, including cultivation of grey, black and hybrid alders (*Alnus hybrida* A. Br.) on former agricultural land, among them grey and hybrid alder as short-rotation forestry species. In cultivation of black alder stands, production of high quality timber is of significance besides production of biomass as a renewable source of energy.

Alders have commonly high production capacity; besides, they have some essential advantages which make them promising species for short rotation forestry. They grow rapidly, are symbiotically N₂-fixing by the actinomycete *Frankia*, and have only a few pests and diseases. The litter of alders decomposes quickly and improves soil properties. After cutting, alders produce root suckers (grey alder) or stump sprouts (black alder), and artificial reforestation of clearcuts is not needed. Alder seedlings withstand direct sunlight and frost.

The aim of this paper was (i) to describe the growth of different alder species on former agricultural land, (ii) to characterise the biomass and production of the aboveground part in tree experimental plantations and (iii) to assess the suitability of the studied alder species as short-rotation forestry tree species in Estonia.

2 Material and methods

2.1 Grey and hybrid alder

The experimental plantation of grey alder was established in 1995 in the southeastern part of Estonia, Põlva county, 58° 3' N and 27° 12' E, on former farmland. As grey alder had not been cultivated in Estonia before, it was impossible to use a nursery-grown planting stock. One-two-year-old natural plants of generative or vegetative origin were employed. The growth of plants of different origin has been discussed earlier (Uri 1997, Uri and Tullus 1999, Uri 2000). In the present study only seedlings of generative origin were used. The total area of the plantation was 0.08 ha. Planting arrangement was 0.7 x 1.0 m.

The experimental plantation of hybrid alder was established next to the grey alder plantation in 1996. Biennial seedlings from the nursery were used. As according to literature data the production of hybrid alder exceeds that of grey alder, and as hybrid alder stands grow higher than grey alder stands (Pirag 1962), planting arrangement 1.0 x 1.5 m was selected. Thus primary density was almost twice as low as in the case of grey alder. The area of the plantation was 0.2 ha.

The established alder plantations were not tended. According to FAO classification the soil in both grey alder and hybrid alder plantations was classified as Planosol.

The above-ground biomass of the grey and hybrid alder plantations was determined annually in August when the formed leaf mass was the largest. Dimension analysis Bormann and Gordon (1984), Löhmus et al. (1996) was applied. Using a random procedure based on height or diameter distribution, seven model trees per plantation were felled (except in the first year of the plantation when from one average model tree the plantation of grey alder and three model trees from the plantation of hybrid alder were used for biomass determination). The diameter at root collar was measured in 1995 and 1996 and the diameter at breast height (1.3 m) was used from 1997. The stem was divided into sections according to annual height increment. For different sections, living branches were divided into fractions: leaves, current year shoots, older shoots and dead branches were separated. From each fraction, a subsample was separated for determination of the dry matter ratio. The samples were dried at 70° C until constant weight and weighed to 0.01g. The share of the wood and bark of stems was determined. The dry mass of different fractions was calculated for each model tree by multiplying respective fresh mass by the dry matter ratio. In the first year after planting, the above-ground biomass of the plantations was calculated on the basis of an average model tree because of the small dimensions of the planting stock. To estimate the biomass of the above-ground part of the plantation during the following years, the regression equation was used:

$$y = ax^b \tag{1}$$

The product of diameter and height was used as an independent variable in the equation, since it yielded a higher coefficient of determination than diameter or height alone. The parameters have been published earlier Uri and Tullus (1999). The annual production of the stemwood, bark and branches was calculated as the difference between the masses of the respective fractions for the studied year and for the previous year.

2.2 Black alder

The experimental plantation of black alder was established in 1978 on a periodically flooded meadow in eastern Estonia, 58° 20' N and 27° 24' E. One-year-old greenhouse grown seedlings with an average height of 30 cm were used for planting (Hainla 1985). The distance between the planting rows varied from 1 to 3 m. The distance between the plants in a row was 1.25 m. According to FAO classification the soil was classified as Umbric Gleysol .

Dimension analysis was applied also in determination of the above-ground biomass of black alder, determined in August 1998 (Vares 2000). Breast height diameter, tree height and height of the beginning of the living crown were measured. On the basis of diameter distribution, five model trees per plantation were felled randomly. The crown of the felled model trees was divided into five sections. For each crown section, branch length and the largest diameter as well as the fresh mass of all branches were measured

and one model branch was taken for further analysis. The leaves and current year shoots of model branches were separated and each branch was divided into three fractions (with bark) with a different diameter each ($d < 5$ mm, $5 \text{ mm} = d < 10$ mm and $d = 10$ mm). From each fraction, a subsample was separated for determination of the dry matter ratio and dried at 70 °C until constant weight. As the production of branches consists of primary and secondary growth, the latter was estimated by dividing branch overbark (wood+bark) mass (without current year shoots) by branch age. Each stem was divided into 1 m sections, discs were taken from the base of each section and the diameter was determined. Bark thickness, width of the last 3–5 annual rings and number of annual rings were measured and mean annual increment was calculated. The relative increment of the wood and bark of an overbark stem were assumed to be equal. Additional sample disks for determination of dry matter were taken from five different heights (0 m, 1.3 m, 0.5 of the naturally pruned stem, beginning of the living crown and the upper third of the crown). For estimation of tree compartments, allometric equation (1) was used.

3 Results and discussion

3.1 Grey and hybrid alder

By the first autumn after planting the biomass of the above-ground part of the grey alder stand was $0.37 \text{ t DM ha}^{-1}$. Data about so young stands are scarce in literature. Rytter (1996) claims that in the first year after clear cutting, the mass of shoots sprouting from root coppice can amount to 1 t DM ha^{-1} . In the sixth year after planting the above-ground biomass of the grey alder stand was $25.3 \text{ t DM ha}^{-1}$ and annual current increment was $11.5 \text{ t DM ha}^{-1}$ (Table 1). Production in 1999 was low due to unfavourable weather conditions (late severe frost in spring damaged the trees, the vegetation period was dry). The maximum value of annual current increment for grey alder is attained at the age of 6–8 (10) years (Rytter 1996, Tullus et al. 1998, Johansson 1999a). The age of plants in the experimental plantation was 7–8 years. In the most favourable site type in Estonia (*Aegopodium*), the above-ground biomass of a six-year-old natural grey alder stand reached $50.9 \text{ t DM ha}^{-1}$ and annual production was $14.8 \text{ t DM ha}^{-1}$ Tullus et al. (1998). According to Saarsalmi (1995), the above-ground biomass production (without leaves) of a 5-year-old grey alder plantation can be 5.8 – $6.1 \text{ t ha}^{-1} \text{ yr}^{-1}$ depending on fertilization, and biomass can be 31 t ha^{-1} . B. F. Telenius (1999) reported the total biomass of 26.7 t ha^{-1} and the last year production of 8.6 t ha^{-1} for grey alder plantations (six-year-old plants). In fertilized and irrigated experimental plantations on organic soils, the current annual increment of above-ground biomass in four-year-old grey alder stands was measured at up to 8 t DM ha^{-1} and in five-year-old stands at up to 12 t DM ha^{-1} Rytter (1996).

Far less information is available on the yield dynamics of hybrid alder, especially for younger stands. In the present study above-ground biomass after the fifth year

was estimated at 10.11 t DM ha⁻¹ and annual production at 5.58 t DM ha⁻¹ (Table 1). Pirag (1962) claims that the diameter increment of hybrid alder stands is 34–40 % larger than that of grey alder or common alder stands of the same age. The relative increment of diameter was the largest (0.8–1.0 cm) in young stands under the age of five years. Depending on the site type the hybrid stand exceeded the grey alder stand in height growth by 11–35 %. Mean annual height growth for stands younger than 15 years was 0.8 m. The annual height growth of two-year-old grey alders was 145.9 cm and that of hybrid alders 158.9 cm (Pirag 1962). According to Granhall (1982), five-year-old plants in Sweden had a mean height of 3.28 m per treatment in the case of *Alnus incana*; the respective parameter for the hybrid alder (*Alnus incana* x *Alnus glutinosa*) triploid was 2.69 m and for the hybrid alder diploid, 2.54 m.

Table 1. The above-ground biomass (B) t DM ha⁻¹ and production (P) t DM ha⁻¹ yr⁻¹ of alder plantations.

	Year of planting	1996		1997		1998		1999		2000	
		B	P	B	P	B	P	B	P	B	P
Grey alder	1995	2.68	2.45	7.61	5.80	12.3	6.74	15.9	6.38	25.3	11.5
Hybrid alder	1996	0.16	0.14	0.94	0.86	2.72	2.20	6.15	4.53	10.1	5.58

As the plantations under study differed both in the time of planting and in primary density (15 750 and 6 700 trees per ha, respectively), their production was compared on the basis of mean stem mass (Fig. 1). Up to the fourth year after planting the mean stem mass of the grey alder plantation was larger than that of the hybrid alder plantation (0.64 kg and 0.58 kg, respectively). In the fifth year after establishment the mean stem mass of the hybrid alder plantation exceeded that of the grey alder plantation. Since the density of the hybrid alders was lower their growth conditions were more favourable. In the fifth year after establishment the mean height of the grey alder stand was larger than that of the hybrid alder stand, 5.22 ± 1.12 m and 4.50 ± 1.15 m, respectively.

Comparison of the share of different fractions in the above-ground biomass of the grey alder and hybrid alder plantations in the fifth year after establishment revealed that for grey alder stands the stems accounted for 75.1 % of total biomass, while for hybrid alder stands the respective figure was 66.7 %. Thus the branches and leaves form a larger share in hybrid alder stands (13.1 % and 15.6 %, respectively) than in grey alder stands (12.3 % and 9.5 %, respectively). The difference in the primary density of the stands can obviously be attributed to the larger share of the branches and the lesser share of the stems in hybrid alder stands. In Finland the share of the branches in total biomass in an 8-year-old grey alder stand was found to be 19.7 % Saarsalmi et al. (1991) and in a 10-years-old stand, 17.7 % (Simola 1977).

As the share of the leaves in hybrid alder stands is larger than in grey alder stands, their leaf assimilation efficiency (above-ground production per leaf mass unit) is proportionally lower as well. Since leaf assimilation efficiency in grey alder stands is known to decrease with age, it remained at a comparatively stable level in hybrid alder stands during the study period. The leaf assimilation efficiency of the stand

varied from 2.2 to 5.4 t t⁻¹ for the grey alder and from 2.0 to 3.5 t t⁻¹ for the hybrid alder in different years. The biomass accumulation ratio (biomass/net production) is used in classification of production conditions of forest communities (Whittaker 1966, Sharma and Ambasht 1991). In 2000, the biomass accumulation ratio (biomass/current annual production) for the grey alder plantation was calculated as 2.2 and for the hybrid alder plantation as 1.8.

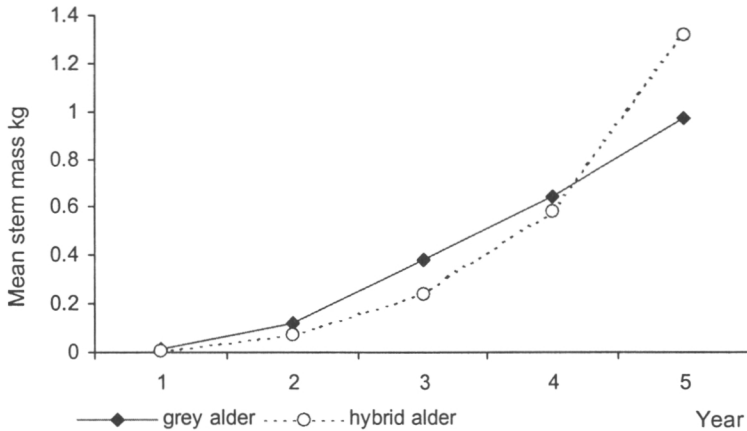


Figure 1. Mean stem mass in planted Estonian grey alder and hybrid alder stands.

3.2 Black alder

In 1998, the mean height and breast-height diameter of the 21-year-old plantation of black alder were measured at 12.4 ± 0.2 m and 10.4 ± 0.2 cm, respectively. Since no thinning had not been carried out earlier the density of the plantation was high (2788 alders per ha).

According to Pregent and Camiré (1985), black alder as a rapidly growing tree species is able to produce a large amount of biomass; the above-ground biomass of a four-year-old black alder plantation can be as much as 15.8 t ha^{-1} . Johansson (1999b) calculated the above-ground biomass for 21 to 91-year-old black alder stands $152.3 \pm 7.7 \text{ t DM ha}^{-1}$ and mean annual increment $3.46 \pm 0.22 \text{ t DM ha}^{-1} \text{ yr}^{-1}$, respectively. In the Netherlands, the amount of biomass in 30-year-old black alder stands ranged from 107.1 to 146.0 t DM ha⁻¹ and mean annual increment ranged from 4.0 to 5.1 t DM ha⁻¹ yr⁻¹ (Meeuwissen and Rottier 1984). The above-ground biomass and mean annual production of the studied 21-year-old black alder plantation were 88.8 t DM ha⁻¹ and 17.1 t DM ha⁻¹ yr⁻¹, respectively (Table 2).

Considering the allocation of above-ground biomass in the investigated plantation, the stemwood formed the biggest share, 74.0 %, while the stembark made up 12.6 % of total above-ground biomass. The proportion of the branches and leaves in total above-ground biomass was 8.9 % and 4.5 %, respectively. A somewhat higher

percentage of foliage occurs in case of dominant trees. The share of the stembark in the biomass of stems was higher for the lower and upper stem parts, as well as for suppressed trees. In this study stembark allocation trends were similar to those observed in Finland (Björklund 1984, Lehtonen et al. 1978).

The stemwood formed the biggest share, 50.9 %, while the stembark accounted for up to 8.8 % of the total above-ground production of the plantation. The share of the branches (wood+bark) and leaves was 17.0 % and 23.4 %, respectively.

The leaf assimilation efficiency in the studied 21-year-old black alder plantation was 4.3 t t⁻¹. According to Borman and Gordon (1984), in 5-year-old red alder (*Alnus rubra* Bong.) plantation, the leaf assimilation efficiency ranged from 4.9 to 5.6 t t⁻¹. In 10- to 50-years-old plantations of Himalayan alder (*Alnus nepalensis* D. Don) the leaf assimilation efficiency varied between 2.4 to 5.3 t t⁻¹. The calculated biomass accumulation ratio of the black alder plantation was 5.1.

Table 2. Above-ground biomass and production of different fractions in black alder plantation.

Tree fraction	Biomass		Production	
	t ha ⁻¹	kg tree ⁻¹	t ha ⁻¹ yr ⁻¹	kg tree ⁻¹ yr ⁻¹
Stemwood	65.7	23.6	8.7	3.1
Stembark	11.2	4.0	1.5	0.5
Primary growth of branches	1.2	0.4	1.2	0.4
Secondary growth of branches	6.7	2.4	1.7	0.6
Leaves	4.0	1.4	4.0	1.4
Total	88.8	31.8	17.1	6.0

4 Conclusions

Two investigated native alder species (*Alnus incana* (L.) Moench, *Alnus glutinosa*, (L.) Gaertn.) and their hybrid (*Alnus hybrida* A. Br.) demonstrated rapid growth on agricultural land. Moreover, these species have high production capacity and perspective for afforestation of abandoned agricultural lands and short rotation forestry in Estonia.

Acknowledgements

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References

Björklund, T. 1984. Tervalepän biomassa. Metsäntutkimuslaitoksen tiedonantoja 151, Helsinki. 71 p.

- Bormann, B.T. and Gordon, J.C. 1984. Stand density effects in young red alder plantations: productivity, photosynthate partitioning and nitrogen fixation. *Ecology* 2: 394–402.
- Granhall, U. 1982. Use of *Alnus* in energy forest production. In: Horstia, E. (ed.) Proc. Second National Symposium on Biological Nitrogen Fixation, Helsinki, June 1982, Nitrogen project Report 1. p. 273–285.
- Hainla, V. 1985. Sanglepa järglas-katsekultuurid. *Metsanduslikud uurimused* XX: 49–56.
- Johansson, T. 1999a. Site index curves for common alder and grey alder growing on different types of forest soil in Sweden. *Scand. J. For. Res.* 14: 441–453.
- , 1999b. Dry matter amounts and increment in 21-to 91-year-old common alder and grey alder and some practical implications. *Can. J. For. Res.* 29: 1679–1690.
- Lehtonen, I., Pekkala, O. ja Uusvaara, O. 1978. Tervälepan (*Alnus glutinosa* (L) Gaertn.) ja Raidan (*Salix caprea* L.) puu- ja massateknisiä ominaisuuksia. *Folia Forestalia* 344. 19 p.
- Lõhmus, K., Mander, Ü., Tullus, H., Keedus, K. 1996. Productivity, buffering capacity and resources of grey alder forests in Estonia. In: Perttu, K., Koppel, A. (ed.). Short rotation willow coppice for renewable energy and improved environment. Uppsala. p. 95–105.
- Meeuwissen T. W. M. and Rottier H. 1984. Development of alder (*Alnus glutinosa*) coppice. *Neth. J. Agric. Sci.* 32: 240–242.
- Meiner, A. (ed.) 1999. Eesti maakate. - CORINE Land Cover projekti täitmine Eestis. Land Cover of Estonia. Implementation of CORINE Land Cover project in Estonia. Tallinn. 132 p.
- Pirag, D. M. 1962. Hod rosta I stroenie drevesina hibridnoi olhi (*Alnus hybrida* A. Br.) v Latviskoi CCR. Academic dissertation, Latvian Agricultural Academy, Elgava, Latvia. [In Russian].
- Pregent, G. and Camire, C. 1985. Biomass production by alders on four abandoned agricultural soils in Quebec. *Plant Soil* 87: 185–193.
- Rytter, L. 1996. The potential of grey alder plantation forestry. In: Perttu, K., Koppel, A. (ed.). Short rotation willow coppice for renewable energy and improved environment. Uppsala. p. 89–94.
- Saarisalmi, A., Palmgren, K., Levula, T. 1991. Harmaalepän ja rauduskoivun biomassan tuotos ja ravinteiden käyttö energiapuuviljelmällä. *Folia Forestalia* 797: 1–23.
- , 1995. Nutrition of deciduous tree species grown in short rotation stands. Academic dissertation, University of Joensuu, Finland. 60 p.
- Sharma E. and Ambasht R.S. 1991. Biomass, productivity and energetics in Himalayan alder plantations. *Annals of Botany* 67: 285–293.
- Simola, P. 1977. Pienikokosein lehtipuuston biomassa. *Folia Forestalia* 302: 1–16.
- Telenius, B. F. 1999. Stand growth of deciduous pioneer tree species on fertile agricultural land in southern Sweden. *Biomass and Bioenergy* 16: 13–23.
- Tullus, H., Uri, V., Lõhmus, K., Mander, Ü., and Keedus, K. 1998. Halli lepa majandamine ja ökoloogia. Tartu. 36 p.
- Uri, V. 1997. Halli lepa kultuuri kasv esimesel istutusjärgsel aastal. EPMÜ teadustööde kogumik 189: 265–270.
- , & Tullus, H. 1999. Grey alder and hybrid alder as short-rotation forestry species. Overend, R.P. and Chornet, E. (ed.). Proceedings of the 4th Biomass Conference of Americas. Oakland, California, USA, August 29–September 2 1999. Vol. 1: 167–173.
- , 2000. Halli ja hübriidlepa kultuurid endisel põllumaal ja nende biomassi produktsioon. *Metsanduslikud uurimused* XXXII: 78–89.
- Vares A. 2000. Biomass, nitrogen and phosphorus allocation in above-ground parts of black alder plantations. *Baltic Forestry* 6: 47–52.
- Whittaker R.H. 1966. Forest dimensions and production in the Great Smoky Mountains. *Ecology* 4: 103–121.

Occurrence of broadleaved trees in Southern Finland

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Abstract

Data of the third Finnish national forest inventory (1951–53) were mainly used as research material. The number of broad-leaved tree species decreased as the site fertility decreased. The broadleaves' share was at its greatest in the bush layer and its lowest among the big-sized trees. Eleven broadleaved tree species were found among the undergrowth. Pubescent birch was most frequent with an average stem number (581 ha⁻¹). Grey alder was the second most common species and silver birch the third one. Aspen was also common. It was found in all dbh-classes (191 ha⁻¹ on average) with its highest proportion among trees exceeding 30 cm. The bush layer contained also a lot of rowan.

Keywords: Aspen, grey alder, pubescent birch, silver birch, rowan, sallow, mixed stand

1 Introduction

The past century has witnessed a large scale felling of broadleaved trees in Finland. Since the 1950's they have been targeted by low thinnings and cleared from felling sites and sapling stands alike. The proportional volume of hardwoods has been on a downward trend for the past hundred years (Ilvessalo 1956, Kuusela and Salminen 1991). In 1951–1953 the hardwoods made up 21 % of the stemwood volume which was 2 % units less than 30 years earlier. The following two decades saw a further drop of 4 % units. The latest inventories (Salminen 1993) proved the percentage of broadleaved trees to be around 17 for the southernmost regions of Finland. However, due to the clear rise of the whole growing stock, the total volume of hardwoods was greater than in the early 1920's.

Despite the considerable drop in proportional volume the total number of hardwood stems rose by 4 % units from the 1950's to the 1970's (Laiho 1994). This was due to an increase in the small-sized (2–6 cm) broadleaved trees. In Southern Finland the proportion of broadleaved trees had doubled on regeneration and shelterwood sites between the third (1951–1953) and the seventh (1977–1984) forest inventories. Thinning, preparatory and regeneration stands had also witnessed a similar increase. The seventh inventory showed that in sapling stands four fifths of the trees exceeding 2 cm in diameter were hardwoods. The percentage of broadleaved trees was at its lowest, 22 %, in silviculturally good stands. In the seventh inventory these good stands formed a third of the forests.

This report will review the occurrence of broad-leaved trees in Southern Finland as recorded in the third (1951–1953) inventory.

2 Material and methods

By the time of the third (1951–1953) Finnish forest inventory low thinning or undergrowth clearing had been practiced only in minor scale. The forest structure, composition and condition were fairly close to that of naturally developed stands albeit having been strongly influenced by their past treatment such as slash-and-burn and grazing. The inventory was carried out as a systematic line plot survey (Ilvessalo 1951, 1956). The plots were spaced at one kilometre intervals along the lines. Each plot represented the stand where the centre of the plot happened to fall. Should this have meant it having elements of two different stands it was moved as per instructions inside one of them (Ilvessalo 1951). Thus each plot encompassed just one stand element. This fact coupled with the use of fixed plot areas enabled the plot by plot processing of the data. The presence of a biologist in each inventory group guaranteed a more comprehensive compilation of data compared to other inventories.

Each plot was assessed for the usual biotope indicators, development class and silvicultural condition. Trees above 10 cm DBH were measured from a 0.1 ha plot and trees between 2–10 cm DBH from a concentric 0.01 ha plot. In this study the trees were divided into 4 cm diameter classes (1 = 2–6, ... , 9 = > 34 cm).

All coppice trees exceeding 2 cm DBH that were not expected to develop a proper trunk were recorded as undergrowth. The understory proper (DBH < 2 cm) was recorded from the same 0.1 ha circular plot used for the trees exceeding 10 cm DBH. The understory was divided into two height categories, i.e. bushes (A: 0.5–1.3 m) and trees (B: height > 1.3 m).

The material was restricted to advanced (thinning, preparatory and mature) stands on mineral soil sites in Southern Finland, with a growing stock of at least 40 m³ha⁻¹. The province of Ahvenanmaa (Åland) was included but the four northernmost conservancies, North Pohjanmaa, Kainuu, Northeast Finland and Lapland were excluded, as well as sapling and seedling stands. The included sample plots totalled 2 157 in all.

3 Results

The number of broadleaved trees fell sharper than that of conifers as their diameter grew (Fig. 1) The hardwoods' share was at its greatest (48 %) in the bush layer and at its lowest (12 %) among the big-sized (over 22 cm) trees. On the best sites (upland forests with grass-herb vegetation; *Oxalis-Myrtillus* type) hardwoods made up more than half of the stems but only 7 % on dry mineral sites (*Calluna* types).

Eleven hardwood species (Table 1) were found among the undergrowth. The number of species fell as the site fertility dropped. Thus only six species of broadleaved trees were found on *Calluna* heath. Their frequency dropped gradually except for aspen, silver birch and willow that were equally common from groves to dryish heaths. The frequency of silver and pubescent birch in table 1 is an underestimate. The figures are based only on bush-sized birch that was not very common on these sample plots. When the undergrowth exceeding breast height is included the frequency of birch rises to 91 %. Adding all stems exceeding 2 cm DBH to the bush-sized undergrowth the silver birch frequency increases up to 66 % and pubescent birch up to 76 %.

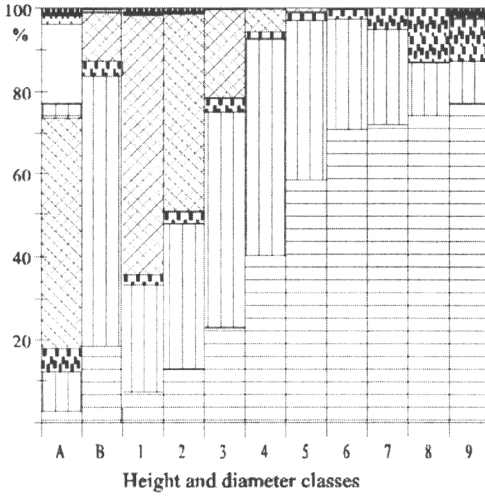
The average number of broad-leaved species in the undergrowth was 2.7 per plot (Table 2). 6 % of the plots had no hardwoods at all. These plots were mostly found on *Calluna* heaths. As the site fertility grew the number of broadleaved species per plot increased up to the maximum of 8.

Pubescent birch was the most frequently found hardwood with an average stem count of 581 ha⁻¹ or almost 2½ times that of silver birch, the third most common of the broadleaved species. Both birch species were conspicuous by their near absence in the bush layer compared to their frequency among the above breast height undergrowth. Birch made up 90 % of the hardwood count of trees exceeding 10 cm DBH. As the diameter increased and the site fertility dropped the silver birch gained ground at the expense of the pubescent.

The second most common hardwood was grey alder (518 ha⁻¹). It was mostly found in the bush layer of upland forests with grass-herb vegetation (*Oxalis-Myrtillus* type) where it was more common than all the other broadleaves. However, unlike the two birches grey alder was not all that plentiful in the undergrowth exceeding breast height. The bush layer also contained a lot of rowan and aspen. The material does not reveal the occurrence of rowan in the actual stands but aspen was found in all DBH classes (191 ha⁻¹ in total), with its highest proportion among trees exceeding 30 cm DBH. Willow, black alder, bird cherry tree, lime tree, Norway maple and oak only made up 4 % of the stem total.

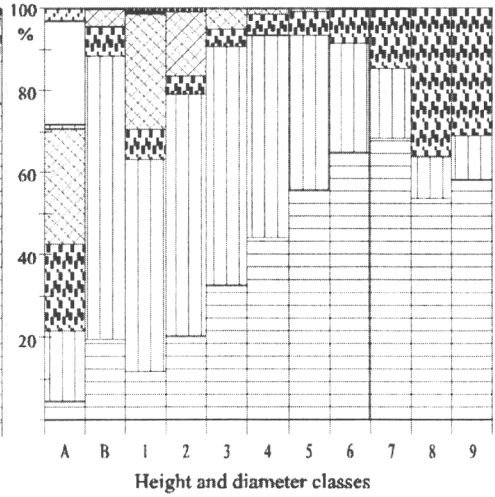
OMT (Oxalis-Myrtillus type)

432 sample plots
Conifers 49% of stems
Broad-leaved trees 51%



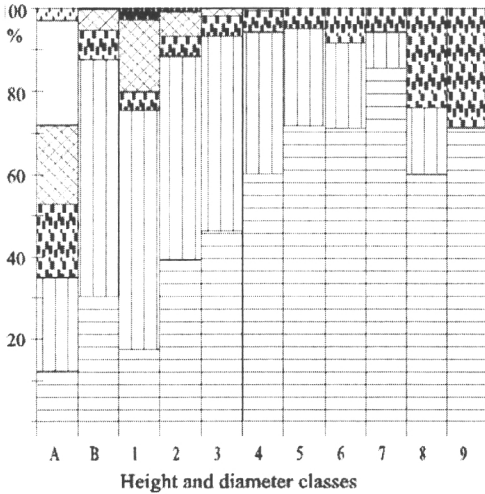
MT (Myrtillus type)

946 sample plots
Conifers 65% of stems
Broad-leaved trees 35%



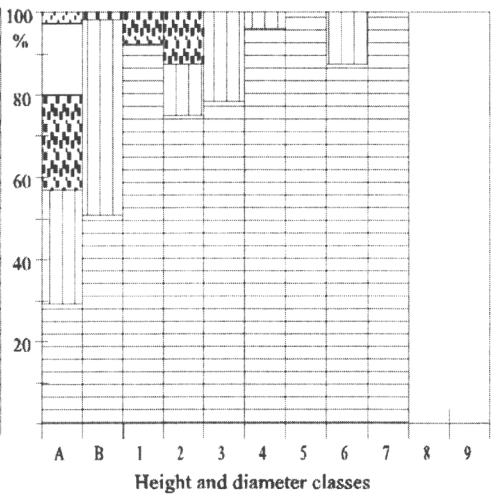
VT (Vaccinium type)

726 sample plots
Conifers 81% of stems
Broad-leaved trees 19%



CT (Calluna type)

53 sample plots
Conifers 93% of stems
Broad-leaved trees 7%



Broad-leaved tree species:

- | | |
|-----------------|---|
| Grey alder | Others (bird cherry, lime and maple; over 2 cm DBH: also grey alder, rowan, willow) |
| Aspen | Sallow |
| Pubescent birch | Rowan |
| Silver birch | Black alder |

Figure 1. Stem number and broadleaved tree composition in advanced forests on mineral soil sites in Southern Finland in 1951–1953. Height and diameter classes: A = 0.5–1.3 m, B > 1.3 m and DBH < 2 cm; Diameter classes: 1 = 2–6 cm, ..., 9 > 34 cm.

Table 1. Occurrence of broadleaved tree species in the understorey (DBH < 2 cm) of advanced forests on mineral soil sites (see Fig. 1) in Southern Finland in 1951–1953.

Tree species	Number of stems ha ⁻¹				Mean	Frequency %				Mean
	OMT	MT	VT	CT		OMT	MT	VT	CT	
Grey alder	1034	311	112	1	381	74	49	29	2	46
Pubesc.birch	532	444	217	61	369	56	55	44	23	51
Rowan	330	261	137	28	227	81	83	69	15	76
Aspen	119	246	106	38	168	39	48	47	36	45
Silver birch	150	125	116	65	132	18	21	29	21	23
Sallow	35	32	17	5	27	18	24	21	11	21
Black alder	59	11	1	0	17	6	2	2	0	3
Bird cherry	34	1	0	0	7	3	1	0	0	1
Lime	1	0.3	0	0	0.3	2	0.1	0	0	1
Oak	0	0.2	0	0	0.1	0	0.1	0	0	0
Maple	0.4	0.01	0.04	0	0.1	0.5	0	0.1	0	0
Total	2294	1432	706	198	1329	98	97	91	58	94
Sample plots	432	946	726	53	2157	432	946	726	53	2157

Table 2. Number of broadleaved tree species by forest site types (see Fig. 1) among the understorey (DBH < 2cm) in advanced forests on mineral soil sites of Southern Finland in 1951–1953.

Number of species	OMT	MT	VT	CT	Mean
0	9	33	66	22	130
1	43	137	146	15	341
2	112	221	182	9	524
3	117	263	168	5	553
4	102	177	104	1	384
5	33	91	51	1	176
6	13	24	9	0	46
7	2	0	0	0	2
8	1	0	0	0	1
Mean	3,0	2,8	2,4	1,1	2,7
Sample plots	432	946	726	53	2157

5 Discussion

This study indicates an abundance of naturally regenerated broadleaved tree species occurring in Southern Finland in the early 1950's. Due to the limitations of the available

material some rare species, like ash and elm, did not show in the results. The undergrowth also included several bush-sized species such as willows, alder buckthorn, daphne, honey suckle, guelder rose and hazel (Kujala 1964). Conifers and hardwoods in varying combinations formed a number of mixed forests (Laiho et al. 1994, 1995). Similar natural dynamics could also be found in the results of the first Finnish forest inventory (1921–24; Norokorpi et al. 1994).

The above mentioned Kujala study (1964) on inventory material not only lists the ground vegetation species but also maps the spread of tree species. These maps show that the most common species, numerically, such as grey alder, pubescent birch, rowan, aspen, silver birch and sallow covered at least the southern half of the country quite evenly. Bird cherry trees occurred scattered all around the area. Other hardwoods, such as lime, oak and Norway maple were limited to the country's southernmost parts.

Pioneering broadleaved trees with their excellent regeneration capacity and resistance to damage and injury of all kinds has helped them to maintain their proportion. However, over the years it seems that different species have seen considerable changes in their absolute occurrence and relative numbers. This can be verified by comparing the 1951–1953 data to the later inventories in which the differentiation between broad-leaved species has been made more comprehensively than earlier (Salminen 1993). Thus aspen has trippled, pubescent birch quadtrippled and rowan turned sevenfold during the next 35 years since 1951–1953 (Lähde et al. 1999).

Large-scale removal of hardwood elements before full maturity has greatly reduced the survival chances of many forest organisms (Zackrisson 1985). Bigger aspen and sallow in particular are vital for the wellbeing of many endangered species (Kuusinen 1994). Broad-leaved trees also play an important part in slowing down both natural and man-made acidification processes of forest soils (Troedsson 1985).

References

- Ilvessalo, Y. 1951. III valtakunnan metsien arviointi. Suunnitelma ja maastotyön ohjeet. Summary: Third national forest survey in Finland. Plan and instructions for field work. *Communicationes Instituti Forestalis Fenniae* 39(3): 1–67.
- , 1956. Suomen metsät vuosista 1921–24 vuosiin 1951–53. Kolmeen valtakunnan metsien inventointiin perustuva tutkimus. Summary: The forests of Finland from 1921–24 to 1951–53. The survey based on three national forest inventories. *Communicationes Instituti Forestalis Fenniae* 47(1): 1–227.
- Kujala, V. 1964. Metsä- ja suokasvilajien levinneisyys- ja yleisyyssuhteista Suomessa. Vuosina 1951–1953 suoritetun valtakunnan metsien III linja-arvioinnin tuloksia. *Communicationes Instituti Forestalis Fenniae* 59(1): 1–137.
- Kuusela, K. & Salminen, S. 1969. The 5th national forest inventory in Finland. General design, instructions for field work and data processing. *Communicationes Instituti Forestalis Fenniae* 69(3): 11–72.

- , & Salminen, S. 1991. Suomen metsävarat 1977–1984 ja niiden kehittyminen 1952–1980. Summary: Forest resources of Finland in 1977–1984 and their development in 1952–1980. *Acta Forestalia Fennica* 220. 84 p.
- Kuusinen, M. 1994. Metsätalouden vaikutus epifyyttijäkälälajiston monimuotoisuuteen. In: Haila, Y., Niemelä, P. & Kouki, J. (eds.). *Metsätalouden ekologiset vaikutukset borealisessa havumetsässä*. Metsäntutkimuslaitoksen tiedonantoja 482: 75–81.
- Lähde, E., Laiho, O., Norokorpi, Y. & Saksa, T. 1999. Uudistuminen ja kasvatust. In: Lähde, E. (ed.). *Luontaisesti syntyneiden sekametsien kehitys- ja metsänhoito*. Metsäntutkimuslaitoksen tiedonantoja 719: 32–58.
- Laiho, O. 1994. Runkolukujakauman ja puulajisuhteiden kehitys 1950-luvulta 1980-luvulle Etelä-Suomessa. *Metsäntutkimuslaitoksen tiedonantoja* 495: 140–147.
- , Lähde, E., Norokorpi, Y. & Saksa, T. 1994. Varttuneiden metsiköiden rakenne 1950-luvun alussa. Summary: Stand structure of advanced forests in early 1950's in Finland. *Metsäntutkimuslaitoksen tiedonantoja* 495: 90–128.
- , Lähde, E., Norokorpi, Y. & Saksa, T. 1995. Undergrowth as regeneration potential and diversity factor in advanced forest stands. *IUFRO XX World Congress*, 612 August 1995, Tampere, Finland. 9 p.
- Norokorpi, Y., Lähde, E., Laiho, O. & Saksa, T. 1994. Luonnontilaisten metsien rakenne ja monimuotoisuus. Summary: Stand structure and diversity of virgin forests in Finland. *Metsäntutkimuslaitoksen tiedonantoja* 495: 54–89.
- Salminen, S. 1993. Eteläisimmän Suomen metsävarat 1986–1988. Summary: Forest resources of Southernmost Finland, 1986–1988. *Folia Forestalia* 825. 111 p.
- Troedsson, T. 1985. The influence of broadleaved trees on long-term productivity of forest soils. In: Hägglund, B. & Peterson, G. (eds.). *Broadleaves in boreal silviculture - an obstacle or an asset?* Swedish University of Agricultural Sciences. Department of Silviculture. Report 14: 37–49.
- Zackrisson, O. 1985. Some evolutionary aspects of life history characteristics of broadleaved tree species found in the boreal forest. In: Hägglund, B. & Peterson, G. (eds.). *Broadleaves in boreal silviculture - an obstacle or an asset?* Swedish University of Agricultural Sciences. Department of Silviculture. Report 14: 17–36.

Software application on the profitability of growing improved aspen

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Abstract

Despite a large-scale growth and yield modelling work conducted in Finland, there have not been many field applications available for practice. The software application to be presented has been developed with a close interaction between the researchers of the Finnish Forest Research Institute and the client. The strong interaction and close-to-practice procedure have enabled the researchers to meet the demand of the client more thoroughly than generally has been done. In this connection the client represents a Finnish forest company which has business attraction on improved aspen.

Initially, genuine growth and yield modelling was conducted, and the results were converted into monetary terms. Several cost variables (silvicultural costs such as soil preparation and planting costs) were added into the calculation procedure so that the profitability would be coherent to real-world conditions as accurately as possible, and further the results could aid the decision making process of a forest owner. The profitability was determined according to NPV, Net Present Value (FIM/hectare). This NPV was then confronted with the corresponding NPVs of other tree species such as Silver birch, Norway spruce and common aspen (i.e. unimproved aspen).

The growth and yield modelling of the other species was mostly based on a case study basis whereas with improved aspen there were over 200 stands underlying the growth and yield modelling. The models developed for improved aspen were so-called dynamic in the sense that the rotation period and timings of the final cuttings could be chosen freely in the software. On the other hand, for common aspen and Silver birch & Norway spruce the models were static with respect to rotation period and timing of the intermediate thinnings, respectively. However, for practical purposes the profitabilities associated with different tree species could be compared in order to determine the best financial outcome. The final software application (an Excel program with VBA coding) consists of several sectors of which the most important are: cost determination (users can freely choose silvicultural costs and the timings of these costs), stumpage price determination (including sophisticated time series modelling), discount rate determination and show view which includes presentation graphs and tables on the results for each tree species.

Utilisation of birch in mechanical wood industry in Finland

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Abstract

The two industrially interesting birch species, *Betula pendula* and *B. pubescens*, make up large and, to some extent, inadequately utilised hardwood potential in Northern Europe. Finland is a major birch producer in Europe with large-dimensioned birch timber of high quality mainly used for plywood, and small-dimensioned, as well as the large-dimensioned birch of poor-quality for pulp, paper and firewood. The production capacity of birch plywood and veneers has remained fairly constant for a few decades already. Considering the resources and properties of birch wood and timber, the potentials of both export and domestic markets give an opportunity for expansion in the manufacture of sawn wood and its further products. Birch lumber is both visually and technically appropriate material for furniture and joinery, including flooring, panelling, and furnishing. Traditionally, sawmills have used mostly large-dimensioned birch timber, which provides the maximum recovery of knot-free lumber. A considerable increase in birch lumber production, caused by the expanded sawing of small-dimensioned logs, however, was seen in Finland during the past few years. This is affected by both the lack of large-dimensioned timber of high quality and the recently grown interest in the birch products where sound knots are visible.

Key words: *Betula pendula*, *Betula pubescens*, veneer, plywood, saw milling, furniture, floorings, parquetry

1 Background

Birch is traditionally known as a raw material for pulp, paper and energy. Since the beginning of the 20th century, the large potential of high-quality birch timber in the forests has also facilitated the development of diverse mechanical wood industry using birch in Finland. The two commercially notable Finnish birch species, silver birch (*Betula pendula* Roth.) and European white birch (*Betula pubescens* Ehrh.) are nowadays valuable raw materials for veneer and plywood industry, as well as for saw mills and further processing industry. The principal end-uses for birch veneers are in furnishing, whereas plywood is widely used in, for instance, furniture, containers and mouldings where high bending strength and hardness are required (e.g., Verkasalo 1997a). Birch sawn wood, on the other hand, is used in high-quality furniture, flooring, panels and joinery products, where the demands focus both on visual quality and mechanical strength (e.g., Heräjärvi et al. 2000, Luostarinen and Verkasalo 2001).

The needs of industry have created a demand for high-quality birch logs and, by this means, facilitated the development of such silvicultural methods, where also birch is considered as an economically potential tree species along with Scots pine and Norway spruce. In fact, plywood industry expects to get one third of its raw material from cultivated silver birch stands in the year 2010 (Verkasalo 1997b). Until the studies of Niemistö (1995, 1998), Niemistö et al (1997), Rantanen et al (2000) and Lehtimäki (2001) the knowledge of the quality of the wood from cultivated stands was fairly poor.

For centuries, birch wood has been used not only for heating but also as a raw material for tools and household supplies. Birch bark, on the other hand, has been a source of numerous practical equipment as well as decorations. In Finland, the first efforts of processing birch timber on the industrial scale, were performed in 1873 when the first factories started manufacturing reels of thread. The export of reels from Finland covered at its largest 80 % of the world markets (Ronkanen 1968). Gradually, other materials replaced wood in thread-reel manufacturing.

Sawing of birch started, presumably, already in the 1850s (Ronkanen 1968). During the 20th century, birch lumber production remained roughly at a constant level, except in the 1960s, when a peak of 0.6 million m³/a was achieved. Most of the lumber produced has been exported. Domestic consumption of hardwood lumber is, nevertheless, marginal when compared with the consumption of softwood lumber (Figs. 1 and 2). Knot-free and sound-knotted birch lumber have been considered as special products rather than bulk products.

Not until 1912, the establishment of plywood industry by Wilhelm Schauman Ltd, in Jyväskylä, real expansion in the use of birch timber occurred. Since that, the use of birch timber by the plywood industry increased until the end of the 1960s reaching the level of ca. 2.5 million m³. Thereafter, the use of domestic birch has continuously decreased until these days (Sevola 2000).

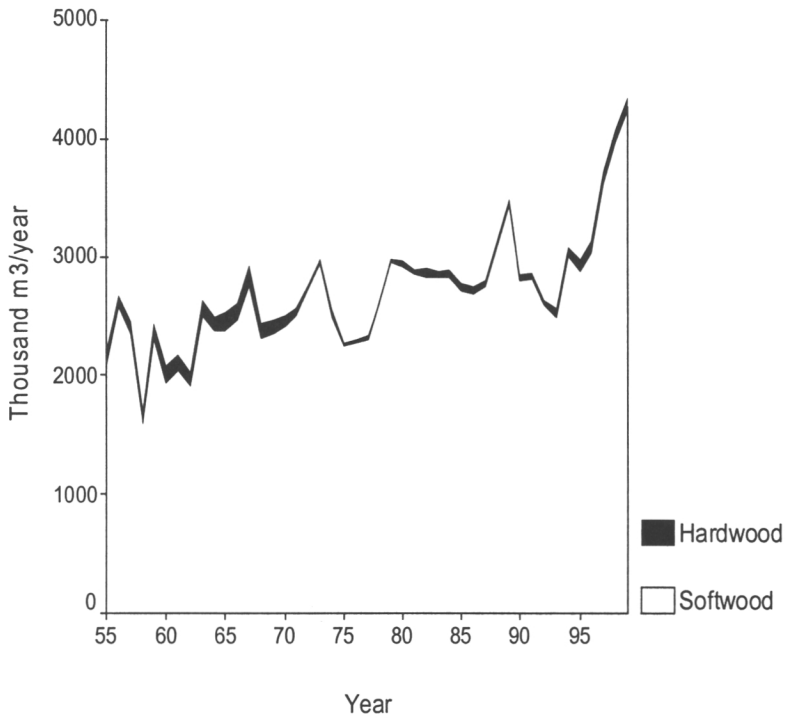


Figure 1. Annual consumption of lumber in Finland since 1955. Source: Finnish Forest Research Institute.

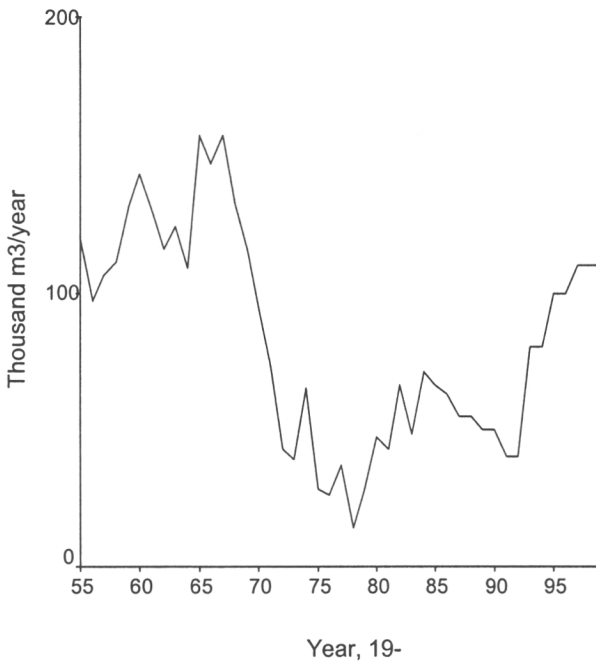


Figure 2. Annual consumption of hardwood lumber in Finland since 1955. Source: Finnish Forest Research Institute.

Between the years 1950 and 1975 more birch was harvested in Finland than what was the annual growth. During the past 25 years, however, the supply of birch has increased and reached the total volume of almost 300 million m³. The birch growing stock is continuously increasing while the annual domestic cuttings are only ca. 50 % of the growth of 13.4 million m³ (Sevola 2000). The availability of domestic birch timber for the wood products industry, on the other hand, is not as obvious as the supply indicates. The best birch grows as an admixture in forests dominated by conifers, and comes into timber markets only at the time of harvesting of spruce or pine. Then, in consequence, birch is often too old and impaired by rot. Furthermore, especially in Western Finland, large amounts of lower-quality white birch grow in peatlands in difficult harvesting conditions.

As shown in Fig. 3, since the 1950s the total consumption of hardwoods by the Finnish mechanical wood industry has been on the average level of 1.5–2 million cubic metres per year. In this sense, the period between the late 1960s and the early 1970s was exceptional, as the total consumption of hardwood timber increased temporarily to the annual level of 3 million m³. Thenceforth, a lowering trend can be seen in the consumption numbers. In the case of the consumption of domestic hardwood timber by veneer and sawmills, a rapid decrease was experienced from the annual level of 1.8 million m³ to 1.2 million m³ between years the 1980 and 2000. Simultaneously, the percentage of imported birch timber increased considerably, mainly concerning mills in Eastern Finland (Sevola 2000).

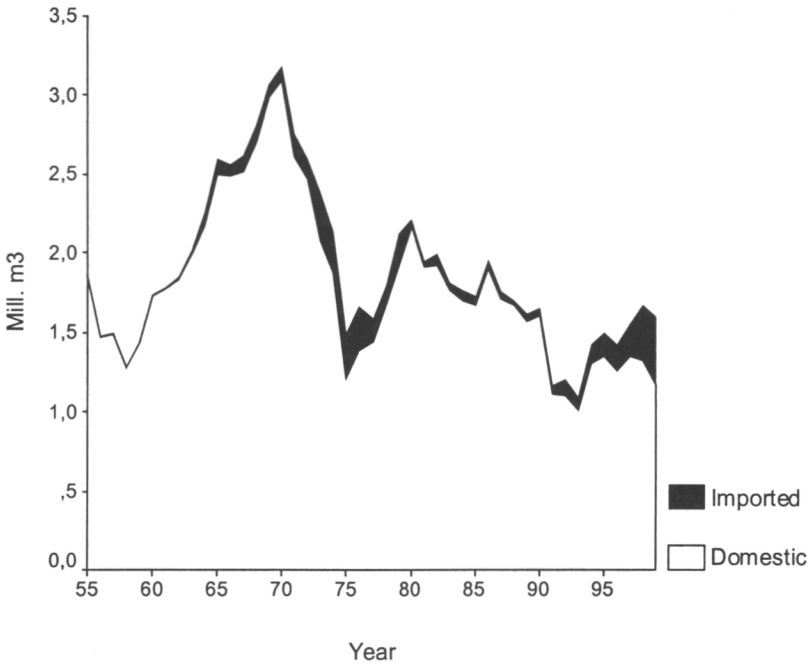


Figure 3. Consumption of hardwood timber by the mechanical wood industry by origin in Finland since 1955. Source: Finnish Forest Research Institute.

2 State of the art – birch using mechanical wood industry

2.1 Production of plywood, veneer and sawn wood

Birch is the only mechanically utilized Finnish hardwood species with industrial relevance, so far. No species-specific studies have been made on the consumption of different hardwood species by the saw mills since the study of Pajuoja and Suihkonen (1994). There is, however, no need to assume radical changes until the present time, concerning the results achieved by Pajuoja and Suihkonen (1994), which indicated that only 10,000 m³ of aspen (*Populus tremula*) and 6,000 m³ of alder (*Alnus glutinosa*, *A. incana*) were used by the Finnish sawmills in 1993. Concerning the two birch species together, the corresponding figure was 180 000 m³. In veneer and plywood industry, although aspen and black alder are occasionally tested species, no regular production has, however, arisen. Saw milling is more or less occasional, as well. This is due to the poor availability of proper raw material of these species. For instance, grey alder has for long been of interest to the furniture manufacturers, as alder-made products would obviously have good markets. However, alder requires fertile sites in order to even have prospects to achieve proper quality for wood products industry. Fertile sites, on the other hand, provide, manifoldly, a higher profit for the forest owner, when Norway spruce or silver birch is grown. Only few private forest owners have assets to grow alder, which insecurely produces logs and has no markets for pulpwood. Hence, in Finland, grey alder stands are mainly located on wastelands, shores and roadsides, often owned by the state or municipalities.

The new capacity for processing small-sized birch logs has caused an increment of ca. 100 000 m³ for the need of sawable raw material. Not until the change of the millennium has this happened, and, thus, can not yet be seen in the statistics (Fig. 4). Traditionally, birch sawing has meant utilising only large-diameter logs. At the end of the 1990s, the first serious efforts were made to produce lumber from logs with a top diameter of only 10 to 18 cm. During the past few years, practically all new hardwood saw mills, or the plans to establish one, have been based on the use of small-diameter timber obtained mainly from domestic thinning forests. Imported wood from Russia and the Baltic countries seems to play, however, a more and more significant role in hardwood markets. Currently, there are less than ten industrial hardwood saw mills in Finland, a considerable percentage of birch lumber is produced by small-sized private circular saw mills (Sevola 2000). The total lumber production of the largest birch saw mills in the year 2000 was still less than 20 000 m³, which is actually not more than 10-20 % of the production of a medium-sized softwood saw mill.

Today, 85 % (ca. 1.3 Mm³) of the mechanically processed birch timber, in Finland, is used by the plywood factories. The average annual production capacity of a Finnish birch plywood factory is ca. 50 000 m³. Furthermore, as shown in Fig. 4, saw mills use some 0.2 to 0.25 Mm³ of birch timber, and ca. 60 000 m³ of very high-quality and large-diameter timber is used for production of special veneers by slicing or rotary

cutting by the less than ten production units. Additionally, for instance in 1993, 7 400 m³ of special quality birch timber was exported from Finland, mainly for veneering purposes in Germany (Saimovaara 1994). Nowadays, almost 95 % of the plywood products (including spruce, spruce-birch and birch plywoods), is exported. European countries (e.g., Germany 29 %, Netherlands 19 %, Sweden 12 %, Great Britain 11 %, Italy 6 %, Denmark 6 %, Norway 5 %) buy most of the exported plywoods and veneers with a share of 93 % of the total amount exported (Sevola 2000). Finland produces ca. 15 % of the European plywoods and veneers, and ca. 24 % of those in the countries of the European Union. Globally, however, Finland covers only ca. 2 % of the total plywood and veneer production, while 80 % of which is produced in Northern America and Asia.

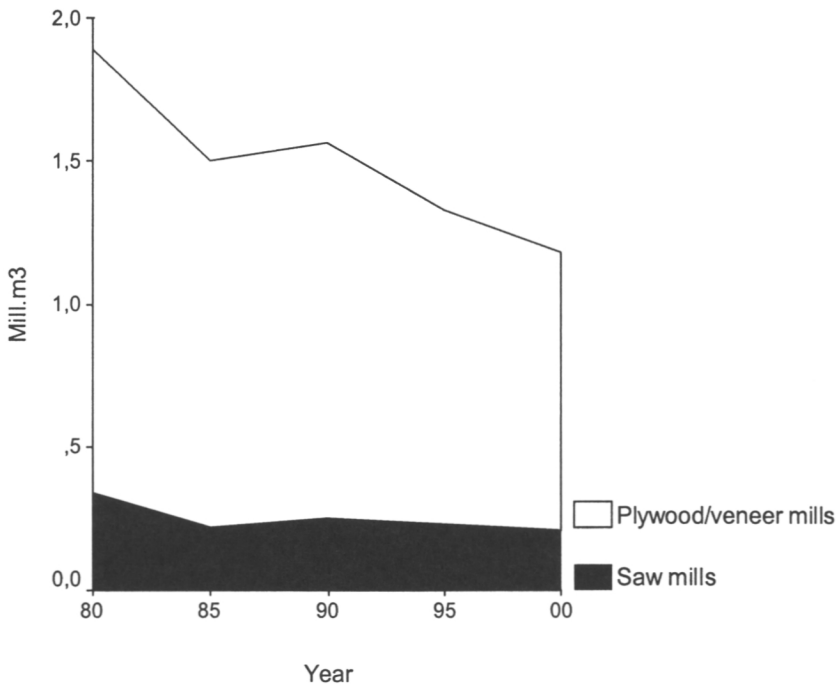


Figure 4. Consumption of hardwood timber (of which ca. 95 % is birch) by the mechanical wood industry by use in Finland since 1980. Source: Finnish Forest Research Institute.

2.2 Wood procurement

Finnish plywood factories, as well as the larger birch using saw mills, are located in eastern and central Finland, where the best-quality domestic silver birch supply is available. In addition, logistics costs for the imported logs remain low when merely short-distance transportation is needed on the Finnish side of the border. The amount of imported plywood logs has gradually grown during the 1990s. Prior to that time, mainly pulpwood was imported to Finland from Russia. In this sense, Finland has

been an exceptional country; Japan, Sweden and Germany have mainly utilised Russian saw logs (Harju 1997).

Plywood, veneer and saw milling companies have traditionally been, and to some extent, continuously are competitors in birch timber markets. Due to the smaller volume of timber used by the saw mills compared to the veneer and plywood mills, no nationwide quality requirements or grading rules are available for birch saw logs. In fact, the larger saw mills either have their own grading rules for logs, or alternatively, they buy the logs following the grading rules used for veneer logs. Presumably, as long as the size of the birch saw mills remains at its current level, and no networks are established between the separate entrepreneurs, no uniform national grading rules will be viable for birch saw logs.

At the moment, quality requirements for birch saw logs differ from those of veneer logs basically in four ways (Luostarinen and Verkasalo 2000). Firstly, veneer logs must be large, which usually means a minimum top diameter of 18 cm, at least. Birch saw logs, conversely, are usable at least until the diameter of 10 to 12 cm, supposing that the logs are fairly straight. Secondly, saw logs must be straighter than veneer logs because in veneer mills, the logs are cut into short, less than two-metre bolts during the process, which decreases the adverse effects of sweep and curves. Thirdly, decay near the pith of a log is more harmful in saw logs because in veneer logs the pith-enclosed wood never ends up in the final product but remains in the peeler core. Finally, dead knots are more problematic in sawn wood than in veneer, while patches can be used to repair holes caused by the loosened knots in veneers. In total, except for the demands for size, the quality requirements used for saw logs are generally more accurate than those used for veneer logs.

According to the latest studies (Heräjärvi and Varis 2000, Heräjärvi 2001), as well as practical experiences, it seems rational to buck the stems into shorter log-lengths than what is currently done, in order to maximise the recovery of saw logs from one tree, as well as the recovery of sawn wood from one log. This concerns especially bucking small-sized saw logs, which are often characterised by sweep.

3 Outlook

Along with aspen, birch is practically the only light-coloured North-European tree species available for furniture and joinery products. Sometimes birch is considered to be even too light in colour. In fact, the variation of colour within a product is a more common and problematic feature than the colour itself. In furniture markets, darker-coloured products have a stable market share, whereas the demand for light-coloured products fluctuates over time. Currently, great marketing efforts are performed in order to increase the market share of light-coloured furniture in Central Europe and the British Isles.

For birch, as well as for aspen and alder, new potential end-uses have opened out along with the production of heat-treated lumber. Not only the controllable colour, but also the lowered equilibrium moisture content and, at least, slightly improved ability to resist decay, widen the end-uses of hardwoods into moister applications than previously. In addition, the heat resistance value of wood improves, not to mention the ecological status of a product processed without chemical treatments (Kotilainen 2001). Hence, heat-treated wood seems to have many positive marketing benefits and the method may, as well, contribute to the consumption of hardwood products, once the markets truly open. Many drawbacks and pitfalls have also been faced while launching the new product. For instance, quality fluctuations were far too high before the knowledge concerning the heat-treatment process developed into a sufficient level. The poor-quality products of the first heat-treatment trials were marketed without considering the consequences. As a result, many customers still ignore heat-treated wood, although the quality of the products has remarkably improved.

For some years already, the success of plywood products in the future has raised doubts. Engineered wood products, such as Oriented Strand Board (OSB), have challenged plywood as cheap and easy-to-build construction material. Regardless of the doubts, at least three of the Finnish birch-using plywood factories have quite recently modernised their production lines, which has caused an increment of some 100 000 m³ per year to the total production capacity of birch plywood. Hence, no rapid decrease is in for Finnish plywood industry. Kivistö and Honkasalo (2001) also found positive expectations for the future of plywood products in their inquiry for the veneer and plywood industry. Especially the best plywood qualities have a stable demand. However, no growth for the use of domestic hardwoods was expected because of the poor availability of raw material (Kivistö and Honkasalo 2001). It is evident, nevertheless, that more and more intensive marketing actions will be needed in the plywood industry in future, in order to maintain the current market share.

In birch sawing, it appears that the most considerable change during the next years relates to the expanding utilisation of small-sized logs from thinning forests. The status of a special product, which birch lumber has traditionally had, will gradually change closer to the status of a bulk-product. This is due to the new high-speed and high capacity saw mills processing the small-diameter birch logs into more or less bulk-quality lumber. Birch products with visible sound knots are nowadays wanted for furniture manufacturing, whereas almost only knot-free lumber was accepted still a few years ago. Along with the evolving machinery, the efficiency of the raw material use will increase. Production of semi-finished products, such as billets and components, becomes more and more rational and cost-efficient; such development can already be perceived in the mechanical processing of softwoods.

The availability of naturally born, high-quality timber is decreasing. It will soon be more or less replaced by cultivated timber which, according to the current knowledge, contains wood material of poorer quality, at least as far as wood density and susceptibility for discoloration and *Phytobia betulae* defects are considered (see Niemistö 1998, Verkasalo 1998, Ylioja et al. 1998, Heräjärvi et al. 2000, Rantanen et al. 2000, Ylioja 2000). Despite of the large supply of birch, there is not enough of best-

quality raw material for every user. In addition to the imported wood, research and development is needed in order to obtain the best possible degree of utilisation both for the high-quality timber, and the poorer qualities and smaller dimensions currently used, to a large degree, for pulp- and fuelwood.

References

- Harju, A. 1997. Luoteis-Venäjän tuontipuu – uhka vaiko ainoa toivo Venäjän kestäväälle metsätaloudelle? In: Heräjärvi, H. (Ed.). Joensuun metsäylioppilaat, Kurssi 13, Kurssijulkaisu. p. 16–19. [In Finnish].
- Heräjärvi, H. 2001. Modelling of harvesting recovery in mature birch stands when aiming for veneer, saw or special logs in Finland. In: Birkeland, R. & Chantre, G. (eds.). 4th Meeting COST E10 Wood Properties for Industrial Uses, Bordeaux, France, March 7-9, 2001. Proceedings. COST E10 & AFOCEL, Laboratoire qualité du bois, Nangis. p. 84–91.
- , H. & Varis, N. 2000. Lyhyitä tukkeja koivusahoille - mitä hyötyä? Puumies 3: 12–13. [In Finnish].
- , H., Verkasalo, E., Kaurala, H. & Lehtimäki, J. 2000. Properties and utilisation of birch (*Betula pendula*, *B. pubescens*) for saw milling and further processing in Finland. In: Usenius, A. & Kari, P. (eds.). Proceedings of the Third Workshop on Measuring of Wood Properties, Grades and Qualities in the Conversion Chain and Global Wood Chain Optimisation, 19th-21st June, 2000, Dipoli, Espoo, Finland. Cost Action E10 Wood Properties for Industrial Use. VTT Building Technology, Espoo. p. 83–102.
- Kivistö, J. & Honkasalo, H. 2001. Kotimaisten lehtipuulajien käyttö vaneri- ja viiluttavan teollisuuden raaka-aineena. Haastattelututkimuksen tulosten yhteenveto. Helsingin yliopisto, Metsävarojen käytön laitos. Helsinki 2001. 23 p. + app. 8 p. [In Finnish].
- Kotilainen, R. 2001. Puun kemiallisen koostumuksen muuttuminen lämpökäsittelyssä ja tuotteen laadunvalvonta. In: Riekkinen, M. & Kärki, T. (eds.). Koivun kuivausmenetelmät 2000-vuosituhanalle, Seminaaripäivän esitelmät. Finnish Forest Research Institute, Research Notes 810. p. 19–20. [In Finnish].
- Lehtimäki, J. 2001. Sahauskelpoisen harvennuskoivun korjuu ja kertymät sekä sahatavaran saanto ja laatu. Manuscript for master's thesis. University of Joensuu, Faculty of forestry. [In Finnish].
- Luostarinen, K. & Verkasalo, E. 2000. Birch as sawn timber and in mechanical further processing in Finland. A literature study. *Silva Fennica Monographs* 1. 40 p.
- Niemistö, P. 1995. Influence of initial spacing and row-to-row distance on crown and branch properties and taper of silver birch (*Betula pendula*). *Scandinavian Journal of Forest Research* 10: 235–244.
- , 1998. Ruskotäplät pelto- ja metsämaan rauduskoivuissa. In: Niemistö, P. & Väärä, T. (eds.). Rauduskoivu tänään ja tulevaisuudessa. Tutkimuspäivä Tampereella 12.3.1997. Finnish Forest Research Institute, Research Notes 668. p. 127–140. [In Finnish].
- , Hukki, P. & Verkasalo, E. 1997. Kasvupaikan ja puuston tiheyden vaikutus rauduskoivun ulkoiseen laatuun 30-vuotiaissa istutuskoivikoissa. *Metsätieteen Aikakauskirja – Folia Forestalia* 3/1997: 349–374. [In Finnish].
- Pajuoja, H. & Suihkonen, V. (eds.). 1994. Raakapuun käyttö Suomessa vuonna 1993. Finnish

- Forest Research Institute. Forest Statistical Bulletin 229. 7 p. [In Finnish].
- Rantanen, A., Jalonen, O. P. & Pitkänen, P. S. 2000. Etelä-Savon lehtipuuvarojen teknis-taloudellinen hyödyntäminen. Helsingin yliopiston maaseudun tutkimus- ja koulutuskeskus, Mikkeli. Publications 72. 47 p. [In Finnish].
- Ronkanen, A. J. 1968. Koivu ja sen teollinen käyttö 1900-luvulla. *Puumies* 6: 158–159. [In Finnish].
- Saimovaara, J. 1994. Puusepänteollisuus. *Tapion Taskukirja*, 22. painos. p. 561–566. Kustannusosakeyhtiö Metsälehti. [In Finnish].
- Sevola, Y. 2000. (Ed.). Finnish Statistical Yearbook of Forestry. Gummerus Kirjapaino Oy., Jyväskylä 2000. 366 p.
- Verkasalo, E. 1997a. Quality of European white birch (*Betula pubescens* Ehrh.) for veneer and plywood. Finnish Forest Research Institute, Research Paper 632. 483 p. + App. 59 p. [In Finnish with English summary].
- , 1997b. Evaluating the potential of European white birch (*Betula pubescens*) for veneer and plywood by timber and wood quality. In: Proceedings of the IUFRO Division 6 WP5.01.04 Biological Improvement of Wood Quality Workshop “Connection between Silviculture and Wood Quality through Modelling and Simulation Software”, Kruger National Park, South Africa, 26-31 August, 1996. INRA-Nancy, France. p. 431–439.
- , 1998. Raudus- ja hieskoivun laatu puuaineen tiheyden perusteella arvioituna. In: Niemistö, P. & Väärä, T. (eds.). Rauduskoivu tänään ja tulevaisuudessa. Tutkimuspäivä Tampereella 12.3.1997. Finnish Forest Research Institute, Research Notes 668. p. 127–140. [In Finnish].
- Ylioja, T. 2000. Relationship between *Phytobia betulae* and its host tree *Betula* spp. University of Joensuu, Faculty of Forestry. 26 p.
- , Saranpää, P., Roininen, H. & Rousi, M. 1998. Larval tunnels of *Phytobia betulae* (Diptera: Agromyzidae) in birch wood. *Journal of Economic Entomology*. 91: 175–181.

Methods for increasing the birch seed crop in a plastic greenhouse

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Abstract

The artificial regeneration of birch started in Finland in the 1960's. In the first phase, the seed for plant production was collected from plus trees or plus stands. In the beginning of the 1970's a new method for birch seed production using plastic greenhouses was developed in Finland. There are several methods for increasing the size of the birch seed crop in greenhouses: CO₂ supplementation, mineral fertilization, insect, mould and weed control, trimming the trees, and improving the light conditions by means of reflecting material. The use of dolomite gravel as a light reflecting material resulted in a significant increase in the seed crop in 1992, 1993 and 1995, and in the average crop during 1992–96. The use of micropropagated clones as seed trees instead of grafts has also had positive effects on the size of the birch seed crop. Nowadays about 10 million birch plants are produced annually. 50–70 kg of seed is needed for birch plant production annually and about 300 kg for direct sowing in the forest. The total area of plastic birch seed orchards in Finland is 1,4 ha. It is planned that all the seed required for birch plant production, and half of the seed used in direct sowing, will be produced in seed orchards. There is no urgent need to increase the seed orchard area of birch in Finland in the near future.

Keywords: birch, seed crop, seed production, plus tree

1 Background

Although plus tree selection of birch started on a small scale already in the 1950's, active breeding work did not start until the 1960's when the first national ten-year program was approved. At the same time there was a rapid increase in the demand for especially good quality birch timber for the plywood industry. The need to develop birch nursery techniques was also generally accepted. Birch seed for plant production was collected from seed collection stands and plus trees. At the time, some out-door seed orchards, similar to those for pine and spruce, were also established. The birch seed crops were, however, relatively variable and it was not possible to control background pollination from surrounding forests.

The Foundation for Forest Tree Breeding started to develop new techniques for birch seed production in plastic greenhouses. As a result of these efforts, the first seed orchard was established in a 2000 m² greenhouse in 1972 with the financial support from the Finnish plywood industry (Lepistö 1972, 1973). The birch seed orchard in greenhouses at Haapastensyrjä during the 1970's has been described in detail by Kärki (1976). Since then, most of the birch seed used in nurseries has been produced in plastic greenhouses (Hagqvist 1991). The production of bred birch seed is included in the national seed production program, which was published in 1989 and revised in 1997 (Metsäpuiden... 1989, Männyn, kuusen ja koivun... 1997).

2 Estimations of the birch seed requirements in Finland

According to the 1997 working group, the annual production of birch plants was estimated to be about 20 million plants in the 1990's. Since then, the plant production has decreased, and is currently 10-11 million plants per year. A decision was made to produce all the birch seed required in nurseries, and half of the seed used in direct seeding, in seed orchards. The amount of *B. pendula* seed used in nurseries at that time was about 80 kg, and of *B. pubescens* 20 kg. At the present time these figures could be decreased to nearly one half of the above levels. In addition to the nursery seed, it was estimated that 300 kg of *B. pendula* and 10–15 kg of *B. pubescens* seed would be needed direct sowing. Owing to a number of exceptionally bad seed years and other problems, it was decided that the size of the seed store should be twice the annual consumption, in this case about 600 kg for the whole country.

3 Why have a greenhouse seed orchard?

There are several advantages to establishing a birch seed orchard in a greenhouse compared to outdoor conditions:

- a. Background pollination can be almost completely avoided by time isolation. Time isolation can be achieved in the greenhouse even without heating, because the temperature sum will be higher in the greenhouse than outdoors.
- b. The growth of grafts or seedlings in a greenhouse is very fast, because the seed-producing surface increases rapidly.
- c. Flowering starts within a few years, and the first seed crops can be harvested in the second or third year.
- d. Seed collection is easy and safe because the trees are only 5–7 m high. Seed can be collected over an extended period, because it remains on the trees for a few months owing to the windfree conditions.
- e. The seed crops are abundant and they can be further increased artificially.
- f. It is easy to replant the seed orchard, which means that improvements in the breeding material can be rapidly applied in practice.

4 Methods for increasing birch seed crop

4.1 CO₂ supplementation

Already during the development phase of the greenhouse seed orchard method, CO₂ measurements indicated that fast-growing birch plants absorb CO₂ at a very fast rate. Thus the addition of CO₂ was necessary. In good conditions in a greenhouse, the birch plants grew 2–3 meters during one growing period. We also realised that CO₂ was needed not only to compensate for the decreased CO₂ level, but that it also had a favourable effect on flower bud formation. There are, unfortunately, no exact data about this; as is the situation with many other external factors, this is based on experience gained over a period of many years (Pirttilä and Saarela 1989). The normal outdoor CO₂ concentration is about 330 ppm. We found that a tenfold concentration was not harmful for birches. However, we recommend about 1000 ppm. It is easier to increase the level of male flowering than that of female flowering. Despite this, we found that in some individuals male flowering was so high at higher CO₂ levels, that it partly replaced the formation of female flowers and leaves.

In Finland propan gas is normally used to increase the level of CO₂. The treatment is started about May 15 and stopped at the end of the first week of July. Daily propan burning is started from early morning (3–4 o'clock) and stopped two hours before the moment, when it is necessary to begin ventilation to control that temperature does not rise too high. Supplement of CO₂ can also be done by release of that gas from a bottle, but it probably is more expensive a way than propan burning.

4.2 Fertilization

As the trees grow very fast, it is clear that the consumption of mineral nutrients is higher than that when raising seedlings out of doors. If the supply of fertilizers is not sufficient and balanced, it causes growth retardation and probably also retards the initiation of flowering. The fertilization regimes used in birch seed orchards in Finland are discussed in detail by Pirttilä and Saarela (1989), and there have been no essential changes since then. Fertilization is normally controlled by taking soil solution samples from the peat substrate in the seed orchard greenhouses twice during the growing period. The samples are analysed by Viljavuuspalvelu Ltd. As stated earlier, the recommendations given here and in the paper of Pirttilä and Saarela are mainly based on the experience gained in connection with practical seed orchard work, as well as on the recommendations of the fertilizer suppliers.

4.3 Insect and mould control

Insect control is usually necessary in birch greenhouse seed orchards, because insect populations may also increase rapidly in these favourable conditions. Therefore the trees have to be checked at regular intervals using a magnifying glass. It is important to detect insect populations in an early phase, because this makes it easier to control them. The most harmful insects in birch greenhouse seed orchards are aphids (many species of *Aphididae*) and vegetable ticks (Pirttilä and Saarela 1989). It is recommended that the greenhouses be thoroughly treated in early September. If there are no or only very small populations left to hibernate in the greenhouse, this will ensure a longer insect-free period in the spring.

Mould control is important especially at the time of seed ripening. The easiest way to do this is to decrease irrigation to a minimum and to keep the seed orchard rather dry. Otherwise mould may attack the catkins and part of the seed crop will be lost.

4.4 Weed control

Weed control is obvious, especially in the early stage of a birch seed orchard. Weeds compete with the seed trees for mineral nutrients, and a strong weed vegetation may also spread mould. Weeds are controlled either manually or by chemicals, e.g. the roots of weeds with glyphosat. Chemical weed control must be carried out very carefully, and spraying the leaves or lower branches of the trees avoided. If a fibre mat and dolomite gravel is spread in the greenhouse, the need of weed control is minimal.

4.5 Trimming the trees

Light and long-day conditions are very important for flower bud initiation (Longman and Wareing 1959, Zimmerman, pers. comm. 1969), as well as a minimum tree size (Longman 1984). Care should be taken every year to ensure that the trees do not develop forks or single, strong, upright branches, which may break later on. Branches that extend down to the ground should also be trimmed. When the trees reach the plastic cover they have to be cut every year and, if a dense mass of branches forms under the top, it has to be trimmed.

Some clones may form a broad canopy, and in this case the densest parts have to be trimmed because otherwise it will gradually decrease the amount of light reaching the inner parts of the crown. Trimming seed orchard trees is done in connection or after seed collection in July or August. Crown trimming does not necessarily increase the seed crop, but it is essential in order to avoid a decrease in the seed crop.

4.6 Improving the light conditions by means of reflecting material

Since light is a limiting factor from the point of view of flower bud initiation, some light reflecting materials have been tested. The most promising material has been coarse dolomite gravel (3–5 cm layer). A sheet of heavy duty woven material is laid under the dolomite to prevent the dolomite from mixing into the underlying peat.

The effect of a layer of dolomite on the size of the seed crop was studied in seed orchard Nr 373 (area 450 m²) during 1991–1996 (Lepistö, Hagqvist and Pöykkö 1998). The seed orchard was established in 1987. There were 48 clones represented by two grafts each (except for one clone). The spacing was 3.0 x 3.75 m. Two grafts of each clone were planted in different halves of the greenhouse. Seven clones located along the border of the treatments were excluded from the analyses. On one half of the greenhouse floor there was a layer of dolomite on the peat, and on the other half only a layer of peat of the same thickness and no dolomite. The seed crops were measured by clone and by treatment during six years. The dolomite gravel was spread in spring 1991, and the first year it affected flowering was 1992.

The grafts on the “dolomitehalf” produced an average of 23.8 kg seed/year, and the control half 17.1 kg/year. 34 of the 41 clones in the study produced more seed on the dolomite side (Fig.1). The use of a reflecting material increased the size of the seed crop significantly in 1992 (p 0.000), 1993 (p 0.030) and 1995 (p 0.039), and the average seed crop for the period 1992–96 (p 0.000). During 1994 and 1996 the difference was not significant, but these were both poor seed years.

The seed crop was 33.4 kg larger on the dolomite side than on the control side. The estimated additional return, excluding maintenance and seed collecting costs, was FIM 35 000, and the costs of the dolomite and the isolation material FIM 14 500. The use of dolomite to increase light, and subsequently the seed crop, in birch seed orchards thus seems to be profitable.

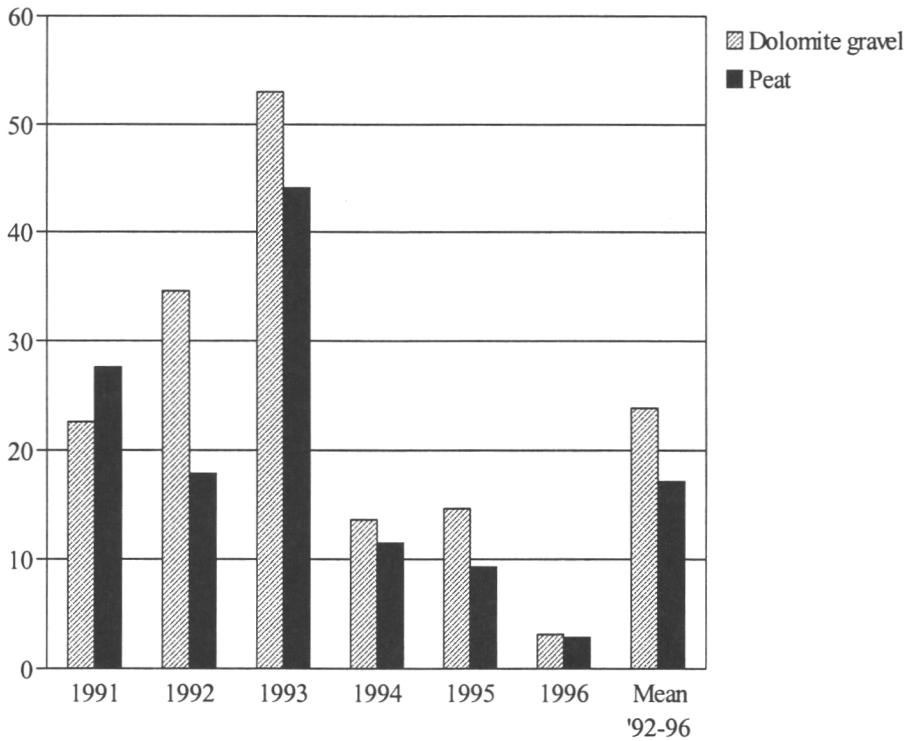


Figure 1. Dolomite gravel as a light reflecting material in a birch seed orchard.

4.7 Use of micropropagated clones as seed trees

Viherä-Aarnio and Rynänen (1994) studied the importance of birch plant material in the form of grafts, micropropagated plants and seedlings in seed production. They found that grafts started flowering and producing seed at the age of two years, one year earlier than the other types of plant. However, at the age of three years the seed production of both the micropropagated plants and seedlings was almost double that of the grafts. The situation for grafts and micropropagated plants continued almost the same up until the age of four years. The variation between the clones was, however, high and the plant type x clone interaction was significant. The authors suggest that micropropagated plants are just as suitable as grafts in birch seed orchards. This recommendation has not been applied for the present, but would be worth testing on a larger bigger scale.

5 Seed crops in greenhouse Nr. 116

A new large greenhouse was built at Haapastensyrjä in 1991. The area of the greenhouse is 1950 m² and the height 9.7 m. The greenhouse was financed by the Forest and Park Service, and made available to the Foundation for Forest Tree Breeding for 15 years for use in seed production. Since the year 2000 it has been used by the Finnish Forest Research Institute. There are three different seed orchards in the greenhouse, two of them produce *B. pendula* seed and one *B. pubescens* seed. All of the seed production is intended for use in the southern parts of Finland. The seed orchards are isolated from each other by walls. The *B. pubescens* seed orchard starts flowering one week later than *B. pendula*, and it is located in between the *B. pendula* seed orchards.

The seed crops harvested from these three seed orchards in plastic greenhouse Nr. 116 are presented in Fig. 2. The height of the grafts was about two meters when they were planted in autumn 1991. The first small seed crop was harvested in 1993, after which the seed crops increased rapidly.

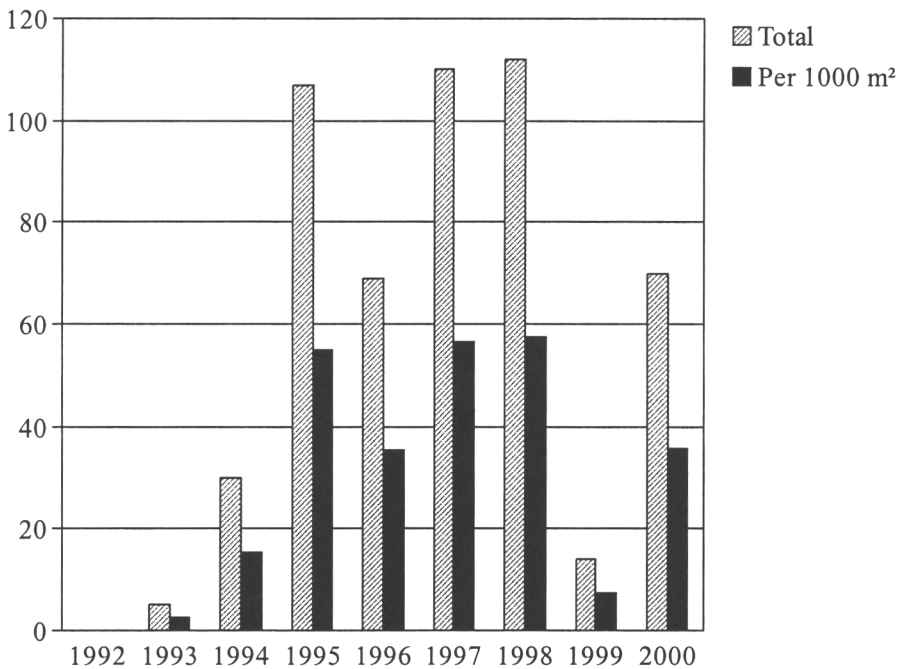


Figure 2. Seed crops of birch in greenhouse Nr. 116 at Haapastensyrjä during 1992–2000.

6 Birch seed production areas in Finland

There are 16 birch seed orchard units currently in production in Finland, and their total area is 14 180 m². Of this area, the Finnish Forest Research Institute owns 6580 m², Forelia Company 4600 m², and the Tapio Seed Centre 3000 m². When calculating the birch seed requirement, it was estimated that *B. pendula* seed orchards in south Finland should produce 20 kg/1000 m²/year, and the seed orchards in north Finland 10 kg. The respective figures for *B. pubescens* are 25 and 15 kg/1000 m² /year. The seed orchards in greenhouse Nr. 116 have produced 29.5 kg/1000 m²/year, which is clearly higher than the target.

If we take the current seed-production area and an average production of 20 kg/1000 m²/year, this means an annual production of about 280 kg. As stated in section 2, based on the estimations made in 1997 a total of 80 + 20 kg would be needed for plant production in nurseries, and about 300 kg for direct sowing. The demand for birch plants has decreased to near 10 million plants, but there is no precise information about changes in the seed requirement for direct sowing. In the near future the seed production of the available areas will probably cover the requirement for bred seed, and there is no urgent need to increase the area of birch seed orchards in Finland.

References

- Hagqvist, R. 1991. Jalostetun koivunsiemenen tuotanto ja saatavuus. Metsänjalostussäätiö 1991, p.12–17. English summary. p. 31.
- Kärki, L. 1976. Toward more effective tree breeding through the use of flower induction halls. The Foundation for Forest Tree Breeding in Finland. Yearbook 1976. p. 37–45.
- Lepistö, M. 1972. Kaskikoivusta viljelylajikkeisiin. Metsä ja Puu 10: 7–11.
- , 1973. Accelerated birch breeding – in plastic greenhouses. The Forestry Chronicle, Vol. 49(4). p. 172–173.
- , Hagqvist, R & Pöykkö, S. 1998. Maanvalkaisun vaikutus koivun siementuotantoon muovihuoneessa. Metsänjalostussäätiön työraportteja 50. 10 p.
- Longman, K.A. 1984. Physiological studies in birch. Proceedigs of the Royal Society of Edinburgh, 85 B. p. 97–113.
- , & Wareing, P.F. 1959. Early induction of flowering in birch seedlings. Nature 184. p. 2037–2038.
- Metsäpuiden siemenviljelyohjelma vuosille 1990–2025. Siemenviljelytyöryhmä 1989. Helsinki. Mimeographed report. 52 p.
- Männyn, kuusen ja koivun siemenviljelysten perustamissuunitelmat. Siementuotannon suunnitteluryhmän muistio 1997. Mimeographed report. 43 p.
- Pirttilä, V. & Saarela, S. 1989. Metsänjalostussäätiö, tiedote 2/1989. (Translated in English by Martti Lepistö). 8 p.
- Viherä-Aarnio, A. & Rynnänen, L. 1994. Seed production of Micropropagated Plants, Grafts and Seedlings of Birch in a Seed Orchard. Silva Fennica 28(4): 257–263.

Posters

Moose (*Alces alces*) browsing on different origins of Silver birch (*Betula pendula*)

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Moose is an important damage agent in young plantations of silver birch in Finland. It can damage the trees by breaking the stem or by browsing leaves and branches. Moose damage may, depending on its severity, reduce the growth or lower the stem and timber quality of injured trees.

Browsing by moose was measured in a provenance experiment of silver birch situated at Loppi, southern Finland. The experiment includes stand seed origins from Finland, Sweden, Estonia, Scotland and Russia, between latitudes 53° and 67°. The trial was established on a typical southern Finnish clear-cut area on moist upland forest site and protected against moose by fencing. After the break-down of the fence the experiment, at the age of 5–11 years, was frequently visited by moose. The effects of browsing were measured in early spring 2001 when the trees were 11 years old.

There were statistically highly significant differences between different origins in the frequency of trees browsed by the moose. The origins imported to Finland from more southern latitudes (Estonia, Scania, Scotland, Russia) were more frequently and more severely browsed than the native ones. The origin from Hammarland, Åland was also more browsed compared to the other Finnish origins.

There was a significant negative correlation between the latitude of seed origin and frequency of trees browsed by the moose. Furthermore, the frequencies of severely browsed as well as repeatedly damaged trees correlated negatively with latitude.

The reason for the variation in damage frequency may lie in phenological differences. At the time of browsing, the southern origins probably had a different physiological status compared to the native ones due to later growth cessation or insufficient winter hardening.

Baltic origins of Silver birch (*Betula pendula*) in Finland

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In a study, which is under way in FFRI, silver birch origins from the Baltic countries are compared with the native Finnish ones as regards growth, yield, stem quality (defects) and wood quality in 22-year-old field trials. Preliminary results are reported here on the growth, yield and stem quality.

The material of the study consists of a provenance experiment, which is situated at Tuusula, near the south coast of Finland. The experiment includes stand seed origins from Latvia, Estonia, Finland and Novosibirsk, Russia. In addition, one single tree progeny from Lithuania as well as two progenies from open-pollination and two progenies from controlled-pollination of southern Finnish plus trees are included.

There was a wide variation in the average height, dbh, average tree volume and volume/ha among different origins. Differences between the different origins were statistically significant. The average estimated volume/ha varied from 76 to 197 m³/ha. The highest volume/ha was produced by origins from northern Latvia (Aluksne, Liepa) and Estonia (Viljandi) as well as by the southern Finnish plus tree progenies. A long seed transfer either from the south or from the north resulted in low production. The origins from Pielavesi, central Finland and Maslyanino, Novosibirsk area had the lowest volume/ha. There was wide variation within both the Finnish and the Latvian group.

The relative frequency of trees with a vertical branch or a forked stem varied from 34 % (Sulkava) to 78 % (Maslyanino, Novosibirsk area). Differences between the different origins were statistically significant. A long transfer from the south seemed to increase the frequency of trees with stem defects. The Finnish plus tree progenies had somewhat higher frequency of defected trees compared to the stand origins.

The higher production and, on the other hand, the higher frequency of trees with stem defects in the Baltic material is probably due to their longer growth period, later growth cessation and poor winter hardening. Earlier it has been shown, within a very similar material from southern Latvia to southern Finland, that there is a significant negative correlation between the latitude and the seedling height in the nursery. The more southern the origin the later is the leaf yellowing in the fall and the lower the

survival in the field.

More information concerning long distance transfers of the Baltic silver birch origins will be obtained as soon as the measurements at the parallel trial at Viitasaari (63°11'N) have been completed. Analysis of the wood quality of the origins in this study are also under way.

Research results on the afforestation of surplus farmland in Latvia

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Keywords: agricultural lands, afforestation, experimental plots, tree species: birch, aspen, black alder, pine, spruce, oak, ash, wild cherry, spacing, fertilization, protection.

The total land area in Latvia is 6.495 million ha, including 2.882 million ha of forest land and 2.829 million ha of farmland. According to the data of the Latvian Institute of Land Survey and Development, about 15.6 % of farmlands are out of use at present. According to the expert opinion the percent of surplus farmlands is likely to increase, taking into account the expected accession of Latvia to the European Union (EU). Because of low fertility, relief features, moisture regime, there is no economic interest in cultivating these lands. The actual land use situation is a proof of it.

In the opinion of Latvian specialists, the following land categories are to be included for afforestation: agricultural lands on lean soils with low degree of cultivation erosion affected and erosion-prone farmlands; areas where natural overgrowing by forest is under way (not counting those where afforestation is excluded); areas with low population density and low forest cover percent; wastelands not cultivated for a long time; degraded lands, as former military training grounds, landfill sites of industrial waste, etc.

In 1994, the Latvian State Forest Research Institute „Silava“ start to study the research programme in afforestation to be carried out along the following lines: creating a basis for the production of seed and top quality planting stock of deciduous, models for afforestation of surplus lands, and the tending of the stands established. Since year 1994 pilot demonstration and experimental plots of the total area of more than 150 ha are established. The related research was focused on the selection: the most suitable tree species for different soil types; optimum planting density; optimum management practices for the afforestation ; fertilization effect on the plantation performance in lean soils; protecting the plantations established (animal damage, suppressing competing vegetation); changing of field ecosystems into a forest; changes in soil agrochemical properties of farmlands after forest establishment.

The pilot sites are distributed all over the country, covering the principal agroclimatic regions and partly also the different soil types. In these pilot plots different tree species are tested: pinus - *Pinus Sylvestris* L., spruce- *Picea abies* (L.) Karst., birch- *Betula pendula* Roth, aspen - *Populus tremula* L., ash-*Fraxinus excelsior* L., oak - *Quercus robur* L., red oak - *Quercus rubra* L., wild cherry- *Prunus avium* L., beech - *Fagus sylvatica* L., black alder - *Alnus glutinosa* (L.) Gaertn., larch- *Larix decidua* Mill., maple- *Acer platanoides* L., lime- *Tilia cordata* Mill. The tree survival, increment in height, diameter increment at breast height, development of the root system, changes in soil agrochemical properties, changes in ground cover vegetation, age of canopy closure, etc. was evaluated. The effect on the growth and performance of individual trees, branching habits, stem quality, canopy closure, stock volume, etc. was evaluated in the plots with different planting density.

The investigations show: the growth in height and survival of trees planted in farmlands depends from the quality of planting stock; the method of site preparation and its quality; soil hydrological properties; soil agrochemical properties; the time of planting; tending applied, fertilisation, protection methods. The best survival and increment during the first years (1994–2000) after planting is shown by different tree species on the fertile sandy clay, sandy clay loam and loamy sand soils (sod-calcareous, alluvial and brown soils).

Fertilization of forest plantations established on lean soils is a management action of no less importance. The fertilization improve the performance of all the tree species tested, and in particular that of birch and pine in poor fine sand and medium sand (typical podzol) soils. In different variants of fertilizer application, the growth of pine in height in the first four years after planting has increased on the average by 42 %, for spruce and birch – by 18 and 41 %, respectively.

The field data of trial plantations for such relatively fast growing species as aspen, black alder, spruce, pine, and especially their annual increment in height, show, that it takes for them two to three years to become established before they start growing very fast. The highest increments in height are observed for black alder, wild cherry and aspen, average 120–150 cm/per year and more.

The field data of trial plantations for such hard-wooded deciduous as oak, ash, red oak, beech on farmlands, especially in open areas, show that the cultivation is difficult due to their susceptibility to late spring frosts under the climatic conditions of Latvia, likely to occur as late as the first two ten-day periods in June.

The field data for the trial plantations of hard-wooded deciduous over a four -year period show their annual increment in height to be comparatively slow (3–8 cm/yr). The highest increment in height is for oak in sod-calcareous soils. Right now trial plantations are laid out for cultivating hard-wooded deciduous in a mix with such frost -resistant trees as birch, lime, black alder, grey alder, aspen.

To achieve success in afforestation, great attention is paid to the management of plantations established. A number of experiments are staged to find out the optimum management methods. Field data for different methods of plantation management (herbicide application, mechanical treatment, mulching), indicates that the elimination of the root mass of herbaceous next to the tree stems has a positive effect on the

survival of trees after planting and their further development. The field data obtained from trial plantations prove that without tending no good quality forest stands are possible on farmlands.

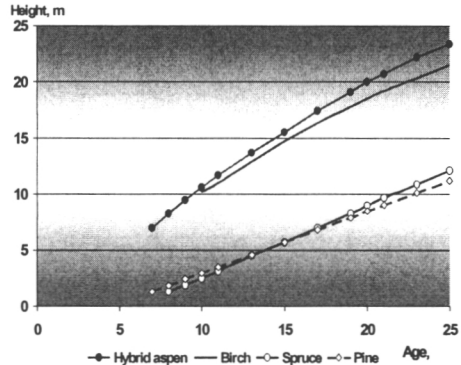
The protection of forest plantations against animal damage (rodents, cervidae) is also of importance. The experience gained shows that forest crops established on farmlands are to a significant extent damaged by mice, gnawing the bark at the root collar of young trees. Tests on protecting the plantations prove plastic tubing to be adequate for protecting trees, and deciduous in particular, against animal damage. It appears that the plastic tubing not only protects the tree, but also acts favourably on the growth of deciduous species. In such cases, the increment in height has increased by 30 %. The use of repellents (Fitorodents and Alcatals) shows good results for the first years. The browsing damage on young deciduous seedlings reached 50–70 % of all the trees on the control plots (without protection), but in the protected plots only 1–2 %.

Intensive management of hybrid aspen in Finland

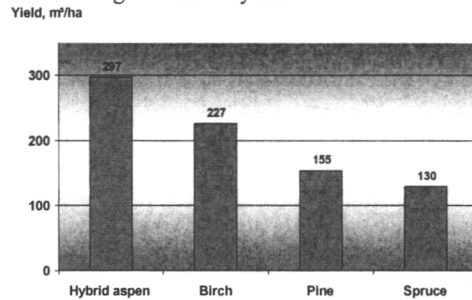
Jari Hynynen¹⁾ and Kaj Karlsson²⁾



Hybrid aspen stand (*Populus tremula* x *Populus tremuloides*)



Height increment of major tree species during the first 25 years



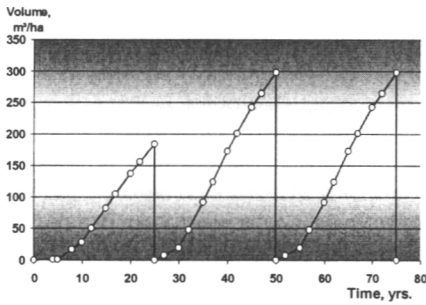
Total yield of the major tree species during the first 25 years

The role of hybrid aspen in Finnish forestry

- Hybrid aspen was introduced to Finnish forestry in 1950's
- Industrial use of aspen:
 - until 1970's: match industry
 - today: raw material for paper
- Intensive management was initiated in the middle 1990's
- Aspen production contracts between Metsäliitto Group and forest owners
- Research co-operation between Metla and Metsäliitto Group covering research in
 - tree improvement
 - growth and yield
 - pest control

Growth and yield of aspen and hybrid aspen

- The most fast-growing tree species in Finland
 - height increment up to 1 m/year in first 25 years
 - volume yield in first 25 years: up to 300 m³/ha, which is 25 % more birch and 100 % more than conifers
- Plantations are very susceptible to pest damages (moose, vole, hare)
- Suitable growing sites are:
 - most fertile forest sites
 - abandoned fields



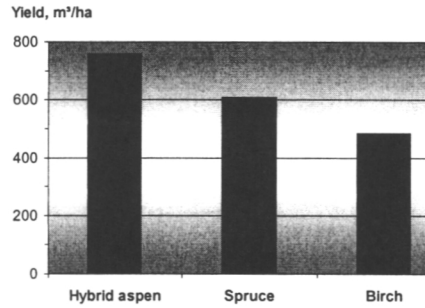
The development of growing stock in the production chain of three rotations



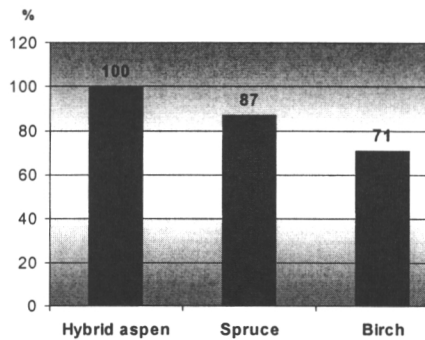
Two years-old hybrid aspen plantation

Management schedule

- Cultivation with selected clones
- Production chain of 2 or 3 successive rotations of 20-30 years
 - 1st generation: planted with selected clones
 - 2nd and 3rd generation originated from root suckers
- No commercial thinnings during the rotations
- Plantations are protected against pests
- Plantations are established in:
 - afforested fields
 - most fertile forest sites
- Regeneration areas infected by spruce butt rot



Yield of commercial wood of different tree species



Relative profitability of wood production (4 % interest rate)

Profitability of forest management

- Comparison of production chains of alternative tree species:
 - hybrid aspen,
 - Norway spruce,
 - Silver birch
- Analysis was based on
 - growth and yield models
 - actual costs for silviculture
 - actual incomes from cuttings
- Volume yield of hybrid aspen is
 - 25 % more than Norway spruce
 - 5 % more than silver birch
- Net returns of hybrid aspen (4 % interest rate):
 - 13 % more than spruce,
 - 29 % greater than birch

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Appendixes

**Scientific conference and workshop:
Management and utilization of broadleaved tree
species in Nordic and Baltic countries
- Birch, aspen and alder**

PROGRAM

Day 1: Wednesday, 16.5.2001 Hotel Vantaa, Tikkurila

Opening Session

- 9:30 – 9:50 Opening of the Meeting (*Jouni Mikola, Finnish Forest Research Institute*)
Presentation of country reports
- forest resources of broadleaved tree species
- utilization and management objectives
- research status
- 9:50 – 10:15 Latvia - *Arnis Gailis, Latvian Forestry Research Institute "Silava"*
- 10:15 – 10:40 Estonia - *Andres Kiviste and Veiko Uri Estonian Agricultural University, Estonia*
- 10:40 – 11:05 Sweden - *Tord Johansson, SLU, Sweden*
- 11:05 – 11:30 Finland - *Erkki Verkasalo, Finnish Forest Research Institute, Finland*
- 11:30 – 12:30 Lunch

Current research and future research needs

- 12:30 – 12:50 Broad-leaved tree breeding in Sweden. *Lars-Göran Stener, Skogsforsk, Sweden*
- 13:50 – 13:10 Long-term breeding strategies of broadleaved tree species in Finland. *Jouni Mikola, Finnish Forest Research Institute, Finland*
- 13:10 – 13:30 Possibilities to control the wood properties of hybrid aspen. *Pertti Pulkkinen, Finnish Forest Research Institute, Finland*
- 13:40 – 14:00 Birch - from seed to established stand. *Anders Karlsson, SLU, Sweden*
- 13:00 – 14:20 The above-ground biomass production of alders (*Alnus incana* (L.) Moench, *Alnus glutinosa*, (L.) Gaertn. *Alnus hybrida* A. Br.) on abandoned agricultural lands in Estonia. *Veiko Uri and Aivo Vares, Estonian Agricultural University, Estonia*

14:30 – 15:00	Coffee
15:00 – 15:20	Occurrence of broadleaved trees in Southern Finland. <i>Erkki Lähde, Finnish Forest Research Institute, Finland</i>
15:20 – 15:40	A software application on the profitability of improved aspen, <i>Anssi Ahtikoski, Finnish Forest Research Institute, Finland</i>
15:40 – 16:00	Utilisation of birch in mechanical wood industry in Finland. <i>Henrik Heräjärvi, Finnish Forest Research Institute, Finland</i>
16:00 – 16:20	Discussion
16:20 – 17:20	Bus trip to Kiljava (ca 50 km north of Vantaa).
17:30	Dinner
18:30 – 19:15	Poster Session
19:00	Sauna

Accommodation in the Hotel Kiljavanranta

Day 2: Thursday 17.5.2001: Field trip

8:00	Departure for the fieldtrip
8:20 – 9:45	Progeny trials of birch and alder (<i>Risto Hagqvist</i>) Management of silver birch (<i>Pentti Niemistö</i>)
9:45 – 10:15	Bus trip to Haapastensyrjä
10:15 – 10:30	Coffee break
10:30 – 11:05	Breeding and seed production of birch (<i>Risto Hagqvist</i> and <i>Martti Lepistö</i>)
11:05 – 11:30	Production of planting material of aspen (<i>Pertti Pulkkinen</i> and <i>Martti Lepistö</i>)
11:30 – 11:40	Spacing trial of hybrid aspen regenerated from root suckers (<i>Jari Hynynen</i>)
11:40 – 12:00	Collection of special forms of forest trees
12:00 – 12:50	Bus trip to Lohja
12:50 – 13:50	Lunch at Restaurant MetsolaSali
14:00 – 15:45	Visit to Mahogany Oy
15:45 – 16:00	Bus trip to Kirkniemi
16:00 – 17:30	Visit to MetsäSerla Kirkniemi Mills

- 17:30 – 18:00 Spacing trial of hybrid aspen (*Jari Hynynen*)
- 18:00 – 19:00 Bus trip to Kiljava
- 19:30 Dinner

Day 3: Friday, 18.5.2001 Hotel Kiljavanranta

- 8:15 – 8:30 Bus trip to Röykkä
- 8:30 – 9:15 Visit to Nurmijärvi nursery
- 9:15 – 9:30 Bus trip to Hotel Kiljavanranta

Planning of the joint research projects:

- 10:00 – 12:00 Workshop on joint research activities
- Exploring the needs and possibilities for cooperation in research
 - Producing the initiatives for joint research projects
 - Alternative funding resources *Anne Luhtala, Finnish Forest Research Institute, Finland*
- 12:00 – 13:00 Lunch
- 13:00 – 14:30 Workshop continues
- 14:30 – 15:00 Closing of the Conference
- 15:00 – 16:00 Bus trip to Helsinki (via airport)

Participants

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