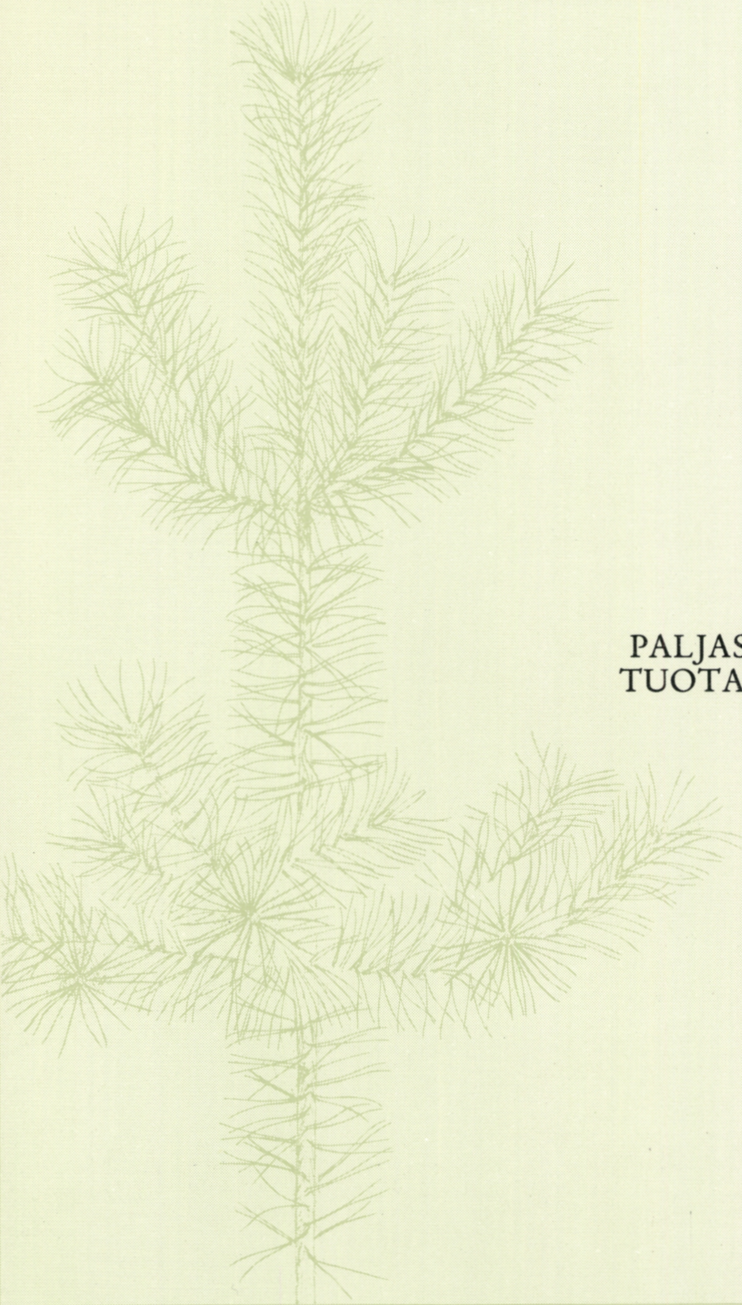
COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE 110

TECHNOLOGY OF THE PRODUCTION OF BARE-ROOT SEEDLINGS



PERTTI HARSTELA &
LEO TERVO

SELOSTE

PALJASJUURISTEN TAIMIEN
TUOTANNON TEKNOLOGIA

HELSINKI 1983

COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE

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Cover (front & back): Scots pine (*Pinus sylvestris* L.) is the most important tree species in Finland. Pine dominated forest covers about 60 per cent of forest land and its total volume is nearly 700 mil. cu.m. The front cover shows a young Scots pine and the back cover a 30-metre-high, 140-year-old tree.

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The study deals with the technology of the production of bare-root seedlings and the possibilities of its development in Finland and some other countries. Technological variables are examined by means of economic, biological, labour policy and ergonomical criteria. Although the scrutiny is holistic, root pruning as a substitute for transplanting and the lifting of seedlings are analysed more broadly than other aspects, and more empirical material has been collected on them that these other parts of the work. The reason for this is that these aspects involve the greatest costs, a greater labour requirement and most of the ergonomical problems in the production of bare-root plants.

Tutkimuksessa käsitellään paljasjuuristen taimien tuotannon teknologiaa ja sen kehittämismahdollisuuksia. Teknologisia muuttujia tarkastellaan taloudellisten, biologisten, työvoimapoliittisten ja ergonomisten kriteerien avulla. Vaikka tarkastelu on kokonaisvaltainen, on juurten leikkuuta ja taimien nostoa tarkasteltu muita asioita laajemmin ja niistä on kerätty myös muita töitä enemmän empiiristä aineistoa. Tämä johtui siitä, että nämä työt aiheuttavat suurimmat kustannukset, suurimman työvoimatarpeen ja useimmat ergonomiset ongelmat paljasjuuristen taimien tuotannossa.

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CONTENTS

1. INTRODUCTION

Relatively few time studies have been conducted on the production of bare-root seedlings and research has been desultory. Contrary to potted seedlings, technical development via the commercial route has been relatively slow. However, over 70 per cent of Finland's seedling production in 1978 consisted still of bare-root plants (Metsätilastollinen ... 1979) and the change to container (or potted) seedlings has been slow, as shown by the table below of the seedlings yield for forest regeneration (Metsätilastollinen ... 1977, 1978, 1979, 1980, Pasanen 1981).

Year	Proportion of bare-root seedlings, %
1976	74
1977	76
1978	72
1979	70
1980	71

The total of seedlings produced in Finland for forest regeneration in 1978 was approx. 187 million of which about 156 million were pine, about 28 million spruce and about 5 million birch seedlings. The corresponding total of seedlings made available for forest regeneration in 1980 was in the neighbourhood of 215 million of which approx. 176 million were pine, about 34 million spruce and about 3.5 million birch seedlings (Metsätilastollinen ... 1979, Pasanen 1981).

Study of the chances of improving the production of bare-root seedlings has been regarded as important with a view to curbing the growth in the costs of forest regeneration, ensuring the biological condition of the seedling material and evaluation of the price development of bare-root plants in ratio to that of potted seedlings.

The present study illustrates with the help of the literature and empirical materials the ergonomical and technological standard of bare-root seedling production, the productivity and costs of the work in Finland and enquires into the technical-economic and ergonomical premisses of developing this production. The biological condition of the seedling material and it's eligibility for forest regeneration purposes were regarded as important criteria when assessing the technical solutions. By way of comparison, reference has also been made to development that has occurred in other countries.

The study constitutes a part of the nursery investigations commenced in 1977 and conducted at Suonenjoki Research Station, Department of Forest Technology, the Finnish Forest Research Institute. The empirical material was collected from the nurseries of Suonenjoki and Pekolampi. The studies were conducted in cooperation with the Department of Silviculture. In addition, miscellaneous data have been received from the seed and seedling office of Central Forestry Board Tapio and the development section of Taimi-Tapio.

The following persons assisted in the study in many ways: Tauno Virkkunen, Aulis Nylund, Juhani Mäkelä, Arvo Huttunen, Urho Ryth and Kauko Kuosmanen from the Regional Forestry Board of North Savo; Pentti Sinkkilä and Aimo Nurminen from Suonenjoen Metalli Oy; Kauko K. Luoma, Teuvo Hinttala, Paavo Hokka, Jari Parviainen, Kyösti Konttinen, Jussi Nuutinen, Mauno Airaksinen and Veikko Järveläinen from the Finnish Forest Research Institute, as well as numerous workers of the Pekolampi and Suonenjoki nurseries.

Marja-Liisa Juntunen, Juhani Korhonen, Carina Besuch, Erkki Okkonen, Urpo Paananen, Pawel Schienke and Kirsi Tuutti participated in the collection and treatment of the material.

The work was divided between the authors of the publication. Pertti Harstela directed the study, drew up the plans together with Leo Tervo, wrote a part of the manuscript and finalised the manuscript. Tervo participated in the planning of the study, headed the field work and the treatment of material and compiled most of the preliminary manuscript. The lifting machine and the root cutter were planned and developed by a working team which included in addition to the authors Antero Harstela who was responsible also for the technical planning of the machines. The manuscript was checked by Pentti Hakkila, Simo Halonen, Erkki Lähde, Juhani Mäkelä, Juhani Niiranen, Pentti Nisula, Jari Parviainen, Antti Pasanen, Risto Rikala, Jouko Tavaila and Tauno Virkkunen. The drawings were executed by Leena Muronranta and Urpo Paananen. Ritva Mölkänen typed the material. Päivikki Ojansuu, Mag. Phil., and L. A. Keyworth, M. A. (Cantab.) translated the work into English.

We thank all those who contributed to the study in different ways.

2. PREMISSES OF THE DEVELOPMENT OF PRODUCTION

The criteria for seedling production can be distributed as follows:

1. Biological criteria of which the most important is probably eligibility for forest regeneration. It influences very strongly also the economicalness of activity for the forest regeneration chain as a whole.
2. Economic criteria which include the costs of seedling production and input-output relations. The present work is concerned chiefly with production costs.
3. Labour force criteria which are the labour force requirement, the seasonal nature of the work and the productivity of work.
4. Ergonomical criteria of which the physical strain of the work and job satisfaction are discussed. These factors probably affect the supply and turnover of labour.

The payroll costs of the production of bare-root plants are distributed between the following cost items in accordance with the cost control data of Suonenjoki and Pekolampi nurseries and Hyvärinen (1980):

	Suonenjoki nursery (*Konttinen 1982a*)	Pekolampi nursery (*Mäkelä 1982*) (all seedling types)	Cultivation of pine 2O+1O*) (*Hyvärinen 1980*)
		proportion %	
— transplanting	24,5	28,9	34,8
— lifting, packing, winter storage and dispatch of seedlings	17,5	17,1	22,7
— cultivation	7,1	17,6	10,6
— irrigation	4,0	1,0	2,9
— fertilization	1,3	1,0	1,1
— other	45,6	34,0	27,9

*) O = open area

Wages are the main cost item in the production of bare-root seedlings. According to Hyvärinen (1980) the share of wage costs in the production of pine 2O + 1O (O= open area) seedlings is 50,6 per cent, of supplies 13,1 per cent, of equipment repair, etc., costs 18,0 per cent and of amortization, interest, etc., 18,3 per cent.

The biggest items in wage costs arise from the lifting of seedlings and associated jobs, and transplanting. The greatest cost savings would obviously be achieved through development of these tasks.

The physiological condition of the seedlings, their state of health, freedom from damage and other factors influencing eligibility for forest regeneration (e.g. root-shoot relation) are often associated with the technology employed in the different phases of cultivation. For instance, lifting and other handling of seedlings that are slow work or carried out in several stages may predispose the seedlings to drying. The evenness and correct spreading of pesticides may contribute to its success. Seedlings can be damaged mechanically in many tending and handling phases. The extent of the root system may be affected by the accuracy of the cutting devices and its shape by the transplanting technique. However, these points often depend also on the carefulness of the work, control by the foremen and organization of the work (e.g., how speedily the sacks of seedlings are transported to storage).

The labour requirement is very uneven in the production of bare-root seedlings, more so than in the production of paperpot seedlings. Fig. 1 shows the labour requirement of three nurseries. The nursery producing bare-root plants has a pronounced labour peak in the spring caused chiefly by the lifting and dispatching of seedlings, but to some extent also by transplanting. The fact that there is a labour shortage in certain districts and that the short-term labour force peak necessitates the use of unskilled labour argues for development of lifting and transplanting work to increase productivity.

According to a field survey carried out at three nurseries the following factors caused the most job dissatisfaction or illustrated the nature of the work (Harstela 1977):

— the worker's back is subjected to severe strain and the work is strenuous (poor working postures)
— the seasonal nature of the work
— exposure to weather conditions
— temporary character of the contract of service

The above factors are accentuated es-

The cost level in this paper is according to the year 1982 (1 FIM = 0,189 USD = 0,448 DEM 31.12.1982).

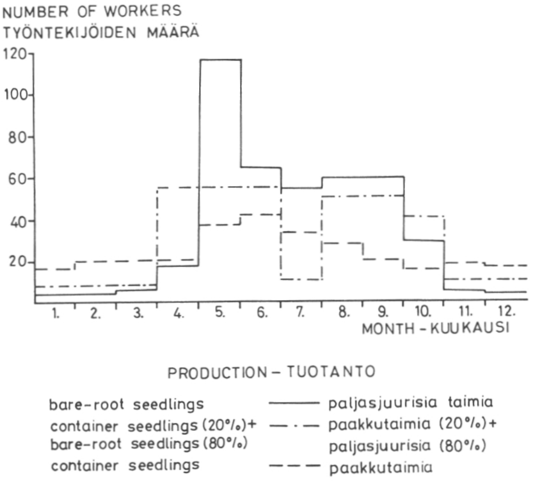

Fig. 1. Labour force requirements of nurseries that represent different production trends
Kuva 1. Erilaisia tuotantosuuntia edustavien taimitarhojen työvoimantarve

pecially in lifting. Studies based on heart rate have also shown that the lifting of spruce seedlings in particular is relatively strenuous work, especially for women (Harstela 1975, Harstela and Tervo 1977). Finnish nursery workers are mainly women. Men are generally employed as tractor operators and are in charge of the dispatch, etc., of seedlings. The majority of the workers employed throughout the year are men.

The majority of nursery workers in Central Europe and England are men. The Federal Republic of Germany in particular has a great many foreign workers (Tervo 1978a, Parviainen and Tervo 1980). There is a shortage of male nursery workers in the United States and many nurseries have therefore hired women for light manual jobs (Hitt 1971).

Most of the development needs mentioned above concern the lifting and transplanting of seedlings. Empirical studies were therefore directed to the cutting of roots as a substitute for transplanting and lifting. In order to throw light on the possibilities of developing production, equipment and machines for these jobs were also developed and with their help empirical time study material was collected by applying the principle of comparative time study.

3. SEEDING

3.1 The preparation of seed beds

The initial cultivation of seedlings in the production of bare-root plants can be performed out of doors or in a plastic greenhouse. A mixture of peat and sand is commonly used as substrate in the outdoor seed beds and peat in plastic greenhouses.

The seedling beds are raised above the surrounding soil surface for the sake of aeration and to achieve suitable moisture conditions. This also reduces the risk of ice scorch. Higher-lying seedling beds are not necessary on soils with good water permeability. On the other hand, they are needed in soils with poor water permeability and in flat areas.

The seedling beds are made by special tractor-mounted bed-maker ploughs. The nurseries constructed these devices themselves. After the shaping of the seedling bed it is generally compacted by rolling to facilitate the use of seeding machines.

3.2 Seeding and covering the seeded areas

Most seed broadcasters have been in use in farming and horticulture. They have been suitable either as such or after minor alterations for use at forest nurseries. A machine constructed specifically for the sowing of forest tree seeds is a seeding device mounted on the body of the TUME fertilizer machine with a row spreading device. This gets the seeds into straight lines. The seed row distance and the seed spacing in the row can be adjusted. When the number of rows is high the seeded areas resemble broadcast seeding. The machines of foreign make have been used also for both seeding and supplementary fertilization during the growing season (Lehto and Simolinna 1966, Aldhous 1972). The seeding machines are manually operated (e.g. LAWN BEAUTY) or tractor-mounted (e.g. TUME). Drill seeding is discussed in Chapter 3.3.

It is not necessary to cover the seeded areas, though covering has certain advantages; for instance, the seeds do not have to be moved because of irrigation or rain. The moisture conditions of the surface of the seed bed are also more favourable than without cover. The seeded areas are usually covered with sand. Tractor-mounted sand spreaders of different types constructed by the nurseries themselves and equipment of foreign make (e.g. EGEDAL) are available for the spreading of sand. The recommended thickness of the sand cover is 2—4 mm (Raulo and Tervo 1980). According to Williams and Hanks (1973), the optimal depth for seeds is approx. 1,5 times the seed diameter. Heikinheimo (1940) reported that a 2 mm deep layer of sand promotes the stocking of seedlings with both spruce and pine. Table 1 gives the results for the effect of the depth of the sand layer on the germination of seeds.

Table 1 shows that germination weakens when the depth of the cover exceeds 2 mm. Heavy covering has the most detrimental effect on larch. According to Heikinheimo (1940), seeds may be covered to a slightly

Fig. 2. TUME seeding machine
Kuva 2. TUME-kylvökone

deeper depth on a substrate that tends to dry; this applies especially to spruce seeds. Covering of seeds to a depth of 4 mm has promoted stocking with seedlings compared with a seeded area without cover (Heikinheimo 1940). It was established in the same experiments that the use of a thick cover is detrimental to birch seeds. Heikinheimo (1940) recommended the covering of birch seed with a 0,5 mm thick layer of ash. Heikinheimo (1915) also observed that ash lowers the germination of seed and it can thus not be recommended without reservation for the covering of seeds. It has been established in later experiments that a sand or peat cover of 2—5 mm is well suited also to birch (Raulo 1962, Raulo and Tervo 1980). Judging by Saloniemi's (1965) studies, the number of seedlings in plastic greenhouse cultivation of pine seedlings was greater when milled peat and Finn humus were used as covering agents than when sand was applied. Experimental plots left uncovered contained a greater number of felled seedlings than the covered plots. However, the number of seedlings in an experimental plot left uncovered has been greater but the mean height of the seedlings smaller than in plots covered with sand or peat.

Among other things sawdust and crushed stone, maximum particle size about 5 mm, are used for cover in Central Europe (Tervo 1978a, Parviainen and Tervo 1980). Aldhous (1972) stated that in Central Europe the soil will be blown away if the area is not well protected against wind. Crushed stone, particle size 3—5 mm, is then to be recommended. If the grain size of the soil is small the surface of the seed bed may become hardened through irrigation, hampering the development of the seeded area. It is appropriate in drill-seeded areas to cover only the seed rows. Mechanized spreading of different covering materials probably raises no problems.

Table 1. Effect of the depth of the sand layer on the germination of seeds (Heikinheimo 1940).
Taulukko 1. Hietakerroksen syvyyden vaikutus siementen itämiseen (Heikinheimo 1940).

Tree species *Puulaji*	Depth of the sand layer, mm *Hietakerroksen syvyys, mm* Germination of seeds, % — *Siementen itäminen, %*				
	2	5	10	15	20
Pine *Mänty*	75	71	53	44	39
Spruce *Kuusi*	87	—	—	—	54
Larch *Lehtikuusi*	67	51	44	15	0

Protecting the seeded areas against the blaze of the sun by means of wooden splints is common in e.g. Central European seedling nurseries (Tervo 1978a, Parviainen and Tervo 1980). According to Heikinheimo (1940), a greater number of seedlings originate in dry nursery soils when protective covers are used, and the seedlings are larger than in unprotected seeded area. Care must be taken when using protective covers to ensure that the seedlings have enough air and light (Kaartinen and Voutilainen 1959).

3.3 Technique and cost of drill seeding

Seedlings produced by the root-pruning method are grown in the open in the seeding and transplanting areas for bare-root plants. Seeding can be performed either into a specifically shaped bed or onto a levelled substrate. In the latter areas, too, a bed is formed later when the tractor tracks sink below the other level. The necessity for a bed depends on, e.g., the water permeability of the substrate. The seeds and seedlings of the outermost rows sometimes move in seeded beds when the edges collapse.

It is better for germination if the seeds are not too deep in the soil. To achieve a good pruning result the seeds must be sown in a narrow line. As a difference of about 2 cm in the cutting distance already affects the seedling quality (Parviainen 1980), approx. 1 cm may be regarded as an acceptable deviation from the direction of the line. The seed bed must be levelled and rolled to achieve a correct seeding depth. Several machines operating on different principles have been used for seeding.

Niiranen (1975, 1981) reported that the desired result was not achieved by NIBEX seeder although alterations were made in the machine in the course of the experiments. The seeds were buried too deep and the result was uneven stocking with seedlings. The result could have been improved by rolling the seed bed. The machine is used for broadcast seeding.

The TUME-MONO precision seeder has proved to be quite serviceable after minor

Fig. 3. TUME-MONO drill seeder
Kuva 3. TUME-MONO-rivikylvökone

Table 2. Effect of the size of the indentation on the number of seeds in the TUME-MONO seeder.
Taulukko 2. Kolon koon vaikutus siemenmäärään TUME-MONO kylvökoneella.

Size of indentation *Kolon koko* Ø, mm	Depth, mm *Syvyys mm*	Number of seeds/indentation — *Siemenmäärä/kolo* Number/m *Keskimäärin kpl/m*	Number/Indentation *kpl/kolo*	Variation *Vaihtelu-väli*
2,5	2,5	.	0,89	0—2
2,7	2,6	70	1,03	.
3,2	3,2	.	2,27	1—3
3,8	2,8	.	3,79	2—5
3,8	3,0*)	121	3,27	.

*) Indentation wheel — *Kolopyörä TUME-MONO PP3*

alterations such as widening the wheels that support the seeding units. This precision seeder operates on the indented wheel principle. The rim of an aluminium wheel (150 mm) has holes into which seeds flow from the container. The holes make it possible to regulate the number of seeds sown and the spacing of the holes permits regulation of the number of seeds per metre of line. The seeding density can be changed by changing the holed wheels. The line spacing can be adjusted steplessly; the minimum between two units is approx. 20 cm. The size of the seed naturally affects the seeding density. Table 2 shows the effect of the size of the indentation on the number of seeds per indentation.

It is advantageous in drill seeding to press a narrow groove near the line to prevent the seeds from moving laterally. The following alterations were made in the TUME-MONO precision seeder used at Suonenjoki nursery:

- the rearmost supporting wheels (driving wheels) of the seeding units were widened by 5 cm to prevent sinking;
- the foremost wheel of the seeding unit was also widened and a 1 cm deep conical ridge was made in the middle; it presses the furrow to prevent the seeds from moving;
- the range of height regulation of the seeding units was enlarged;
- shields were made to guide the dropping of the seeds into the furrow made by the ridge of the foremost wheel;
- the construction of the frame was altered to permit the changing of the line spacing also to below 20 cm;
- the gear ratio of the driving/holed wheels was changed;
- the diameter of the holes in the wheels was 2,7 mm and depth 2,6 mm.

Nurseries use also the TUME seeding device which is attached as auxiliary equipment to the row fertilizer. The quantity of seeds is proportioned by a plastic cog-wheel. From the proportioning device the seeds flow onto the soil through a plastic tube. Line spacing is adjusted by changing the distance between the tubes. The spacing between the seedlings is not as constant with this machine as when the holed wheel principle is employed (Fig. 2).

Sowing of seeds mixed in fluid and pre-germinated has been developed in e.g. England and tested in Finland (Tervo 1978a, Niiranen 1981). The pre-germinated seeds are sown mixed in a gelatinous fluid by a special seeding machine. According to Silokangas (1981), the FLUID-DRILLING seeding machine is capable of fairly good seeding accuracy. If the aim is 70 seeds/metre of line, the variation is — +10 seeds/metre of line. Use of the fluid drilling method presupposes in addition to the drilling machine also a germination tank and mixer.

Fig. 4 shows the costs of drilling. The calculations comprise solely the payroll and machine costs and the costs of the fluid needed in fluid drilling. The calculation bases were as follows:

	Fluid drilling	TUME-MONO
— 5-line driller, germination tank and mixer, FIM	60 000	7000
— fluid needed for seeding, pennies/metre of line	25	—
— time of amortization, a	10	10
— interest, %	10	10
— residual value in per cent of purchase price	20	20
— maintenance + preparatory work, marks/a	800	200

60,00 marks was taken as the hourly cost of the tractor and operator and 24,89 marks as that of the helper (incl. social security costs). The driving speed was taken to be 1 500 m/h, and turning, interruptions and filling of the seeding units were assumed to account for 15 per cent of the effective time.

The costs of fluid drilling are distinctly higher than those of conventional drilling. When the production quantity is fairly small the difference is considerable. Performed correctly (e.g. pre-germination period) fluid drilling may have biological advantages compared with conventional drilling.

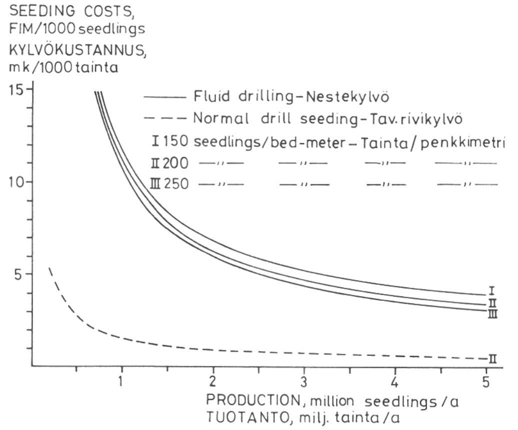

Fig. 4. Costs of drill seeding
Kuva 4. Rivikylvön kustannukset

4. IRRIGATION

4.1 Irrigation systems

The growth of seedlings can be improved appreciably by irrigation. It is indispensable especially during the germination period. The surface of the substrate must be kept moist constantly at that time (e.g. Williams and Hanks 1973).

Irrigation does not involve great costs. The share of the payroll costs of irrigation in seedling payroll costs is approx. 4 per cent (Konttinen 1982a). The capital costs are sometimes considerable. According to Holopainen (1979a), the automated irrigation equipment of a plastic greenhouse of 1 000 m^2 which has Finnish ITU automated regulation costs 20 marks/m^2.

Irrigation devices can be classified according to their installation and working technique as stationary, movable and mobile (Nisula 1975). The watering pipes and their nozzles in the stationary apparatus are in the same place throughout the growing season. With the movable irrigation systems the piping must be moved in accordance with the watering requirement. Circular sprinklers of pendulum type (e.g. BAUER equipment) are generally employed in this system. Mobile irrigation devices move during sprinkling by means of a source of power. Table 3 presents the irrigation systems and their targets used in Finnish seedling nurseries (Rikala 1978).

4.2 Irrigation in plastic greenhouses

As seen in Table 3, it was mainly stationary irrigation systems that were used in plastic greenhouses in 1978. Several nurseries now have mobile systems. They are also common in the seedling nurseries of Sweden (Parviainen and Tervo 1980). The use of mobile, so-called ramp irrigation devices is motivated in North America by the evenness of irrigation. However, the greater proneness to disturbances of the equipment is mentioned (Tinus et al. 1974).

There is at Suonenjoki nursery a so-called ramp irrigation equipment designed by Nisula which moves on a pair of rails. It has FLOODJET nozzles. The amount of water from the nozzle is approx. 0,34 l/min. at a pressure of 1,0 kg/cm^2. Evaporation in different parts of the plastic greenhouse was taken into consideration in the placing of the nozzles of Nisula's (1976) overhead sprinkling equipment. This sprinkler system is placed in a heated plastic greenhouse measuring 16 m × 50 m.

Moving the sprinkling device manually is cumbersome. The evenness of irrigation suffers if the speed of moving the apparatus is not constant. It is possible to use an electric motor to move the device to ensure even movement. A reversing engine makes the device travel automatically forward and backward and the sprinkling pattern is then rectangular in shape. However, even the automatically functioning devices need to be kept under observation.

The evenness of irrigation is an important factor. As evaporation varies in the different parts of plastic greenhouses this must be taken into consideration in the irrigation arrangements. When a stationary equipment

Table 3. The irrigation systems and their targets in nurseries (Rikala 1978)
Taulukko 3. Taimitarhojen kastelujärjestelmät ja -kohteet (Rikala 1978).

Targets *Kastelun kohde*	Irrigation system — *Kastelujärjestelmä*		
	stationary *kiinteä*	movable *siirrettävä*	no irrigation *ei kastelu-järjestelmää*
	Nurseries — *Taimitarhoja*		
Plastic greenhouse with heating systems *Lämmitettävä muovihuone*	9	—	—
Plastic greenhouse *Muovihuone*	26	1	—
Open area *Avomaa*			
— Seeding area — *Kylvöala*	11	19	—
— Transplanting area — *Koulinta-ala*	4	26	3

is used it is possible by means of closer placement of nozzles to compensate for the need of supplementary irrigation caused by the greater evaporation (Holopainen 1968). According to (Holopainen (1968) and Welch (1970), irrigation is most even if the nozzles are placed alternately. The result did not change significantly, however, although the nozzles were on the same cross section lines of the greenhouse. In this case RECORD nozzles were used. The pressure losses of the pipes must also be considered in the placing of the nozzles. Holopainen (1979b) reported on the evenness of the spraying given by several mist spraying and watering nozzles used in a stationary irrigation system. According to the study the evenness of the watering by different nozzles varied. For instance, the evenness of irrigation with DGT-blue mist spray nozzles was superior to that of other nozzles covered by the study. As to watering nozzles, RECORD and DGT-yellow were found to be good. Mist spraying yields more even irrigation than droplet irrigation, but the root systems developed less well when mist spraying was used. As the watering continues for a long time in mist spraying, it has been suggested that salts pass more readily from the superficial layers as the result of continuous dissolution (Hanan et al. 1978).

4.3 Irrigation in the open area

Movable circular sprinklers of oscillating type have been the commonest in outdoor seeded areas. They are commonly used in Central Europe, too. The pressure of the network there was about 10 kg/cm^2, which is considerably higher than that generally used in Finnish nurseries (Parviainen and Tervo 1980). The droplet size decreases as the pressure increases. Large drops fly farthest (Kara 1971). English nurseries use the EVENSHOWER equipment shown in Fig. 5 in outdoor seeded and transplanting areas. Satisfaction was expressed with the functioning of this apparatus (Tervo 1978a). The demands made of irrigation equipment depend essentially on the need of supplementary irrigation. If it rains after sowing the additional need of irrigation is small. It is possible in such a case to achieve good growth even with inferior equipment.

Movable devices are the commonest in outdoor transplanting areas. Mobile apparatuses are gaining ground (Fig. 6). The working width of the LÄNNENVILLE sprinkling system which is moved by water pressure and is used in outdoor cultivation is about 50 m. It has two RAIN-BIRD 85 E-NT nozzles and the nozzle pressure is 5 bar.

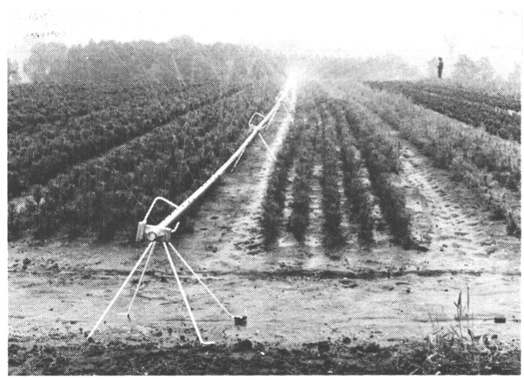

Fig. 5. EVENSHOWER irrigation device
Kuva 5. EVENSHOWER-kastelulaitteisto

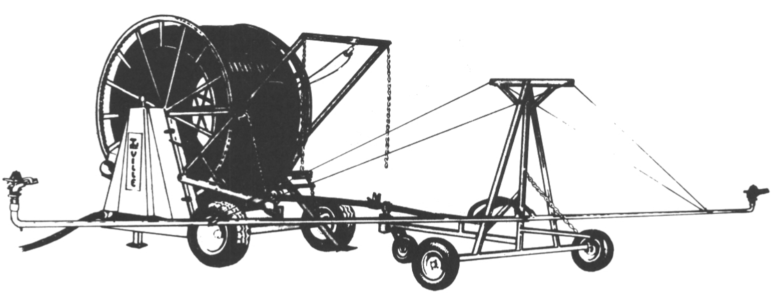

Fig. 6. LÄNNENVILLE irrigation device
Kuva 6. LÄNNENVILLE-kastelulaitteisto

It was reported by Christensen (1961) that the spraying given by sprinklers and irrigation devices is distributed unevenly on the surface to be watered. According to Nisula (1975), a good circular sprinkler should irrigate so that the amount of irrigation decreases rectilinearly away from the sprinkler. Fig. 7 shows the distribution of the sprinkling by three different circular sprinklers (Christensen 1961).

Large droplet size and too liberal irrigation may destroy the fine structure of the soil and thus diminish its aeration (e.g. Hanan et al. 1978). This may become a problem especially outdoors where a large droplet size is used in order to achieve a wide radius of irrigation. It is possible that it will be necessary in the future to develop irrigation in such a way that the fine structure of the soil is not broken by irrigation.

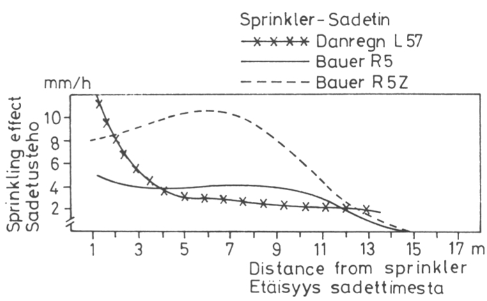

Fig. 7. Distribution of the spraying of circular sprinklers (Christensen 1961)
Kuva 7. Ympyräsadettimien sadetuksen jakautuminen (Christensen 1961)

4.4 Determination of the irrigation need

Determination of the irrigation requirement is generally based on practical experience. The seed beds should be kept evenly moist, especially during the germination period. Generous and rarely repeated irrigation is the aim in transplantation areas. The risk of washing away fertilizers in substrates with easy water permeability can be reduced by giving smaller amounts of water more frequently (Rikala 1978). It is possible to use evapometers and tensiometers for evaluation of the irrigation need.

Automated regulation of irrigation is already in common use in plastic greenhouses. One such system is the Finnish ITU mist-spraying and irrigation automation. In this system the irrigation need is controlled by an ITU sensor. The sensor amplifier measures continually with the aid of the sensor the radiant heat from outside; when the intensity of the radiation reaches a predetermined limit, it sends a sprinkling order to the sprinkling centre. The sprinkling density depends on the rate of evaporation in the greenhouse.

According to Rikala (1978), the irrigation is problematic in practical nursery work, especially as regards the evenness of irrigation, and hence further study serving practical needs is indicated.

Development of cultivation automation in heated plastic greenhouses is in progress at Suonenjoki Research Station and different irrigation systems and their automation are also being studied within the scope of the project.

5. TRANSPLANTING

5.1 General

Transplanting means moving the seedlings from their original site, the seed bed, to another site where they are planted more spaced out. The aim is to make the root system thicker, make the seedlings sturdier, improve the root-shoot ratio and increase the eligibility of seedlings for forest regeneration purposes (e.g. Aldhous 1972, Parviainen 1980). In Finland, seedlings are grown after transplanting for 1—2 years before planting in the terrain. As stated in Chapter 2, the costs of transplanting are a relatively great cost item and considerable attention has therefore been paid to the development of transplanting.

5.2 Transplanting technique

Only small nurseries continue to transplant manually. The longitudinal furrow can be made by a tractor-drawn plough and the seedlings are placed in the furrow using e.g. Lindell's device. Transplanting by board is performed in the bed in the transverse direction. The transplanter digs a furrow with a spade and places the seedlings manually in the furrow at fixed intervals.

In Finland, transplanting is done chiefly with tractor-drawn transplanting machines. The plate transplanting machines with rubber plates LÄNNEN and ACCORD are the commonest of these units. There are only a few specimens of the SUPER-PREFER plier transplanting machines with spring-loaded pliers. 15-unit machines have been constructed for major nurseries by combining three conventional 5-unit machines. A medium-sized (40—50 kW) farm tractor can be used as the driving force for the 5-unit machine. A large (55 kW) farm tractor with four-wheel drive or equipped with tracks is needed as the driving force for a 15-unit machine. In each case a reducing gear is required in the tractor.

In addition to cost savings (Chapter 5.3), machine transplanting has the advantages of easing the work, protecting the workers

Fig. 8. A 15-unit transplanting machine at Pekolampi nursery
Kuva 8. 15-paikkainen koulintakone Pekolammin taimitarhalla

against weather conditions, a smaller human labour requirement, better protection of seedlings and the point that the transplanting furrow does not dry. Machine transplanting was regarded in a field survey to be more pleasant work than manual transplanting (Harstela 1977). Disadvantages, again, are a more uneven transplanting result and the ease with which "hook roots" originate. Hooked roots can be overcome to some extent by deepening the furrow-making plough. There are drawbacks also in the ergonomical conditions of the transplanting machines.

Self-propelled transplanting machines are used extensively in Central Europe. Their profitability in Finnish conditions is questionable because of the short working season, with capital outlays probably exceeding the per-hour costs of the tractor. Central Europe also has relatively more plier-fed machines than Finland (Parviainen and Tervo 1980). Advantages of these machines are more even seedling spacing and the fact that seedlings are better able to remain vertical than in plate-fed machines. The plate-fed machine requires great accuracy of the transplanter if the seedlings are to be correctly positioned. A disadvantage of the plier transplanting machine is the cumbersome placing of the seedlings into the pliers. The plate transplanting machine is moreover probably more reliable in operation because of the smaller number of moving mechanical parts.

Ergonomical problems of transplanting machines are primarily a poor working position and poor seats. The working position is better in the plier-fed machine as the plant need not be placed as far as in the plate-fed unit. The ergonomical properties of the plate-fed machine were improved in the following manner at Suonenjoki Research Station (Fig. 9):

- padding and back rests for the seats
- the adjustability of the seat
- the point of pressure of the plates was brought forward which shortened the distance to the disks
- wearing of padded harnesses with springs by workers with a weak back

The experience gained from these changes was positive.

The intensity of light in the transplanting machine on a semicloudy day was:

Fig. 9. Seats with back rest and a spring strap which supports the worker in a transplanting machine
Kuva 9. Selkänojalliset istuimet ja yläruumista kannattava jousitettu hihna koulintakoneessa

- when the machine was covered with a tarpaulin 30 lux
- when the machine was covered with plastic 1000 lux.

The former value is insufficient for the sorting of seedlings.

Full mechanization of transplanting was experimented with in Finland at the end of the 1960s on the initiative of the Foundation for Forest Tree Breeding by the band transplanting method of which a Norwegian application is also available (Moen 1968). A prototype machine has also been developed for transplanting seedlings glued or stitched between strips of paper (Halme 1981). Adoption of the method was probably prevented by the poor biological results and the dearness of the method. In addition to the costs of the materials, just placing the seedlings between the strips requires almost as much manual work as transplanting by the present machines. An advantage would be that work could be shifted to the winter season.

5.3 Productivity and costs of transplanting

The expenditure of time on jobs associ-

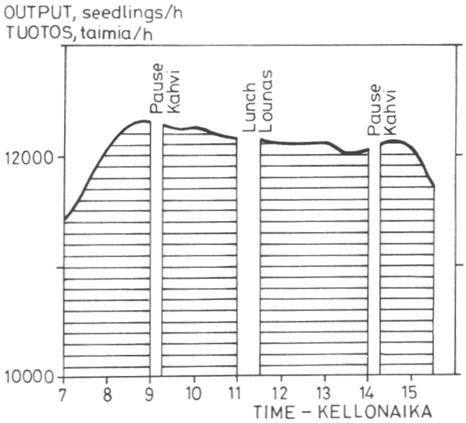

Fig. 10. Per-hour output in mechanized transplanting for a team of six transplanters during a working day (Rummukainen and Mäkelä 1968)

Kuva 10. Konekoulinnan tuntituotos kuuden koulijan ryhmällä työpäivän aikana (Rummukainen ja Mäkelä 1968)

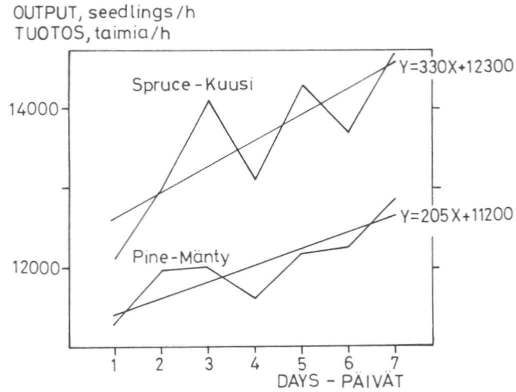

Fig. 11. Development of the hourly output in mechanized transplanting during the transplanting phase for pine and spruce (Rummukainen and Mäkelä 1968)

Kuva 11. Konekoulinnan tuntituotoksen kehitys koulintajakson aikana männyllä ja kuusella (Rummukainen ja Mäkelä 1968)

ated with transplanting was as follows (Huusko 1971):

			Value of work*), cmin/100 pcs
— lifting into boxes	spruce	1P+O	149—197
	pine	1P+O	110—194
— sorting	spruce	1P+O	516
	pine	1P+O	445
— manual transplanting using a comb	pine	1P+O	718—776
— manual transplanting as furrow transplanting	pine	1P+O	678
— making the transplanting furrow with a spade	pine	1P+O	194
— mechanized transplanting	pine	1P+O	472

*) normal-time study P = plastic greenhouse
O = open area

To free the seedlings prior to lifting a tractor-drawn device is employed in the open; it undercuts the soil and shakes the seedlings free. The seedlings can also be sorted in connection with transplanting, which is probably the commonest method at present. According to various sources, the productivity of mechanized transplanting is as follows (Väre 1972, Harjula and Karppelin 1974, Herranen 1980):

- pine and spruce 1P+O 9 000—17 000 seedlings/8 h/unit (= transplanter)
- birch 6 000—8 000 seedlings/8 h/unit (= transplanter)

Rummukainen and Mäkelä (1968) reported the average result of the transplanters in mechanized transplanting as approx. 2 000 seedlings/h. The differences between individual transplanters can be great. Fig. 10 shows the productivity of work in mechanized transplanting during a working day. The tree species is also of importance for productivity. Fig. 11 shows the productivity in mechanized transplantation of spruce and pine seedlings. The transplanting result with the Nisula method has been 60 000—80 000 seedlings/8 h/8 transplanters (Nisula 1978).

Transplanting is done manually in some nurseries in Finland. The arguments for manual transplantation are: the cultivation plots of a size unfavourable for mechanized transplanting, the shape of the plot, the stoniness of soil, etc. The row spacing in manual transplanting is about 15 cm and in mechanized transplanting approx. 20 cm. The seedling yield per area is consequently greater than in mechanized transplanting. The average results in manual transplanting have been 5 500—9 500 seedlings/8 h (Väre 1972, Mattila 1981, Seppälä 1981).

According to one study, the cost of lifting the seedlings was 3—10 marks/1 000 seedlings at the cost level for 1980 and the cost of transport from the seeding area to the transplanting area was 3—4 marks/1 000 seedlings (Mäkelä 1981). Seedlings are lifted into boxes in order, which speeds up and facilitates the work on the transplanting machine. The costs of mechanized transplanting proper are shown in Fig. 12 when the bases of calculation were as follows (Tervo 1981):

	5 units	15 units
— purchase price, marks	22 000	65 000
— residual value in % of purchase price	20	20
— time of amortization, a	10	10
— interest, %	10	10
— repair and maintenance, marks	1 000	1 800

60 marks/h was taken as the hourly cost of the tractor and its operator for a 5-transplanting unit machine and 65 marks/h for a 15-transplanting unit machine. The hourly wages of the transplanters including social security costs was 29,40 marks/h and the machine output was 10 000 and 15 000 seedlings/8 h/transplanting unit. Each machine carried in addition to transplanters one worker who exchanged the empty seedling boxes for full ones, inspected the transplanting result and corrected the position of the seedlings. The 15-unit transplanting machine was more economic than the 5-unit one for an annual transplanting quantity of approx. 1 million.

The expenditure of working time in mechanized transplanting by a 5-unit transplanting machine was 40—50 per cent smaller and the payroll costs of the

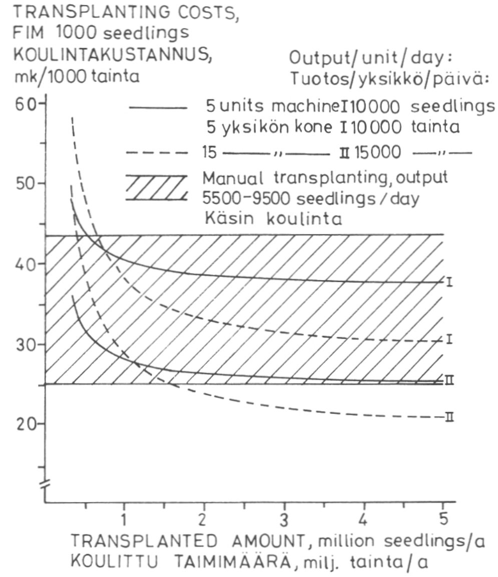

Fig. 12. Costs of transplanting
Kuva 12. Koulinnan kustannukset

transplanters smaller by roughly the same amount than in manual transplanting (Huusko 1971, Harjula and Karppelin 1974). As shown in the foregoing, costs generally decrease on changing to a 15-unit transplanting machine. Even when the costs of the tractor and its operator are added, mechanized transplanting is generally cheaper than manual. The annual number of hours of use naturally affects economicalness.

6. ROOT PRUNING

6.1 General

The technique of production of bare-root plants has been at nearly the same level for a long time. The most significant change was the change some 10 years ago from manual transplanting to mechanized transplanting for the most part. As transplanting is still work that involves a great deal of expenditure, a method has been evolved for rationalization of the work in which seedlings are grown in rows outdoors. Pruning the root system during the growing period permits guidance of its growth and promotes its branching (Parviainen 1980). Root pruning has been known since the 19th century when it was used to facilitate planting (Wittwe 1898, Spitzenberg 1908). Root pruning as a cultivation method was reported in Central Europe in the 1930s (Swart 1935). In the Nordic countries attention began to be paid to root pruning as a growing method at the beginning of the 1950s (Børset 1953, Hiorth 1954). The method was experimented with in Finland at seedling nurseries in the 1970s and it has been subjected to intensive study since 1975 (Parviainen 1980, Niiranen 1979, 1981). Root pruning in practical experiments at nurseries has been slight as the pruning distance from the base of the seedlings has been as great as 10 cm. However, biological studies have shown that pruning with a J-blade should be done at a distance of about 5 cm from the base of the seedling and to a depth of about 8 cm (Parviainen 1980).

6.2 The technique of root pruning

Several different cutting implements can be used for cutting between rows of seedlings. Manual tools that cut a row at a time were employed in the 19th century (e.g. Wittwe 1898). Later, a J-shaped blade was used (Trede 1932). If a knife-like blade is used, pruning is facilitated by a to-and-fro movement (Laiho 1966, Lott and Hallman 1973).

The coulter cutter is very suitable for side-pruning. It is not easily clogged by pieces of wood, etc., in the soil. The distance between the coulters must, however, be sufficiently great to prevent soil from sticking to the revolving cutters, especially in moist substrate (Harstela and Tervo 1977). A coulter cutter in which the coulters are in a V-shaped position when viewed from behind has been employed in e.g. Central Europe as a horse-drawn implement (Ludemann 1962). The Danish EGEDAL implement among others has a U-shaped blade (Mosegaard 1976). In Canada, the USA, New Zealand etc., roots have been pruned from underneath with an implement in which a narrow blade passes beneath the seedling bed making a to-and-fro sawing movement (e.g. Lott and Hallman 1973). Another alternative is that the undercutting blades slant backwards leaving a hole in the centre (Aldhous 1972).

The moisture of the substrate affects the success of pruning. Roots may move on wet and plastic soil before the blade without breaking, however. A better result is achieved especially in these conditions by a mobile than a stationary blade (Eis 1968, Eis and Long 1973). The blade material must be such that the blade retains its sharpness for long periods (Eis 1968). The sharpness of the blade also affects the pruning result.

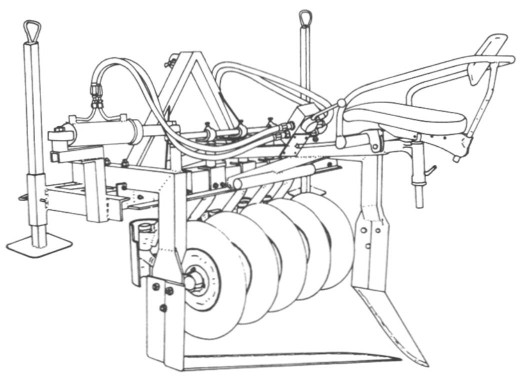

Fig. 13. Coulter cutter constructed at Suonenjoki Research Station. It also has undercutting blades
Kuva 13. Suonenjoen tutkimusasemalla rakennettu kiekkoleikkuri, jossa on myös altaleikkaavat terät

According to Dusek (1967) the blade used in root pruning must not be thicker than 3 mm. If a thicker blade is used the cambium of the root system may be damaged and the root system ruptured.

Root pruning with the same machine in differing conditions (soil, moisture conditions, obstacles such as stones and pieces of rootstock, etc., which interfere with cutting) requires adjustability of the pruning machine. The same is required for varying seedling size if the aim is to cut with the same machine also roots of transplanted seedlings.

A root-pruning machine of Swedish make has been used also in Finland. The speed of the to-and-fro movement of the J-shaped blade of this machine is approx. 1,000 times per minute and the stroke length is about 3 cm (Niiranen 1975, Sjövall 1977).

A coulter cutter was constructed by Suonenjoki Research Station in cooperation with the nursery. It was intended primarily for the cutting of transplanted seedlings for regeneration purposes and the aim was to facilitate lifting (Harstela and Tervo 1977). Undercutting blades were also fitted to this machine. They are at an angle of about 45° backwards, leaving a hole. Due to the blade position and hole, roots etc. do not adhere to the machine to the same extent as they stick to a straight stationary blade. Experience has shown that the blades must be relatively rigid to enable them to move at the precise depth also in the middle part of the machine.

A test-bench machine for root pruning has been constructed at Suonenjoki Research Station. It is possible to adjust the technical variables in the machine and to experiment with different blade alternatives with a view to finding the best pruning result. Both these machines have been used to prune the roots of pine and spruce seedlings.

The blades of the test-bench machine are exchangeable and their stroke length and speed can be adjusted. The blade movement improves cutting and obviously reduces clogging of the blade. The velocity of the to-and-fro movement depends on the driving speed; the movement can be slower at low speeds than at higher speeds. The pruning accuracy, too, depends on the driving speed. The pruning is more accurate at lower speeds.

Fig. 14 "Test-bench machine" for root pruning.
Kuva 14. Juurten leikkuun "koepenkkikone"

The test-bench machine is equipped with an accurate hydraulic control. According to experience gained, control based on, say, support wheels is not sufficiently accurate in difficult conditions (wet and soft substrate). Control of the blades of this machine has been made accurate and reliable by basing the control movement on the weight of the tractor. The pruning machine is attached to the three-point lifting device of the tractor. The range of adjustment of the control is around 300 mm.

This test-bench machine has been used at Suonenjoki nursery since 1977. Pruning blades of J-shape were decided upon on the basis of experience. This machine which is now in serial production differs from the Swedish pruner with J-shaped blades (Jakabffy 1969, Sjövall 1977) on the following points:

- hydraulic control in ratio to the tractor (only the blades with their frames are directed). Control is consequently light and accurate.
- there is no separate vertical pruning blade in front of the J-blade.
- there are no support wheels. The pruning depth is adjusted by the lifting device of the tractor.

Hydraulic control is accurate also on wet and soft soil. Support wheels produce a lag in the control and pruning may take place either too close to or too far away from the seedling. If the root system is pruned too

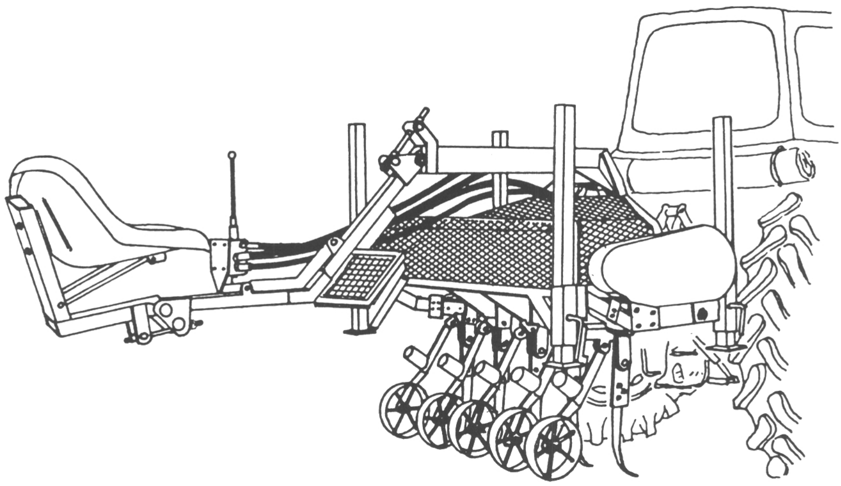

Fig. 15. Root-pruning machine (J-blade) manufactured by Suonenjoen Metalli Oy
Kuva 15. Suonenjoen Metalli Oy:n valmistama juurtenleikkuukone (J-terä)

close the seedling is damaged and is no longer eligible for forest regeneration. On the other hand, if pruning is done from too far away the biological result intended in the root-pruning method is no longer achieved.

6.3 Costs and the need of area

The most noteworthy difference in the production costs of transplanted and pruned seedlings arises from the omission of transplanting when root pruning is used. The payroll and machine costs of the lifting and moving and transplanting of seedlings are about 2,9 p/seedling when a 15-unit machine is used (unit output 12 500 seedlings/8 h) and the production quantity is 2 million seedlings/a.

The payroll and machine costs of root pruning are given in Fig. 16. The bases of calculation used were as follows:

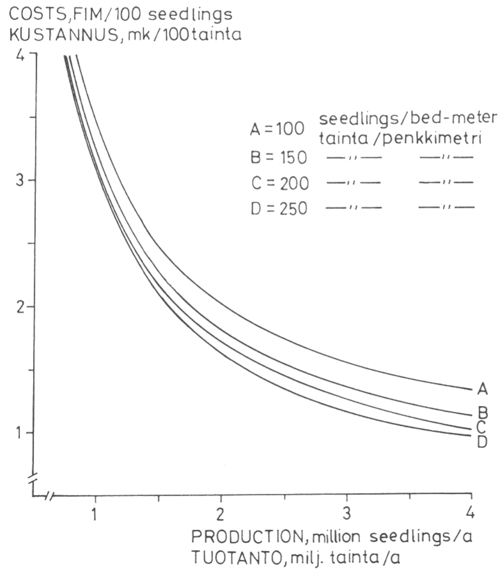

Fig. 16. Costs of root pruning
Kuva 16. Juurten leikkuun kustannukset

— machine purchase price 18 500 marks
— time of amortization 10 a
— interest 10 per cent
— residual value 20 per cent of the pruchase price
— repair + maintenance 100 marks/a

60,00 marks war used as the per-hour cost of the tractor and its operator. The figure for the driver was 24,89 marks (incl. social security outlays). The driving speed was 1 500 m/h and the share of turning and interruptions was 10 per cent.

The costs of root pruning for a production volume of 2 million seedlings is 0,2 p/seedling, which is 2,7 p/seedling cheaper than transplanting.

According to Niiranen (1981), the variable cultivation costs (incl. wages and supplies) of 2-year cut seedlings grown at the nursery of the Foundation for Forest Tree Breeding in 1978—1980 have averaged 2,67 p/seedling and those for transplanted 2O+1O seedlings 7,30 p/seedling. The above costs do not include the lifting and sorting costs of the seedlings. The lifting of transplanted seedlings has been estimated to be approx. 0,5 p/seedling cheaper than that of cut seedlings. The difference in direct variable costs between the seedling types mentioned in the foregoing is according to Niiranen (1981) about 4 p/seedling.

An area of the same size is needed in the root-pruning method for seedlings of different ages. In the method based on transplanting the need of seeding area is relatively small. Table 4 shows the need of effective area for the production of 1 million seedlings. It is probably possible both biologically and technically in the root-pruning method to reduce the row spacing considerably below 20 cm.

Table 4. Need of effective area in different production methods for the production of 1 million seedlings/a (Parviainen 1980)

Taulukko 4. Tehollinen pinta-alantarve eri tuotantomenetelmällä 1 milj. taintala tuottamiseksi (Parviainen 1980)

	Cut seedlings — *Leikatut*				Transplanted seedlings — *Koulitut*	
	2O *2A*	2O *2A*	3O *3A*	3O *3A*	1P+1O *1M+1A*	2O+1O *2A+1A*
	yields seedlings/m² — *saanto tainta/m²*				sowed 500 seedlings/m² *kylv. 500 tainta/m²*	
	200	250	125	150	transplanting 100 seedlings/m² *koulinta 100 tainta/m²*	
	Cultivation area/ha — *Kasvatuspinta-ala, ha*					
1. year *1. vuosi*	0,5	0,4	0,8	0,7	0,2	0,2
2. year *2. vuosi*	0,5	0,4	0,8	0,7	1,0	0,2
3. year *3. vuosi*	—	—	0,8	0,7	—	1,0
Total *Yhteensä*	1,0	0,8	2,4	2,1	1,2	1,4

O = open area
A = avomaa

7. FERTILIZATION

Fertilization is an important tending operation during the growing period of seedlings. The growth of seedlings can be improved perceptibly through good fertilization (e.g. Lehto and Simolinna 1966). Fertilizers can be administered either as grains or solution. Liquid fertilization has become common in cultivation in plastic greenhouses; it is administered in connection with irrigation. In outdoor cultivation (transplanting areas) surface fertilization or row fertilization is used. Table 5 shows the fertilization spreading methods by cultivation targets employed at Finnish nurseries (Rikala 1978).

According to Table 5 surface fertilization has been the commonest form used in plastic greenhouses. The situation may have changed since 1978 and liquid fertilization during irrigation may be the commonest method today. The development of liquid fertilization automation and irrigation automation, etc., has contributed to this.

Recommendations have been made for the basic fertilization of the substrate and the cultivation of plants (e.g. Ingestad 1962, Puustjärvi 1973). Know-how obtained by experience and soil and needle analyses are methods of determining the fertilization requirement. According to Rikala's study (1978), users of soil analysis utilise more nitrogen in outdoor seeding areas than growers that base themselves on experience gained in practice. The situation has been reversed in the fertilization of transplanting areas.

Table 5. Methods of spreading fertilizers at Finnish seedling nurseries (Rikala 1978)
Taulukko 5. Lannoitteiden levitystavat Suomen taimitarhoilla (Rikala 1978)

Fertilization object *Lannoituskohde*	Spreading method — *Levitystapa* Surface spreading *Hajalevitys*	Surface spreading and row spreading *Haja- ja rivilevitys*	Surface spreading and irrigation spread. *Hajalevitys ja liuoslannoitus*
	Nurseries, % — *Taimitarhoista, %*		
Plastic green house *Muovihuone*	54	—	46
Open area *Avomaa*			
— seeded areas *kylvöalat*	46	5	49
— transplanted areas *koulinta-alat*	58	23	19

Fertilizers must be spread as evenly as possible (e.g. Lehto and Simolinna 1966). Even spreading of fertilizers calls for good spreading equipment. The evenness of fertilization administered in conjunction with irrigation depends on the irrigation equipment. The role of the evenness of irrigation by the irrigation equipment is thus accentuated further. A sufficiently moist soil is a basic premiss for the uptake of nutrients by plants (e.g. Raitio and Rikala 1981). The surface and row devices used for basic and supplementary fertilization in the open are the same as those employed in farming (e.g. the TIVE fertilizer, TUME row fertilizer and hoe).

The evenness of fertilization with the TIVE fertilizing machine was measured at Suonenjoki nursery. The spreader has a centrifugal thrower. The replicate measurements numbered nine. The tractor driving speed was that usually employed for fertilization and the fertilizer was calcium ammonium nitrate. As shown by the results presented in Fig. 17, the spreading of the

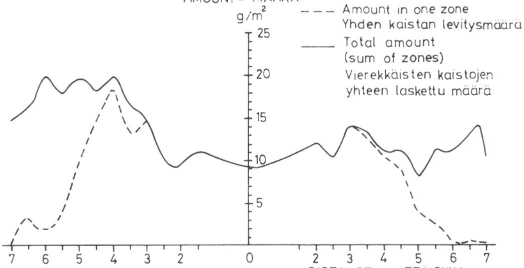

Fig. 17. Evenness of fertilization with the TIVE fertilizing machine
Kuva 17. Lannoituksen tasaisuus TIVE-lannoittimella

fertilizer was not very even. The values measured in accordance with Mann-Whitney's U-test at distances of 1,5 and 4,5 m from the fertilizing machine (left side) differ from one another at the 5 per cent risk level and the higher value is approx. 1,5-fold. The evenness of fertilization may be affected by the rotational velocity of the wheel that throws the fertilizer. The effect of rotational velocity was not elucidated in this experiment, however. The evenness of fertilization can be improved by driving along a different route during the different fertilization occasions.

The most even overall result in this case is given by leaving 5 seedling beds between the driving strips. Spreaders operating on this principle should in fact be tested and the width of the spreading strips be determined accordingly.

Care must be taken in fertilizing to ensure that the fertilizer is not left on the seedlings. Post-fertilization irrigation washes the fertilizers off the surface of the seedlings and furthers their sinking and dissolution from the substrate (Lehto and Simolinna 1966). Excessive irrigation may wash the fertilizers down too deep in which case their action remains small.

According to Rikala (1979), an attitude of reserve should be adopted to liquid fertilization in the open with the present irrigation technique. No great differences were seen in the effects of surface fertilization and row fertilization on the growth of seedlings. Mechanical hoeing in connection with fertilization has been regarded as an advantage of the row fertilization. Row fertilization may give a better result than surface fertilization in fine soil as the fertilizer then reaches the right depth and the danger of nutrients being washed away is smaller than in coarse soils because of the smaller need of irrigation.

The fertilizers used at nurseries are generally easily soluble. Fertilization has to be repeated several times during the growing period. Slowly soluble fertilizations (e.g. OSCOMOTE 14-14-14) have also been experimented with. Hänninen (1979) reported that the consumption (nutrients kg/ha) of slowly soluble fertilizers is nearly the same as that of readily soluble. The price of slowly soluble fertilizers is many times the price of readily soluble fertilizers. Fertilizer spreading costs represent only a small part of fertilizer expenses. Slowly soluble fertilizers are consequently not economically motivated in transplanting areas.

The use of wood and peat as a source of energy and, on the other hand, the soil "fatigue" phenomena and seedling growth disturbances may increase the use of ash manuring and green manuring in the future.

8. SPREADING OF PESTICIDES

Nurseries use pesticides against insect and fungus damage, especially fungi causing damage to plants during winter dormancy. Pesticides are given mainly by tractor-mounted sprayer (Fig. 18). Knapsack sprays are employed chiefly in plastic greenhouses and over small areas. Pesticides are administered both in dust and in liquid form.

Seed disinfection is used at some nurseries. The seeds are protected against fungus damage during the stage of germination and against damage caused by birds (Simolinna 1965).

Pine seedlings that are to be used for regeneration purposes are protected against pine weevil (*Hylobius abietis* L.). The shoots of the seedings are wet with lindane solution. The treatment is probably administered mainly in the forest prior to planting. Use of personal safety equipment and protective clothing in accordance with instructions is imperative.

According to measurements made, no great work hygiene problems are associated with the handling of pesticides at nurseries, with the possible exception of plastic greenhouses. The exposure is greatest for the workers when measuring the substances and filling the sprays. In the spraying process, the exposure of the tractor operator is probably smaller than that of the helper (Kangas et al. 1980). Use of personal safety equipment and protective clothing is a must.

Fig. 18. Spreading of pesticide by a tractor-mounted sprayer

Kuva 18. Torjunta-aineen levitystä traktorisovitteisella ruiskulla

According to Kangas et al. (1980), the following measures can be applied to reduce exposure to pesticides:

— filling the spray tank from made-up pesticide packages instead of weighing
— taking wind conditions into consideration when giving the pesticides
— work training
— wearing of adequate protective clothing and of face masks
— avoiding ingestion of food and beverages, and smoking during dissemination
— frequent washing
— avoiding the use of a knapsack duster or spray (using preferably a tractor spray)
— storing the pesticide only for one year at a time in order to avoid decomposition during the storage period. The storage must be dry, cool, dark and well ventilated.

Spreading of pesticides has been regarded in field studies as one of the most cumbersome jobs (Harstela 1977). The reason for this may be a psychic fear of pesticides.

It is customary with the pesticide spreaders in use today to treat the entire plant association from above. The spaces between the rows and the pathways, too, are thus treated. The share of inter-row spaces and pathways may be as great as 80 per cent, the seedling coverage only approx. 20 per cent (Figs. 19 and 20). The greatest part of the agent used then passes directly into the soil though it is intended for the seedlings. The pesticides employed do not as a rule act through the root system. The technique of pesticide dissemination should be directed to the development of methods and equipment ensuring that only the seedling or a certain part of it is treated. The pesticide fall-out in the soil would thus be smaller than with the current methods. Electrostatic sprays are one solution proposed: the charged drops sprayed seek their way to the plants. These solutions have made it possible to reduce the consumption of pesticides to a half (Farm . . . 1977, The Status . . . 1982).

Chemicals or vaporising are used to disinfect the soil. Chemicals are sprayed in connection with e.g. ploughing. The result is a decrease in the useful micro-organisms, too. It has been observed in Central Europe that soil becomes packed and poorly water permeable after several episodes of disinfection. The cost of the treatment is around 8 000 marks/ha (Haller 1978, Parviainen and Tervo 1980).

Fig. 19. Coverage of 2O pine seedlings after autumn transplanting

Kuva 19. Männyn 2A-taimien peittävyys syyskoulinnan jälkeen

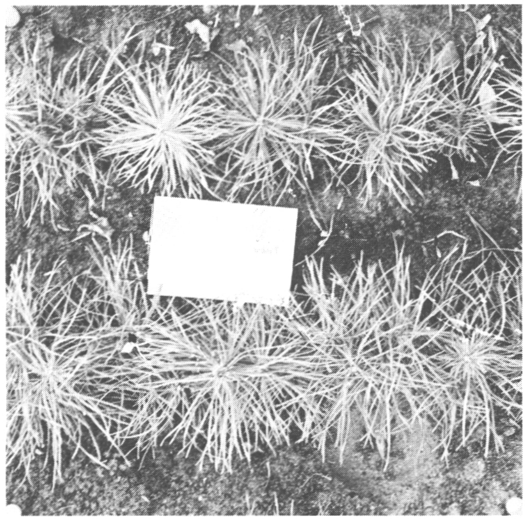

Fig. 20. Coverage in the autumn of pine seedlings transplanted in spring

Kuva 20. Keväällä koulittujen männyn taimien peittävyys syksyllä

9. WEED CONTROL

Lehto and Simolinna (1966) at the beginning of the 1960s reported the share of the weed control costs in seedling cultivation costs to average 40 per cent. The share of weed control is today 7—10 per cent of the cultivation costs (Mäkelä 1982, Tavaila 1982). According to Rummukainen (1981), the annual cost of weeding of transplanting areas has been approx. 10 000 marks/ha, of hoeing about 4 100 marks/ha and, when chemical weed control is used, about 1 300 marks/ha. When chemical control is performed in the spring and hoeing is carried out as required during the growing period the weed control costs have amounted to about 1 250 marks/ha.

Fallowing is an important method of combating weeds. Soil disinfection which was discussed in the previous chapter also destroys the seeds of weeds. During cultivation, chemicals are spread by broadcasting in the seeded areas or are sprayed between the rows. A spray for use between the rows has been constructed at Suonenjoki nursery. As it is placed before a tractor no separate control is necessary (Konttinen 1982b). To reduce the consumption of the pesticide and to prevent its entry into the soil, so-called electrostatic sprays have been studied in the USA. Their charged drops seek their way to plants (Farm . . . 1977, The Status . . . 1982).

Manual weeding, manual hoes and tractor-drawn hoes or cultivators are used for mechanical weed control. Manual weeding has been mechanized in the United States by constructing low weeding wagons. They are tractor-drawn or may have a motor of their own. The wagon travels above the seed beds at a speed that allows the workers time to pull out the weeds. The work is speedier and the working position better than in conventional manual weeding (Evans and Swartz 1977). Weeds are easier to pull out after rain or sprinkling (Williams and Hanks 1973).

Mechanical cultivators can be used in transplanting and drilling areas. The knives are generally driven from the tractor take-off or they are equipped with a separate motor. Biological cultivation presupposes continuous hoeing (Parviainen and Tervo 1980). Packing of soil associated with the soil "fatigue" phenomena may increase the need of cultivators. In England, J-shaped blades have been replaced by I-shaped blades in cultivators in order to prevent packing of the soil (Tervo 1978a). In addition to mechanized methods, the following may be used to substitute chemical control: heat (e.g. flame), electricity, radiation, microwaves or seed disinfectants (sawdust, chips, plastic, etc.) (The Status . . . 1982).

10. LIFTING OF SEEDLINGS

10.1. Manual lifting

Bare-root seedlings are still lifted mainly by hand. The seedling bed is cut by a tractor-mounted freeing device to facilitate lifting. The device has an under-cutting blade and blade-lengthening pieces which are moved by lever arms and which soften the soil. The power derives from the tractor take-off. The majority of the freeing devices are lifting-mechanism mounted. Use is made also of devices mounted under or on the side of the tractor (e.g. Rotty 1971).

The cutting depth must be correct in the freeing process. Cutting too near the surface in particular over-cuts the root and causes rejection of the seedlings. Moreover, seedlings tend to dry after being freed and freeing on the day preceding lifting cannot be recommended. It would be ideal to be able to lift the seedlings within two hours of their freeing (Williams and Hanks 1973). Care must be taken in freeing for manual lifting that roots are not left exposed to excessive drying, that is, that the vibration is not too intense (e.g. Lehto and Simolinna 1966).

The working position is poor in manual lifting and especially the freeing of large spruce seedlings from the soil is relatively strenuous work as shown by the tensile resistance measurements performed at Suonenjoki Research Station and the workers' heart rate values which appear from Tables 6 and 7 (Harstela and Tervo 1977).

Table 6. The average heart rate values of the test subjects in lifting 2O+2O spruce seedlings at Suonenjoki nursery

Taulukko 6. Koehenkilöiden keskimääräiset sydämen sykintäarvot kuusen 2A+2A taimien nostossa Suonenjoen taimitarhalla

Subject *Koehenkilö*	Method *Menetelmä*	Heart rate *Sydämen sykintä kertaa/min*
1	I	123
	II	120
2	I	128
	II	124

I = under cutting + vibration
alta leikkaus + tärytys

II = under and side cutting + vibration
alta ja sivulta leikkaus + tärytys

No great strength is needed to lift small seedlings and the workers' heart rate and work strain are relatively low (Harstela 1975). Heart rate does not, however, illustrate fully the negative aspects of the working position.

Several different working positions are used in manual lifting. Those seen in Figs. 21—23 are the most frequent. The soil is moist in both the spring and autumn, and in the spring it is also cold. When working in the kneeling position the worker has to wear protective clothing or separate knee protectors. The standing posture is least energy-consuming when the speed of movement is relatively great, but the strain on the back is also great. This position cannot be recommended at all for persons with back pain. The consumption of energy in work of lifting type is smaller in the squatting than in the upright position (Vos 1973). As local strain bears in this position on the lower limbs, a change in the working position from time to time will probably help. Kneeling on one knee can be used. The circulation in the legs is easily obstructed in the kneeling position. A special footstool was studied at Suonenjoki Research Station to this end. It showed that the stool must not be too high or the worker's back is subjected to strain because he is bent forward.

Table 7. Resistance of spruce seedlings to freeing at Suonenjoki nursery

Taulukko 7. Kuusen taimien irroitusvastukset Suonenjoen taimitarhalla.

Type of seedling *Taimilaji*	Under cutting + vibration *Alta leikkaus* + tärytys	Side and under cutting + vibration *Sivulta ja alta leikkaus + tärytys*
	resistance, kg/seedling *vastus, kg/taimi*	
1P + 2O *1M + 2A*	5,5	2,7
2O + 2O *2A + 2A*	7,3	2,7

P = plastic green house
M = muovihuone
O = open area
A = avomaa

Figs. 21—23. Various working positions in manual lifting
Kuvat 21–23. Erilaisia työasentoja käsinnostossa

Fig. 24. Footstool that reduced the strain on the legs in the kneeling position
Kuva 24. Polviasennossa jalkojen kuormittumista vähentävä jakkara

10.2. The cutting technique and its effect on lifting

To reduce the work strain and speed up the work in the lifting of spruce seedlings, a cutter was developed at Suonenjoki nursery which supplements under-cutting and vibration. The cutter cuts the seedlings free in the lateral direction from between the seedling rows. It was assumed that cutting would also speed up the planting of the seedlings as there would not be numerous long roots to hamper planting as when under-cutting alone is used.

Knife-like blades which were placed in an ordinary freeing device were used initially. The roots, however, tended to stick to the blades and the cutting result was poor. This was partly because the cutting device was hard to manipulate (Harstela and Tervo 1977).

The cutter without an under-cutting blade shown in Fig. 13 has been used for side-cutting. It embodies five coulters, diameter 500 mm and thickness 4 mm (number of rows is six). The cutting part of the coulter is sharpened on either side.

The cutting coulter was at first guided mechanically, later hydraulically, and this increased the adjustability of control. Depth adjustment was solely by the tractor lifting device which was found to be sufficient in the investigation conditions.

Several technical solutions can be used for controlling the cutting coulters. Solutions of this type which differ from the prototype are to be found in e.g. the models constructed by Suonenjoen Metalli Oy and Pekolampi nursery. Mechanical control is heavy to operate. Hydraulic control is easy to operate and it gives an accurate cutting result and an adequate flexibility of control.

Use has been made in the USA of the coulter cutter for cutting roots. The coulters have been rotated by hydraulic motor to achieve a better cutting result (Hitt 1971). The publication does not mention whether cutting was used in connection with lifting or for root pruning instead of transplanting. According to Ruha (1981), the J-blade cutter manufactured by Suonenjoen Metalli Oy has also been used for cutting the root systems of transplanted pine and spruce seedlings. Side- and under-cutting of the roots prior to lifting can be done to restrict the growth of the root system and at the same time to make it denser. Furthermore, cutting facilitates lifting and planting.

Fig. 25. The cutting result of a coulter cutter
Kuva 25. Kiekkoleikkurin leikkuujälki

As seen in Table 7 and later in Chapter 11, side-cutting of spruce seedlings reduces perceptibly the resistance to freeing and increases the productivity of the lifting work. However, it is advisable to perform the pruning for spring lifting in the autumn before the growth of the root system ceases and for autumn lifting a couple of weeks before lifting to give the wound surface time to heal to a scar and the seedlings to develop new root tips.

10.3. Mechanized lifting
Lifting machines

Belt-lifting machines have been used for a long time in Central Europe. Lifting machine makes in common use are e.g. CLIMAKS, FAMO, ROBOT, EGEDAL, PLANT LIFT (Brown 1971, Haller 1978), Parviainen and Tervo 1980). These lifting machines lift one row at a time. Several machines have a separate bundling device. Bundles of seedlings are transported to large sorting storages for sorting by size, counting and re-bundling.

According to Haller (1978), the following problems have been encountered in the use of these machines:

— the thickest seedlings are damaged when squeezed by the belts
— the bark of the seedlings may suffer damage owing to the different belt speeds
— operating disturbances occur in wet clayey soils.

In the experience of some users the FAMO lifting machine causes less damage to the seedlings than other belt-lifting machines as its belt runs over a large-rimmed wheel, whereas the belts are pressed between rolls in other machines (Tervo 1978a, Rahte 1980). The above belt-lifting machines are suitable only for relatively large seedlings and their productivity is limited by the fact that they generally lift only one seedling row at a time. Output in good conditions has been reported to be approx. 10 000 seedlings/h (Wood 1978).

The FOBRO-LIFTER with which the seedlings can be lifted by seedling beds was developed in Austria. Seedlings are freed by an under-cutting blade to which is added intensive vibration to shake off the substrate. The seedlings are then pressed between two moving rubber mats and lifted to the sorting level where they are sorted, counted, bundled and sacked. The machine incorporates as a separate additional device an automatic bundler. The labour requirement extra to the tractor operator is six persons. Eight persons in all can work on the machine; six of them sort and two sack. The average output has been reported to be 60 000—80 000 seedlings/day. If the seedlings are not sorted and counted, the machine is said to be capable of lifting 400 000 seedlings/day. The forepart of the FOBRO-LIFTER (under-cutting blade and vibration) can be detached and used as a separate unit for under-cutting and vibration for manual lifting (Haller 1978, Parviainen and Tervo 1980). Wet soil or many weeds cause operating difficulties (Lang 1980).

Several lifting machines of different models for bare-root plants are to be found in the USA. The Virginia Division of Forestry has developed a belt lifter which lifts eight rows at a time. Most machine solutions are based on introducing the seedlings between belts. The North Carolina Forest Service has modified the potato-harvesting machine to make it suitable also for the lifting of seedlings. The machines usually embody a packaging device. Packed seedlings are transported for further handling to specific storages (Hitt 1971, Williams and Hanks 1973).

The working principle of the Canadian GRAYCO lifting machine also resembles that of the potato-harvesting machine. It is possible to treat the seedlings in three ways after lifting and cleaning the root system:

— the seedlings are dropped onto the ground or into boxes in the rear of the machine
— the seedlings are dropped into a loading device operating on the side and it loads them into a trailer which travels alongside
— the seedlings are guided to the rear of the machine where there is a packaging unit

After each alternative the seedlings are sent on for further handling (McDonald 1976, Lowman and McLaren 1976).

The Rath & Enzensberger company in Austria has been developing a fully automated (sorting, counting, bundling, sacking) lifter. Sorting is based on an air current which moves small and light-weight seedlings to another belt which has an optical reader. This device controls the operation of the bundling implement. Operation of the machine presupposes cleaning of the base of the seedlings prior to lifting (Haller 1978). According to Lang (1980), this machine is not yet in functioning order.

A seedling lifter has been developed in Sweden by the Board of Forestry (Skogsstyrelse) in cooperation with Svenska Sockerbolaget company. It is a tractor-drawn belt machine which lifts five rows at a time. It is necessary prior to lifting to prepare the seedling bed with a tractor-mounted unter-cutting device. The seedlings must remain upright after under-cutting and vibration must consequently not be intensive. Four workers operate the machine: the tractor operator, the machine operator and two sackers. Seedlings in the substrate are taken by rows and placed between two belts that press against one another. When freed from between the belts the seedlings drop in a horizontal position onto another conveyor which moves them into sacks. The number of seedlings is counted on the basis of the distance covered by the machine and a seedling inventory is made before lifting. The output of the machine is stated to be 150 000—200 000 seedlings/day. The seedlings are sent unsorted to the terrain. The machine functions technically, but damages the seedlings somewhat (Bovinder 1980, Rikala and Tervo 1979).

A lifting machine for bare-root seedlings has been developed also in New Zealand. This belt lifter which lifts two rows at a time is self-propelling and requires that the seedlings are freed without vibration prior to lifting. The seedlings upright in the bed move up between rubberised belts and turn automatically into a horizontal position before packing. The seedlings drop into cardboard boxes. One worker is needed in packing to sort the seedlings. A box takes approx. 250 1A seedlings. The box is closed and moved to the "chute" down which it slides to the trailer behind the machine. Five persons are needed at the lifting machine and the trailer. From the trailer the boxes are moved to containers each of which takes 64 boxes. The containers can be stacked and are kept in cold storage where the air moisture content is high and the temperature +5 °C. Some of the containers are taken directly to the planting site. The containers and boxes are returned to the nursery and it is estimated that they can be used 5—6 times (Trewin 1976, Gårdh 1980). Output in the lifting of 1A seedlings is stated to be 57 000 seedlings/h. They are then sorted into the bed and the sorting cost has been 0,4 p/seedling. According to Trewin (1976), some problems still attach to the use of the machine. The belts which are suitable for the lifting of large seedlings are not eligible for small ones. They are not always able to pull the seedlings out of the soil and problems have been encountered in the cleaning of the roots. Belt lifters require under-cutting and/or side-cutting before lifting (e.g. Wilson 1977, Bovinder 1980).

In Finland The Foundation for Forest Tree Breeding has developed the prototype of the lifting machine, where calculation and bundling of seedlings have been automatized. In this machine the seedlings are lifted up by big plate. The working principle is the same as in the transplanting machine, but the opposite process is carried out (Pitkäniitty 1982).

Harter lifting machine

In the lifting machine (HARTER) for bare-root plants developed jointly by Suonenjoki Research Station and nursery the aim was a machine capable of lifting seedlings of different kinds and sizes so that its utilization will be the longest possible. It was desired moreover to hold capital costs to a minimum by keeping the structure simple. For good productivity the seedlings are lifted throughout the width of the seedling bed and a conveyor-belt like method of work is applied. The possibility of sorting and sacking was regarded as important.

The lifting machine is tractor-drawn. Its maximum length is about 7 m and it weighs approx. 2 000 kg. For prototype tests the following technical variables were made adjustable: blade position, position and speed of movement of the conveyor, intensity (speed and stroke length) of vibration. The measurements and dimensions of the human body and the working conditions (weather conditions etc.) were taken into consideration in establishing the dimensions of the machine (Tervo 1978b, Harstela and Tervo 1979, 1981).

The machine lifts a whole seedling bed at a time regardless of the number of seedling rows. The seedling bed is cut by an under-cutting knife at the desired depth. The first vibrator attached to the under-cutting knife

Fig. 26. HARTER lifting machine
Kuva 26. HARTER-nostokone

is immediately behind it. After undercutting, the seedlings and most of the substrate enter the slanting conveyor. This conveyor is at an angle of about 20°. Its length is about 320 cm. There may be 1—3 vibrators on the slanting conveyor for shaking the substrate off the seedlings. The appropriate vibration is achieved by adjusting the intensity of vibration (stroke length and speed of movement). The soil drops back to the bed. From the slanting conveyor the seedlings move on to the sorting level where sorters remove rejects and count the seedlings.

The size of the seedling bundle varies with the different tree species and the seedling size. Studies showed that pine seedling bundles consisted of 25 and spruce seedling bundles of 10 plants. If desired, the pine seedling bundles can also be tied with e.g. rubber bands. Tying of bundles of spruce seedlings is probably not necessary as the sack in itself is a sufficiently small unit (150—200 seedlings/sack) for forest regeneration purposes.

From six to eight sorters can work on the machine, depending on the size of the seedling material, and two sackers. According to experience gained during the study, as many as eight sorters may be justified for the lifting of pine seedlings (1P + 1O or 2O + 1O). It is practical to use six sorters for the lifting of spruce seedlings (1P + 2O or 2O + 2O) as there is then, because of the larger seedling size, much more material to be sorted at the sorting level than in the lifting of pine seedlings.

A separate narrow conveyor has now been constructed for the machine for made-up seedling bundles. It was assumed that this would facilitate and speed up sorting as it has sometimes been difficult to find space for the bundles at the sorting level. As the sacker can adjust the conveyor speed it is possible to reduce the pressure of work on the sackers or, alternatively, only one sacker is needed in the lifting of pine seedlings. The way the machine works can be seen in Fig. 27. There are no time studies yet on this version and the results reported in the following refer to machines which did not have the conveyor in question.

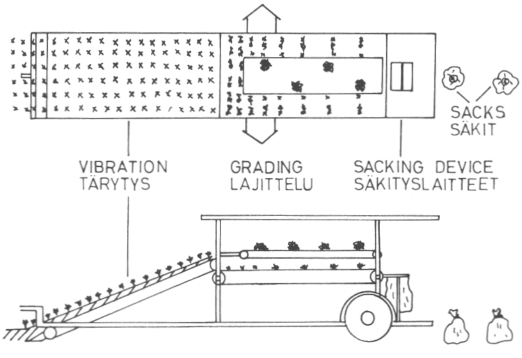

Fig. 27. Schematic presentation of the functioning of the HARTER lifting machine
Kuva 27. HARTER-nostokoneen toimintakaavio

Fig. 28. Loading of seedling sacks on the loading conveyor of Pekolampi nursery
Kuva 28. Taimisäkkien kuormausta Pekolammin taimitarhan kuormauskuljettimella

11. TIME STUDY RESULTS FOR LIFTING

11.1 Material and methods

The material was collected at the Suonenjoki nursery of the Finnish Forest Research Institute in 1979—1981 using a prototype machine and at Pekolampi nursery of the District Forestry Board of North Savo in 1980—1981 using a machine manufactured by Suonenjoen Metalli Oy on the basis of the prototype. The same test subjects were employed at both nurseries in both manual and mechanized lifting. In addition, material on the workers' heart rate was collected at Pekolampi nursery in the experiments of 1980. The size of the material appears from Table 8.

11.2 Sorting of seedlings and quality control

The seedlings were sorted in connection with lifting into those eligible and ineligible for regeneration purposes: the latter are called here rejects (Maa- ja metsätalousministeriön . . . 1979). The rejects were left on the substrate in manual lifting. In mechanized lifting they were placed in separate collecting bins. A part of the rejects fell onto the ground from the sorting level. They were also taken into account in quality control.

Sorting, the quality of the work, was examined in both manual and mechanized lifting. The quantities of eligible seedlings and rejects in the seedling sacks were recounted and for the rejects the causal factor was determined, e.g. under-sized and damaged. Eligible seedlings may also be mixed with rejects during sorting. Sample lots were taken to establish this point. The results of the sorting are presented in Tables 9 and 10.

The binomial t-test was used to test the results for 1981 for the significance of the difference in the counting error between manual lifting and mechanized lifting.

Sorting errors in the lifting of pine seedlings were slightly greater with one exception in mechanized than in manual lifting. The result was the reverse for the lifting of spruce. As spruce seedlings are larger they may rise up to the sorting level in better order and their sorting is therefore easier. The number of seedlings per sack was generally greater than the target quantity, but a smaller proportion than the target quantity was eligible for regeneration purposes. Sorting at nursery 2 was rather good in 1981 except that for pine a relatively large number of seedlings eligible for regeneration had been included among the rejects. Under-sized was the

Table 8. Volume of the material in time studies on the lifting of seedlings
Taulukko 8. Aineiston määrä taimien noston työntutkimuksessa

Lifting method *Nostotapa*	Tree species and seedling types *Puu- ja taimilaji*	Seedlings lifted *Nostettuja taimia* 1980	1981
Machine *Kone*	Pine-*Mänty*		
,,	2O+1O *2A+1A*	500 000	422 950
,,	2O+1O[1)] *2A+1A*	110 000	—
,,	2OPr *2AL*	22 000	—
,,	1P+1O *1M+1A*	54 200	219 600
,,	1P+1O[1)] *1M+1A*	—	8 200
	Spruce-*Kuusi*		
,,	2O+2O *2A+2A*	238 950	290 270
,,	1P+2O *1M+2A*	164 100	83 160
Manual *Käsin*	Pine-*Mänty*		
,,	2O+1O *2A+1A*	70 200	28 450
,,	1P+1O *1M+1A*	53 750	9 250
	Spruce-*Kuusi*		
,,	2O+2O *2A+2A*	75 750	20 900
,,	1P+2O *1M+2A*	9 625	12 225

Pr = pruned
L = *leikattu*
1) = grading before lifting in the bench
lajittelu penkkiin

commonest reason for rejection. There was no significant difference between the different lifting methods as regards damage to seedlings.

Sorting was carried out also before lifting onto the seed bed. The number of sacked seedlings eligible for regeneration was then 2 per cent less than the target quantity. The total of seedlings was exceeded by 1 per cent. The amount of sorting and counting errors did not differ essentially from sorting in connection with lifting.

Table 10 shows that eligible seedlings were mixed up with rejects. Sorting of spruce seedlings was relatively good in this respect. But for pine seedlings a relatively large number of eligible seedlings were included amongst the rejects. The results were contradictory for mechanized and manual lifting. If the seedling material contains many seedlings to be rejected it may affect the accuracy of sorting.

The seedling sacks accepted for regeneration were weighed. The results in Table 11 are seedling-specific values (weight of the seedling and the substrate in the root system).

The binomial t-test was used to test the 1981 results for the significance of the difference in the counting error between manual lifting and mechanized lifting.

The weights of the seedlings and the substrate adhering to them were greater at nursery 1 in manual than in mechanized lifting. The results were the reverse at nursery 2, on the other hand. The seedling sacks weighed more at nursery 2 than at nursery 1.

It is possible in mechanized lifting to adjust the shedding of the substrate from the root system through the intensity of vibration. In manual lifting, too, different workers shook the substrate off the root system in different ways. In the study conducted by Leikola and Raulo (1972), the total dry weight of pine 2O + 1O seedlings was 5,0 g on average and that of spruce 2O + 2O seedlings approx. 11 g. Rikala (1982) reported the green weight of a seedling to be 2—2,5 times its dry weight.

Table 9. Counting and sorting errors of seedlings to be used for forest regeneration
Taulukko 9. Metsitykseen menevien taimien laskenta- ja lajitteluvirheet

Lifting method *Nosto-tapa*	Nursery *Taimi-tarha*	Tree species *Puulaji*	Number of seedlings in one bundle *Metsityskelpoiset taimet* Difference from the target, % *Ero tavoitetaimimäärään, %-tavoitteesta* 1980	1981	Seedlings to be rejected, % *Raakkitaimien osuus, %* 1980	1981
Mechanized *Kone*	1	Pine *Mänty*	+5,8	—4,5 (3,7***)	10,7	8,2
Manual *Käsin*	1	” ”	—2,8	—3,4	6,0	3,5
Mechanized *Kone*	1	Spruce *Kuusi*	—3,4	—3,8 (1,8*)	4,6	4,7
Manual *Käsin*	1	” ”	—5,6	—5,1	5,7	7,0
Mechanized *Kone*	2	Pine *Mänty*	+0,6	+0,7 (4,2***)	0,9	1,5
Manual *Käsin*	2	” ”	+0,2	+0,2	1,7	0,5
Mechanized *Kone*	2	Spruce *Kuusi*	—2,2	+0,4 (9,6***)	6,5	4,1
Manual *Käsin*	2	” ”	—6,6	—2,0	7,9	3,9

( ) = t-value
( ) = t-arvo

Table 10. Distribution of rejected seedlings between those eligible and ineligible for regeneration
Taulukko 10. Hylättyjen taimien jakaantuminen metsityskelpoisiin ja metsityskelvottomiin

Lifting method *Nostotapa*	Nursery *Taimitarha*	Tree species *Puulaji*	Good seedlings *Metsityskelpoisia*		Must be rejected *Metsityskelvottomia*	
			Pieces/bed metre - *kpl/penkkimetri*			
			1980	1981	1980	1981
Mechanized *Kone*	1	Pine *Mänty*	9,9	3,3	17,0	17,1
Manual *Käsin*	1	,, ,,	1,2	7,4	16,9	42,1
Mechanized *Kone*	1	Spruce *Kuusi*	0,5	0,5	9,2	3,5
Manual *Käsin*	1	,, ,,	0,2	0,3	9,7	7,6
Mechanized *Kone*	2	Pine *Mänty*	0,1	4,9	4,6	3,9
Manual *Käsin*	2	,, ,,	2,3	3,8	5,5	2,3
Mechanized *Kone*	2	Spruce *Kuusi*	0,2	0,2	8,8	0,5
Manual *Käsin*	2	,, ,,	0,1	0,7	3,5	2,2

Hence, the weight of the substrate in the root systems of the seedlings exceeded the weight of the seedlings. More substrate is shaken off the root system when the seedling sacks are being handled so that the situation is another in the planting phase. The differences between nurseries as regards the weight of the seedling sacks are probably due in the main to different substrates.

11.3 Output of lifting work

Sorting in connection with lifting

The per-hour outputs in lifting were calculated per hour of operation. The operating time of machine work includes effective working time, changing beds (bed length 200 m), marking and tying of the sacks and 10 per cent as the share of interruptions in effective working time. In manual lifting the share of interruptions was considered to be 5 per cent of effective working time.

Table 12 shows the per-hour outputs. The output of the machine is divided by the number of workers. The output in manual lifting is the average output of the workers.

Table 11. Weight of the seedlings and the substrate in the root system in manual and mechanized lifting
Taulukko 11. Taimien paino ja juuristoon sitoutunut kasvualusta mukaan luettuna käsin- ja konenostossa.

Lifting method *Nostotapa*	Nursery *Taimitarha*	Tree species *Puulaji*	Total weight g/seedling *Kokonaispaino, g/taimi*	
			1980	1981
Mechanized *Kone*	1	Pine *Mänty*	26,2	24,2 (0,824)
Manual *Käsin*	1	,, ,,	36,4	27,8
Mechanized *Kone*	1	Spruce *Kuusi*	—	56,0 (1,981*)
Manual *Käsin*	1	,, ,,	—	64,5
Mechanized *Kone*	2	Pine *Mänty*	33,0	38,2 (0,969)
Manual *Käsin*	2	,, ,,	26,4	46,5
Mechanized *Kone*	2	Spruce *Kuusi*	149,8	99,4(-4,315**)
Manual *Käsin*	2	,, ,,	160,3	74,4

( ) = t-value
( ) = t-arvo

The worker's average output at nursery 1 as the mean of both years in the mechanized lifting of spruce seedlings was approx. 5 per cent greater than in manual lifting and in the lifting of pine seedlings approx. 30 per

Table 12. Outputs per operating hour in lifting
Taulukko 12. Noston käyttötuntituotokset

seedlings/worker/h — *kpl/työntekijä/h*	1980 Mechanized *Kone*	1980 Manual *Käsin*	1981 Mechanized *Kone*	1981 Manual *Käsin*
Nursery 1. — *Taimitarha 1.*				
Pine *Mänty*				
2O+1O *2A+1A*	1152	963	—	—
1P+1O *1M+1A*	—	—	1177	825
Spruce *Kuusi*				
1P+2O 1M+2A	867	904	955	837
Nursery 2. — *Taimitarha 2.*				
Pine *Mänty*				
2O+1O *2A+1A*	1607	1787	1268	1727
2O+1O *2A+1A*	—	—	1240 2)	1394 2)
1P+1O *1M+1A*	2173	1801	—	—
Spruce *Kuusi*				
2O+2O *2A+2A*	1431	1535 (1366) 1)	1169 2)	1133 2)

1) no side cutting
ei sivulta leikkausta
2) workers have no experience on nursery work (students)
työntekijät taimitarhatyöhön tottumattomia (opiskelijoita)

cent greater than in manual lifting. The result for 1981 at nursery 1 was influenced by the smaller number of rejected seedlings in mechanized than manual lifting. According to the result for 1980, the difference in the lifting result of pine seedlings was 20 per cent in favour of mechanized lifting.

At nursery 2 the output of mechanized lifting of 1P+1O seedlings in 1980 was an average of about 5 per cent greater than in manual lifting. In contrast, judging by the results for 1981, the manual lifting result for pine was distinctly greater than the mechanized. There was an abundance of weeds in the pine cultivation area in this case, especially couch grass. This hampered mechanized lifting considerably more than manual lifting. Weeds prevented the sorting mat from moving evenly. Mechanized lifting, however, had the advantage that weeds were easier to remove after it from the cultivation area than after manual weeding as the machine lifts them out of the soil and leaves them in heaps. The manual lifting result of persons familiar with nursery work was greater in the lifting of spruce seedlings than the mechanized lifting result. The seedlings were then cut also from between the rows. The output of persons not familiar with the work showed a small difference in favour of mechanized lifting of spruce seedlings.

The size of the work team in mechanical lifting was also studied. In the lifting of pine seedlings in customary conditions (no profuse weeds) it was better to use eight rather than six sorters. When eight sorters were used, three sackers were employed, versus two sackers for six sorters. According to the breakdown of working time, sacking could be managed by two persons also when eight sorters were at work, especially as a new conveyor for made-up bundles has been installed in the machine. The per-worker output would then rise to about 10 per cent. The manual lifting output for side-cut spruce seedlings was 11 per cent greater than that for uncut seedlings.

The seedling yields at nurseries 1 and 2 in 1981 were as follows:

	At nursery 1 Machine	At nursery 1 By hand	At nursery 2 Machine	At nursery 2 By hand
	yield, units/metre of bed			
pine	67,4	62,7	101,5	100,6
spruce	61,6	67,2	109,9	

The seedling yield was considerably better at nursery 2 than nursery 1 and this explains in part the difference in the productivity of lifting at nurseries. At nursery 2 the seedling bed had five rows, whereas at nursery 1 there were six rows. This accentuates the magnitude of the difference. Special attention is drawn to the high spruce yield (109,9 seedlings/metre of bed). According to Mäkelä (1982), the total yield was 107,7 seedlings/metre of bed. This assumes a seedling spacing of about 4 cm in transplanting.

The per-hour output of workers on different sides of the sorting level in mechanized lifting was observed. The following table shows the output in relative values when the output of the "slower" side is denoted by 100.

spruce	100	124
pine		
— experienced workers	100	141
— inexperienced workers	100	107
— working team a combination of the above	100	121

The output difference between the different sides is due to the lateral slope of the ground. Seedlings tend to move on the slanting conveyor in accordance with the slope to the other edge. Because of this a greater number of seedlings come within reach of the sorters on one side than the other. The result is affected primarily, however, by the work of the first sorter. To achieve a good working result every sorter should have a steady supply of seedlings. Yet, to avoid unnecessary shifting of the seedlings at the sorting level there should not be too many.

Relatively much time was expended at nursery 1 on waiting for seedlings and removal of rejects. This accounts for the productivity difference between the nurseries and shows how important it is to adjust the tractor moving speed to the sorters' work.

At nursery 2 in the lifting of pine seedlings sorters counted a certain number of seedlings into a bundle and tied it with a rubber band. The tied bundle was placed in the middle of the sorting belt which took it on to the sackers. Initially, a method was tried in which the sackers tied the bundles. This was abandoned because of the risk of the seedling bundles becoming undone. The sackers also found it difficult in some cases to observe the number of bundles.

The bundles were not tied in the lifting of spruce seedlings but counted into 10-seedling "bundles" which were placed in the middle of the sorting belt which moved them on to the sackers. Sorter 2 or 3 sometimes handled again a bundle made by sorter 1. That the bundles were untied required special attention by the sackers. On the basis of experience gained a supplementary conveyor was constructed for the lifting machine to facilitate the handling of sorted bundles.

The results showed a difference in the expenditure of time by individual workers at the same work site. Work sites were changed several times in the course of the study. These circumstances support the reliability of the results. All members of the working team affect the output in mechanized lifting, including the tractor operator. The seedlings should rise to the transport level in an even stream. All sorters should have sufficient seedling material for sorting. The amount of working time spent on waiting for seedlings ought generally to be shorter. The workers at the 1-places of the sorting level and above all an experienced tractor operator can contribute significantly to this.

Rejects were removed before lifting from some seedling beds. This was done manually without any implements. The rejected seedlings were collected into a sack. Sorting before lifting was experimented with only for pine seedlings. The sorter advanced at 14—52 m/h. When the speed rose to 52 m/h there were 17,7 rejects per metre of bed. The seedling yield was then 84,2 seedlings per metre. When the rate of advance was 14 m/h the number of rejects was 42,3 seedlings/metre of bed. The last-mentioned conditions were exceptional.

The per-worker lifting output for seedlings sorted prior to lifting in mechanized lifting was an average of 332 seedlings/h greater than in mechanized lifting in which sorting took place in connection with lifting.

Sorting at the storage

The lifting of seedlings for storage sorting was also studied with the HARTER lifting machine. The seedlings were lifted without sorting into sacks. The sacks were taken unclosed immediately after lifting to the storage sorting site. Seedlings were sorted on a moving rubber mat and the situation thus corresponded to sorting during lifting.

The output per working hour without sponded to sorting during lifting.

The output per working hour without sorting in the lifting of pine seedlings when the yield was 100 seedlings/metre of bed was as follows:

- — 2 + 2 person working team 48 000 seedlings/h
- — 0 + 2 person working team 28 000—30 000 seedlings/h

In a team of four persons two placed the seedlings on the sorting level and two were engaged in sacking. The best output per operating hour for this team was 58 000 seedlings. In this case the 2-person team encountered difficulties in sacking the seedlings. An operating hour output of nearly 60 000 would obviously be possible as a longer-term job, but would require one additional person for the sacking. Seedlings can also be packed in boxes for storage sorting. The labour requirement could then be smaller than when sacks are used.

The output per operating hour per person in storage sorting was 1 063 seedlings. It was approx. 100 seedlings/worker smaller than in sorting during lifting. When seedlings were lifted directly into a sack or box their arrangement was not good. The more frequently seedlings have to be shifted, the more their arrangement suffers. This hampers sorting. In addition, the risk of drying is greater for seedlings in storage sorting than in sorting performed directly in conjunction with lifting.

11.4 Eligibility of seedlings for forest regeneration

The effect of the mode of lifting on the later development of the seedlings was studied by establishing fairly small (approx. 100 seedlings/method of lifting) planting experiments in limit conditions in sandy soil. According to plant experiment 1, the survival rate of pine seedlings was 79 per cent for manually lifted seedlings, 93 per cent for machine-lifted and 92 per cent for plants lifted mechanically and sorted at storage. According to the U-test of MANN-WHITNEY, the difference in survival between manually and mechanically lifted seedlings was significant. In experiment 2 the survival rate of both manually and mechanically lifted seedlings was 100 per cent after two growing seasons. In experiment 3 manually lifted seedlings survived better than mechanically lifted. There was in this experiment a period of several weeks of cold storage after lifting and before planting. The share of viable seedlings in a pine seedling planting experiment was only 31 per cent for manually lifted and only 9 per cent for mechanically lifted specimens.

The height growth and base diameter of seedlings were measured in autumn 1981. The results of experiment 1 (pine) were as follows:

	height growth cm	SD	base diameter mm	SD
manual lifting	21,9	8,6	13,1	2,9
mechanized lifting	18,8	6,4	12,7	2,3
mechanized lifting + sorting at storage	19,3	5,9	13,2	2,2

The results of experiment 2 (spruce) were:

	height growth cm	SD	base diameter mm	SD
manual lifting	8,9	3,3	9,3	2,7
mechanized lifting	8,2	2,2	8,7	2,1

SD = standard deviation

The height growth of manually lifted seedlings was slightly greater than that of machine-lifted seedlings. The base diameters were of the same magnitude in the different methods. According to the t-test, the differences between the methods of treatment were not significant.

11.5 Physical strain in lifting work

Material was collected at nursery 2 in 1980 also in the workers' heart rate in lifting. Table 13 gives the results for the heart rate of five test subjects when lifting seedlings.

The heart rate in manual lifting of pine seedlings was at the same level as reported by Harstela (1975) for the lifting of pine transplanting seedlings. The heart rate was of the same magnitude in the manual lifting of spruce seedlings as reported by Harstela and Tervo (1977).

There is no significant difference in the strain of lifting pine seedlings as indicated by heart rate between manual and mechanized lifting. However, it must be noted that heart rate illustrates poorly the strain of the working position on the skeletal system. Mechanized lifting is in this respect probably less straining than manual lifting also in lifting pine seedlings. In contrast, the resistance of the seedling to being pulled out of the soil is great for spruce seedlings (Harstela and Tervo 1977). The heart rate of all the test subjects was distinctly lower

Table 13. Heart rate of test subjects in the lifting of seedlings
Taulukko 13. Koehenkilöiden sydämen sykintä taimien nostossa

Tree species and lifting method *Puulaji ja nostotapa*	Test subject — *Koehenkilö* 1	2	3	4	5		s	Difference *Erotus*
	Heart rate — *Sydämen sykintä, kertaa min.*							
Pine - *Mänty*								
— manual - *käsin*	97,9	98,0	92,5	92,0	99,0	95,9	3,3	
— mechanized - *kone*	100,7	86,7	90,8	97,5	95,4	94,2	5,5	1,7
Spruce - *Kuusi*								
— manual - *käsin*	115,6	112,6	102,3	116,0	113,6	112,0	5,6	
— manual[1)] - *käsin*[1)]	—	116,4	117,7	112,8	107,6	113,6	4,5	1,6
— mechanized - *kone*	98,0	92,4	88,0	91,0	91,9	92,3	3,6	21,3**

1) Roots side cutted
Juurten leikkaus sivulta

in mechanized than in manual lifting. The differences are significant according to the U-test of MANN-WHITNEY. The results indicate that the strain of mechanized work was of the same level in lifting different tree species. The heart rate was slightly higher on average in the manual lifting of side-cut spruce seedlings than in that of uncut plants, but the difference is not significant. It was assumed that the difference would have been discernible, but the result may have been affected by the productivity of lifting work which was approx. 11 per cent greater in lifting side-cut than uncut seedlings.

The variables associated with the ergonomics of mechanized lifting that were measured were the noise level of the machine and the vertical acceleration of the vibration affecting the legs. The noise level (A level) of the machine was as given in the schedule below.

	Nursery 1 v	o	Nursery 2 v	o
	noise level, dB			
first sorter	80	80	86	87
second sorter	77	78	81	85
third sorter	76	77	80	81
sacker		73		79

v = left side o = right side

The noise level of the prototype machine of nursery 1 had risen since the measurements made in 1979 by 3 dB for the first sorter and by 8—9 dB for the third sorter. This was probably due to the wear on the mobile parts of the machine, e.g. the vibrators. The noise level of the machine at nursery 2 was higher. The reason was the supplementary vibrators installed afterwards. Working on the machine calls for the use of ear protectors by at any rate the first sorter. A part of the noise was caused by the tractor, the prime source of power. A noise level of 98 dB was measured outside the cabin at the middle of the tractor at nursery 1.

When the substrate was dry dust difficulties arose in mechanized lifting, especially in windy weather, and thus the use of eye protectors is recommended.

According to ISO standards, vibration of the machine did not exceed the limit of fatigue and reduced working efficiency. The lighting conditions were good at Suonenjoki nursery in the machine covered with plastic.

11.6 Lifting costs

The bases of cost calculation in mechanized lifting when using the HARTER machine were:

	Sorting in connection with lifting	Storage sorting
machine purchase price, marks	85 000	55 000+25 000
amortization time, a	10	10
interest, %	10	10
residual value of purchase price, %	10	10
maintenance and repairs marks/a	2 000	2 000

65,00 marks/h was taken as the per-hour cost of the tractor and its operator,

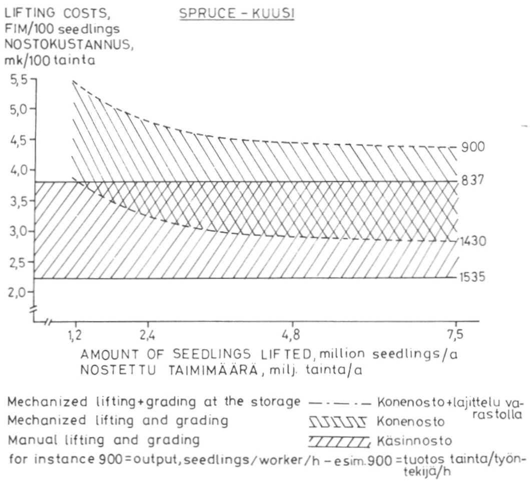

Fig. 29. Cost of lifting pine seedlings
Kuva 29. Männyn taimien nostokustannus

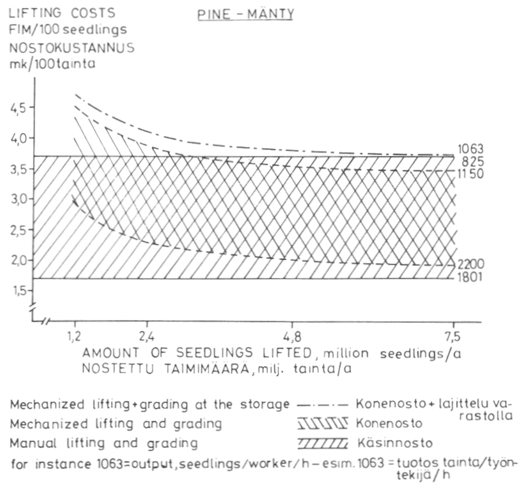

Fig. 30. Cost of lifting spruce seedlings
Kuva 30. Kuusen taimien nostokustannus

29,40 marks (incl. social security outlays) as that of the workers. The cost calculation for the mechanized lifting work schedule for storage sorting assumed a per-hour output of 30 000 seedlings and two workers in lifting by machine. The worker/hour output in sorting was 1 063 seedlings. The cost of transporting the seedlings to the storage sorting site was 0,3 p/seedling. The costs are shown in Figs. 29 and 30.

The manual lifting outputs varied by worker from 825 to 1 801 units/h in the lifting of pine seedlings and from 837 to 1 535 units/h in the lifting of spruce seedlings.

The cost of manual lifting of pine seedlings was 1,7—3,7 p/seedling and that of spruce seedlings 2,2—3,8 p/seedling. Side-cutting lowered the manual lifting costs of spruce seedlings by 0,3 p/seedling, but the root-cutting cost was approx. 0,2 p/seedling. It is necessary for manual lifting to free the substrate with a tractor-mounted under-cutting and vibration device. The cost of this work phase was 0,1 p/seedling.

Manual lifting costs for spruce seedlings were lower on average than those for mechanized lifting. The share of direct machine costs in mechanized lifting was relatively large. This proportion decreases, however, when the amount of seedlings to be lifted annually grows (Fig. 31). Costs in the lifting of pine seedlings were of the same magnitude for an annual lifting quantity of

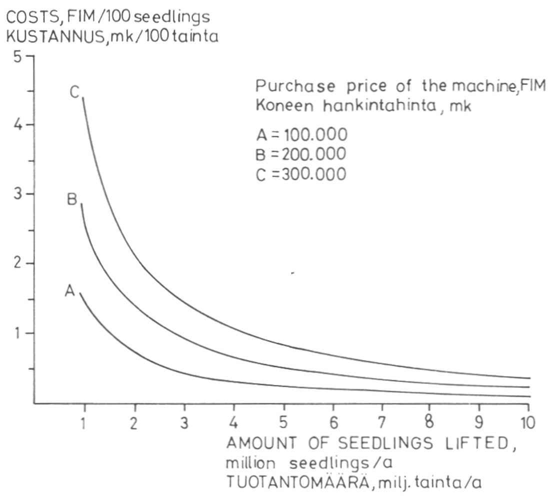

Fig. 31. Capital costs of variously priced lifting machines
Kuva 31. Erihintaisten nostokoneiden pääomakustannukset

approx. 4 million seedlings. However, it must be noted that the machine in question is under development.

Lifting of seedlings by machine and sorting at the storage was the most expensive of the alternatives employed. The pine seedling lifting and sorting costs were about 0,3 p/seedling higher than those for sorting performed by the same team of workers during mechanized lifting.

The effect of incorrectly sorted seedlings on the total costs of production was relatively great. If the sale price of a seedling is 25 p and 2 per cent of seedlings eligible for regeneration get mixed up with the rejects, the additional cost is 0,5 p/seedling.

Several variously priced seedling lifting machines are on the market. The purchase price of a belt-lifting machine which lifts several rows at a time is 200 000—300 000 marks. Fig. 31 shows the capital costs of machines of various prices when the amortization time is 10 years, interest 10 per cent and residual value 20 per cent of the purchase price.

The calculation does not take into consideration repair and maintenance costs which may be greater for an expensive machine than for a cheaper one owing to the more complex construction.

The share of capital costs decreases relatively steeply at first when the number of seedlings to be lifted rises. Capital costs (amortization and interest) are approx. 0,9 p/ seedling when the number of seedlings lifted annually is 5 million and the purchase price of the machine employed for the work is 300 000 marks. Capital costs are then 30—40 per cent of the costs of manual lifting. If the productivity of the machine and the degree of automation are relatively high, and hence the need of human labour is small, mechanized lifting may be cost competitive with manual lifting combined with e.g. sorting in the bed. This probably presupposes automation of the counting and bundling of seedlings.

The costs of sorting before lifting are affected by the number of rejected seedlings. The costs of sorting in the bed in the conditions of the study were 0,7 p/seedling. The sorting costs may be at a considerably lower level in favourable conditions, as is shown by studies carried out in New Zealand (Trewin 1976).

The mechanized lifting output per worker rose in sorting in the bed to about 330 seedlings/worker/hour. This lowered the lifting costs by 0,8 p/seedling when the per-hour output in lifting-cum-sorting was 1 150 seedlings/worker and by 0,2 p/seedling when it was 2 200 seedlings. Sorting in the bed is profitable when the number of seedlings rejected is small or when the average lifting output of the nursery is low.

12. OTHER JOBS AND OTHER STANDPOINTS

The production of seedlings includes many other jobs, one of which is preparing the soil. For instance, the use of soil improvement materials, fallowing and the "cropping system with rotation" in the form of green manuring may gain increasing importance as "fatigue" of the soil has been observed at nurseries that have been in use for a long time. Technology developed chiefly for farming or horticulture is employed in these jobs.

Transplanting seedlings are grown to some extent in plastic greenhouses. Although the optimal temperature for seedling growth is lower, the temperature in plastic greenhouses may rise to over 30 °C. As the relative humidity of the air is high, the worker is exposed to a considerable heat strain. According to Axelson (1974), the productivity of work is lowered in the following manner as a function of effective temperature (T) if the air movement is 0,5 m/s:

Effective temperature, °C	Productivity of work
25	100
27	95
29	91
31	75

Workers in plastic greenhouses must be allowed under the current collective agreement a 5-min. break outdoors at intervals of 30 min. Most interviewees in field have stated heat and humidity to hamper working in plastic greenhouses. Some interviewees have complained of fatigue, respiratory difficulties and headache (Harstela 1977).

Special caution must be observed in the handling of pesticides in plastic greenhouses. Considerable pesticide concentrations have been recorded in the air of plastic greenhouses as late as three days after spraying, in spite of airing. Exposure to pesticides has otherwise been small at seedling nurseries (Kangas 1979, Kangas et al. 1980). Factors such as heat, moisture and ventilation, which affect the disintegration of pesticides, contribute to the pesticide content of plastic greenhouses. Pesticide spraying should not be performed in sunny weather or at the same concentrations as are used outdoors.

Storage is an important phase for the physiological condition of seedlings and their eligibility for forest regeneration. Seedlings are mostly packed in plastic sacks in Finland. Studies suggest that a paper sack would be best for the condition of the seedlings, but its poor durability in transport constitutes a problem. The temperature is lower in a sack that is black inside and white on the surface than in a sack that is white on both sides (Kauppi and Hari 1980).

Birds cause considerable damage to seeded areas. The harmful effects of birds have been encountered in both plastic greenhouses and in the open (Kostamo 1981, Nuutinen 1981). It proved necessary at English seedling nurseries to protect seeded areas with netting to prevent damage by birds (Tervo 1978 a).

Protection of large outdoor seeded areas in expensive. Birds can get used to intimidating devices (e.g. implements that give a loud report at fixed intervals) and their effect is thus small. Many nurseries have in fact organized guard duty during the germination period of the seeded areas. Gallinaceous birds have done significant damage also in transplanting areas by eating terminal buds.

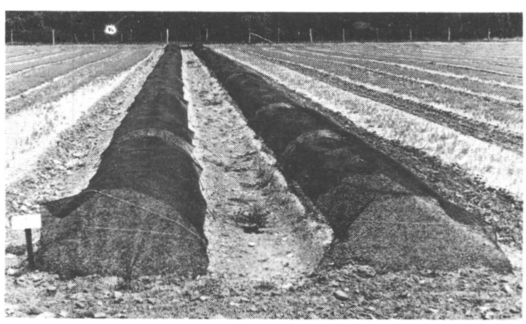

Fig. 32. Seed bed protected with netting
Kuva 32. Verkolla suojattu kylvöpenkki

13. COST COMPARISON OF PRODUCTION SCHEDULES

Cost calculations were made in the foregoing for alternative methods of work for each job. Their advantages are often decided by conditions and production quantities. Two principal production schedules compete in the production of bare-root pine seedlings: transplanted seedling and root pruned seedling which are roughly equal as regards eligibility for forest regeneration (Parviainen 1980). A cost comparison is made in the following between these seedling types. The comparison is based partly on the cost appraisal of nurseries, partly on time study results, but also on the following assumptions.

The procurement and clearing cost of nursery land (clearing and other preparation costs) was assumed to be 10 000 marks/ha. No amortization was calculated, but 5 per cent was used as the annual interest (cf. Hyvärinen 1980). Capital costs and overheads were calculated to be in other respects the same per seedling for the different types of seedling as it was assumed that the same buildings, machines and work supervision would be needed for the production of a certain quantity of seedlings by the different methods. The yield of broadcast sowing in the open was put at 4,2 million seedlings/ha for the total area. The yield of the transplanting area, correspondingly, was taken to be 0,5 million seedlings/ha, the yield of 2O pruned seedlings 1,2 million seedlings/ha and that of 3O cut plants 1 million seedlings/ha. The transplanting cost was calculated for an annual production of 5 million seedlings using a 15-place transplanting machine. The cost of root-cutting was calculated for a corresponding production quantity. The lifting costs were based on manual lifting.

The production costs at the 1981 price level are as follows:

	Transplanted 2O + 1O	Pruned 2O	Pruned 3O
		p/seedling	
Preparation of soil, sowing and tending during the first two growing seasons	2,5	2,8	3,2
Lifting and transplanting	2,5	– –	– –
Pruning of roots	– –	0,2	0,4
Tending of seedlings during the third growing season, payroll expenses incl. social security costs	1,7	– –	1,9
Lifting, sorting, packing, storing and dispatching of seedlings	2,7	3,2	3,2
Capital costs of nursery ground during the growing period	0,2	0,2	0,3
Other capital costs, overheads and supplies	13,6	13,6	13,6
	23,2	20,0	22,0

If a denser plant association than the one taken here is used in drilling, the costs of cultivation of cut seedlings decrease slightly but the eligibility of the seedlings for regeneration decreases at the same time in that the base diameter of the seedling diminishes (Parviainen 1980). If a denser plant association is used in drilling by, for instance, reducing the spacing of the rows, it is probably possible to reduce the row spacing also in transplanting in which case the cost ratio between these seedling types will probably remain as shown by the calculation. Seedling cultivation costs vary, of course, with the conditions, and the above calculation does not represent average conditions but simply serves as an example.

14. DISCUSSION

According to the study, no great cost savings can be achieved by developing the production of bare-root plants. On the other hand, cost savings can be effected in several jobs. For instance, through side-cutting in the lifting of spruce seedlings, by adopting 15-place machines in transplanting, through dense row spacing in transplanting and drilling, etc. The greatest cost saving would, however, be achieved by changing from transplanted to pruned seedlings which is in a way a new seedling type in our country. It would appear that cost savings could be achieved also by labour management measures. One such savings target would be more careful sorting during lifting as relatively numerous good seedlings have been mixed up with rejected seedlings, especially in the lifting of pine seedlings.

On the other hand, no great cost savings can be expected in the production of containerised seedlings as the production line is already fairly extensively mechanized. As can be seen in Fig. 33, the maximum sale prices of bare-root and container seedlings have developed relatively equally rapidly in recent years, those of container seedlings even faster in the most recent years. Hence, the price competitiveness of bare-root seedlings will probably remain unchanged. According to one study, payroll costs were 50 per cent in the production of 2O + 1O pine seedlings. The corresponding costs in the production of pine FH-408 seedlings were 46 per cent. If wage costs and the materials costs of container seedlings are assumed to rise in the next five-year period by as much as during the previous five years and other costs to grow similarly and relatively as much as for both seedling types, the result will be that the price of bare-root seedlings will rise by less than 1 per cent unit faster than the price of container seedlings.

However, the profitability of seedling types must be assessed in the light of the benefits and costs of the whole forest regeneration schedule. As there will probably be no great differences in the price development of bare-root and container seedlings in the next few years, other factors associated with forest regeneration may decide the development of demand for types of seedlings.

Nor have studies revealed factors associated with technical progress that decrease the eligibility of seedlings for forest regeneration, unless the hook-shaped roots caused by transplanting are regarded as such. This, too, can probably be decreased by technical development. The cutting of roots has not been observed to cause a significant risk of fungal disease to the root system, especially if there is peat in the substrate (Petäistö 1982). The cutting of roots can, on the other hand, direct the root-shoot relations of seedlings and the shape of roots and this

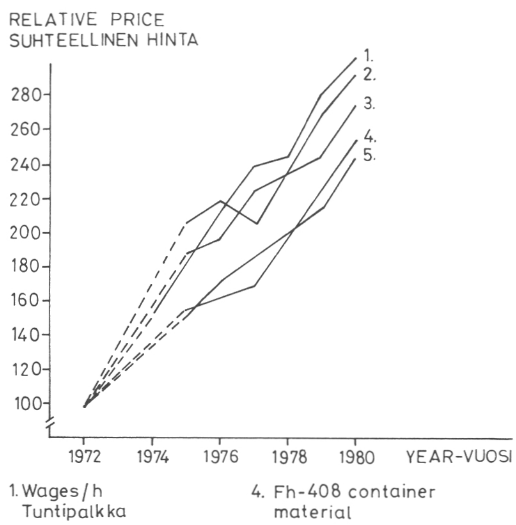

Fig. 33. Development of the prices of seedlings and container materials and of wages
Kuva 33. Taimien ja paakkumateriaalin hintojen sekä työpalkkojen kehitys

may be of great advantage in planting. Decreasing the row spacing is perhaps possible in transplanting, especially in the cultivation of pine seedlings. Biologically significant advantages can be achieved by the cutting of roots, even for transplanted seedlings.

Shortage of labour has been regarded as a factor that limits seedling production. Production of bare-root plants is more labour intensive than that of containerised seedlings. According to the present study, it is possible to reduce the need of human labour somewhat by means of mechanization and other rationalization measures in lifting work and by changing from a transplanted to a pruned seedling. Mechanized lifting makes it possible also to employ young, old or handicapped workers (e.g. persons with mild back trouble) in lifting. Two prototypes of the HARTER lifting machine were constructed. One of them did not do well and the result was a great many interruptions. This was due to different technical constructions compared with the first prototype. As the first prototype has lasted relatively well, it will evidently be possible to make the machine type operationally reliable.

In addition, it will be possible to improve the ergonomics and thus job satisfaction. Nursery machines (e.g. the seats) have not always been designed for the ergonomic optimum. Straining of workers can be reduced also by organizing the work and using various aids.

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SELOSTE

Paljasjuuristen taimien tuotannon teknologia

Tutkimuksessa käsitellään paljasjuuristen taimien tuotannon teknologiaa ja sen kehittämismahdollisuuksia. Teknologisia muuttujia tarkastellaan taloudellisten, biologisten, työvoimapoliittisten ja ergonomisten kriteerien avulla. Vaikka tarkastelu on kokonaisvaltainen, on juurten leikkuuta ja taimien nostoa tarkasteltu muita asioita laajemmin ja niistä on kerätty myös muita töitä enemmän empiiristä aineistoa. Tämä johtui siitä, että nämä työt aiheuttavat suurimmat kustannukset, suurimman työvoimatarpeen ja useimmat ergonomiset ongelmat paljasjuuristen taimien tuotannossa.

Taimien tuotannon kehittämisen perusteet on jaettu seuraavasti:

1. Biologiset kriteerit, joista tärkein lienee taimien metsänviljelykelpoisuus. Se vaikuttaa erittäin voimakkaasti myös toiminnan taloudellisuuteen silloin, kun tarkastellaan koko metsänviljelyketjua.
2. Taloudelliset kriteerit, joita ovat muun muassa taimien tuotantokustannukset ja panos-tuotos-suhteet. Tässä tutkimuksessa tarkastellaan lähinnä tuotantokustannuksia.
3. Työvoimakriteerit, joita ovat työvoiman tarve, työn kausiluonteisuus ja työn tuottavuus.
4. Ergonomiset kriteerit, joista käsitellään työn kuormittavuutta ja työviihtyvyyttä. Näillä tekijöillä lienee vaikutusta työvoiman tarjontaan ja alalla pysyvyyteen.

Paljasjuuristen taimien tuotannossa palkkojen osuus on 50,6 % (Hyvärinen 1979). Näistä koulinnan osuus 24,5—34,8 % ja taimien noston, pakkauksen, talvivarastoinnin ja lähetyksen 17,1—22,7 % (Hyvärinen 1979, Konttinen suull. 1982, Mäkelä suull. 1982).

Taimien fysiologinen kunto, terveydentila, vaurioitumattomuus ja muut metsänviljelykelpoisuuteen vaikuttavat tekijät (esim. juuri-verso-suhde) ovat usein sidoksissa eri kasvatusvaiheissa käytettävään teknologiaan. Esim. hidas tai monessa vaiheessa tehty nosto ja taimien muu käsittely voi saada taimet alttiiksi kuivumiselle. Torjunta-aineiden levityksen tasaisuus ja kohdistuminen voivat vaikuttaa torjunnan onnistumiseen. Taimia voidaan mekaanisesti vaurioittaa monissa hoito- ja käsittelyvaiheissa. Juuriston laajuuteen voi vaikuttaa leikkauslaitteiden tarkkuus ja muotoon koulintatekniikka. Usein kuitenkin nämä seikat riippuvat myös työn huolellisuudesta, työnjohdon suorittamasta valvonnasta ja töiden järjestelystä (esim. kuinka nopeasti taimisäkit kuljetetaan varastoon).

Paljasjuuristen taimien tuotannossa työvoimantarve on hyvin epätasaista ja epätasaisempaa kuin paakkutaimien tuotannossa. Kuvassa 1 on esitetty kolmen taimitarhan työvoimantarve. Siinä paljasjuurisia taimia tuottavalla taimitarhalla on voimakas työvoimahuippu keväällä, jonka pääasiassa aiheuttaa taimien nosto ja lähetys, mutta jossain määrin myös koulinta. Se, että eräillä alueilla työvoimasta esiintyy niukkuutta ja lyhytaikainen työvoimahuippu pakottaa käyttämään ammattitaidotonta työvoimaa, puoltaa nosto- ja koulintatyön kehittämistä työn tuottavuutta lisäävästi.

Kolmella taimitarhalla suoritetun haastattelututkimuksen mukaan seuraavat tekijät aiheuttivat eniten työtyytymättömyyttä tai kuvasivat työn luonnetta (Harstela 1977):

— selkä joutuu kovalle koetukselle ja työ on raskasta (huonot työasennot)
— työn kausiluonteisuus
— alttiina olo sääolosuhteille
— työsuhteen tilapäisyys

Kylvötekniikasta on vähän varsinaisia tutkimustuloksia. Julkaisussa käsitellään sekä haja- että rivikylvöä. Kylvösten peittämisellä saavutetaan joitakin etuja mm. estetään kastelun ja sateiden aiheuttama siementen liikkuminen. Taulukossa 1 on esitetty hietakerroksen syvyyden vaikutus siementen itämiseen Heikinheimon (1940) tutkimuksen mukaan.

Yleisesti käytössä olevat kylvökoneet on esitelty sekä erääseen niistä tehdyt muutokset kylvötarkkuuden parantamiseksi. Taulukossa 2 on esitetty kolon koon vaikutus siemenmäärään TUME-MONO kylvökoneella kokolajitellulla (2,0—2,3 mm) siemenellä. Rivikylvön kustannuksia on verrattu kuvassa 4.

Nisulan (1975) mukaan kastelulaitteet voidaan jakaa asennus- ja käyttötekniikan perusteella kiinteisiin, siirrettäviin, liikuteltaviin ja liikkuviin. Suomessa muovihuonekasvatuksessa käytetään pääasiassa kiinteitä kastelulaitteistoja (Rikala 1978). Näissä on jo yleisesti käytössä automatiikkaa ohjaamaan ja säätelemään kastelua. Ruotsin taimitarhoilla liikkuvat laitteistot ovat yleisiä (Parviainen ja Tervo 1980). Liikkuvien kastelulaitteistojen etuna pidetään kastelun tasaisuutta, mutta haittana laitteiden häiriöalttiutta (esim. Tinus ym. 1974). Avomaakasvatuksessa yleisin laitteisto on siirrettävä (Rikala 1978). Ympyräsadettimia käytettäessä paras kastelun tasaisuus saavutetaan, jos kastelun määrä vähenee suoraviivaisesti sadettajasta poispäin (Nisula 1975). Kuvassa 7 on esitetty sadetuksen jakautuminen eräillä ympyräsadettimilla (Christensen 1961). Yleisesti kastelun tasaisuus koetaan ongelmaksi metsätaimitarhoilla. Suuri pisarakoko ja liiallinen kastelu voivat rikkoa maan hienorakennetta ja siten vähentää maaperän ilmanvaihtoa (Hanan ym. 1978). Sumukastelussa saadaan tasaisempi kastelu kuin pisarakastelussa, mutta toisaalta on pelätty, että sumukastelulla juuristot kehittyvät heikommin.

Koulinnassa on siirrytty lähes kokonaan konekoulintaan. Konekoulinta onkin useimmissa tapauksissa halvempaa kuin käsinkoulinta. Haastattelututkimuksissa sitä on pidetty myös miellyttävämpänä työnä kuin käsinkoulintaa (Harstela 1977). Konekoulinnan tuottavuus on ollut eri tutkimusten mukaan seuraava (Väre 1972, Harjula ja Karppelin 1974, Herranen 1980):

— mänty ja kuusi (1M + O) 9 000—17 000 tainta/ 8 h/yksikkö (koulija)
— koivu 6 000— 8 000 tainta/ 8 h/yksikkö (koulija)

Koulintakustannukset on esitetty kuvassa 12. Tämän mukaan 15-paikkainen koulintakone on edullisempi kuin 5-paikkainen jo n. 1 milj. taimen vuotuisella koulintamäärällä.

Taimien juuria leikataan sivuilta ja/tai alta. Leikkaamalla kasvatuksen aikana juuristoa, voidaan sen kasvua ohjata ja samalla edistää haaroittumista (Parviainen 1980). Juurten leikkausta rivien välistä käytetään myös nostotyön helpottamiseen erityisesti kuusella.

Suonenjoen tutkimusasemalla on rakennettu juurten leikkuun koepenkkikone, jossa teknisiä muuttujia voidaan säätää sekä kokeilla erilaisia terävaihtoehtoja parhaan leikkaustuloksen selvittämiseksi. Kokemusten perusteella päädyttiin J-muotoisiin leikkuuteriin.

Biologisissa tutkimuksissa on todettu, että leikkaamisen tulisi tapahtua n. 5 cm:n etäisyydeltä taimen tyvestä ja n. 8 cm:n syvyydeltä (Parviainen 1980). Riittävän leikkuutarkkuuden saavuttamiseksi koneessa käytettiin hydraulista ohjausta. Tuotettaessa paljasjuurisia taimia juurten leikkuumenetelmällä leikkuun kustannukset olivat 0,1—0,4 p/taimi, kun vastaavasti koulinnan kustannukset olivat n. 3,0 p/taimi.

Taulukossa 5 on esitetty Suomen taimitarhoilla käytetyt lannoitteiden levitystavat (Rikala 1978). Lannoitteiden tasainen levitys edellyttää hyvää levityslaitteistoa. Lannoitteita annetaan myös kastelun mukana. Tästä johtuen kastelun tasaisuuden merkitys korostuu entisestään. Kuvassa 17 on esitetty lannoituksen tasaisuus TIVE-lannoittimella. Mittaustulokset osoittavat käytettävien lannoittimien testauksen tarpeellisuuden. Testauksen perusteella voidaan määrittää kunkin lannoittimen optimaalisen levityskaistan leveys.

Taimitarhoilla käytetään torjunta-aineita mm. hyönteis- ja sienituhoja, eritoten talvituhosieniä, vastaan. Torjunta-aineet levitetään pääosin traktorisovitteisilla ruiskuilla. Ruiskutuksissa traktorinkuljettajan altistuminen lienee vähäisempi kuin apumiehen (Kangas ym. 1980). Henkilökohtaisten suojainten ja suojavaatetuksen käyttö on välttämätöntä. Kankaan ym. (1980) mukaan torjunta-ainealtistusta voidaan vähentää tietyin sivulla 25 mainituin toimenpitein.

Nykyisin käytössä olevilla kasvinsuojeluainelevittimillä koko kasvusto käsitellään päältäpäin. Tällöin myös rivivälit ja käytävät tulevat käsitellyiksi ja suuri osa käytettävästä aineesta menee suoraan maahan. Torjunta-aineiden levitystekniikan kehittely tulisi suunnata sellaisten menetelmien ja laitteiden kehittämiseen, joilla pelkästään taimi tai määrätty osa siitä käsitellään.

Rikkaruohojen torjuntakustannusten osuus on ollut 1960-luvun alussa taimien kasvatuskuluista n. 40 % (Lehto ja Simolinna 1966). Nykyään torjuntakustannusten osuus on 7—10 % (Mäkelä suull. 1982, Tavaila suull. 1982). Rummukaisen (1981) tutkimuksessa mekaanisen torjunnan kustannus on ollut korkeampi kuin kemiallisen.

Paljasjuuriset taimet nostetaan vielä pääasiassa käsin. Koneelliseen nostoon on olemassa useita erilaisia vaihtoehtoja. Keski-Euroopassa on käytössä enimmäkseen rivin kerralla nostavia hihnanostokoneita. Suomessa on taimien noston koneellistamista kokeiltu Metsänjalostussäätiön ja Metsäntutkimuslaitoksen toimesta. Koneellisessa nostossa lajittelu voidaan tehdä noston yhteydessä, penkkiin ennen nostoa tai noston jälkeen erityisillä lajittelupaikoilla. Jos raakattavien taimien määrä on vähäinen, näyttää lajittelu penkkiin ennen nostoa olevan kannattavaa. Jos lajittelua ei tehdä noston yhteydessä, voidaan nostokoneella saavuttaa varsin korkea tuotos. Lajittelu välivarastolla lisää noston kokonaiskustannuksia. Traktori- ja pääomakustannuksista johtuen ei koneellisessa nostossa ole vielä päästy kustannussäästöihin käsinnostoon verrattuna. Lajittelun laadussa ei ollut suurta eroa kone- ja käsinnoston välillä.

Tutkimuksen mukaan ei suuria kustannussäästöjä ole saatavissa paljasjuuristen taimien tuotantoa kehittämällä. Sen sijaan pieniä kustannussäästöjä on luonnollisesti saatavissa useissakin töissä, esim. kuusen nostossa sivulta leikkauksen avulla, siirtymällä koulinnassa 15-paikkaisiin koneisiin, tiheämmällä rivivälillä koulinnassa ja rivikylvössä jne. Suurin kustannussäästö kuitenkin olisi siirtyminen koulitusta taimesta leikattuun, joka on meillä uusi taimityyppi. Kustannussäästöjä näyttäisi olevan saatavissa myös työnjohdollisin toimenpitein. Eräs tällainen säästökohde tulosten mukaan oli huolellisempi lajittelu noston yhteydessä, koska varsinkin männyn taimien nostossa on hylättyjen taimien joukkoon mennyt verraten paljon hyviä taimia.

Tutkimuksessa ei ilmennyt tekniseen kehitykseen liittyviä taimien metsänviljelykelpoisuutta vähentäviä tekijöitä, ellei sellaisena pidetä koulinnan aiheuttamaa koukkujuurisuutta. Sitäkin voitanee teknisellä kehittämisellä vähentää. Juurten leikkuun ei ole todettu aiheuttavan merkittävää sienitautiriskiä juuristolle varsinkaan, jos kasvualustassa on turvetta (Petäistö 1982). Juurten leikkuulla taas voidaan ohjata taimien juuriverso-suhteita ja juurten muotoa, mistä saattaa olla suurtakin etua istutuksessa.

Työvoimapulaa on pidetty eräänä taimien tuotantoa rajoittavana tekijänä. Paljasjuuristen taimien tuotanto on ihmistyövaltaisempaa kuin paakkutaimien tuotanto. Tämän tutkimuksen mukaan ihmistyön tarvetta on mahdollista hieman vähentää koneellistamisen ym. rationalisointitoimien avulla nostossa ja siirtymällä koulitusta taimesta leikattuun. Koneellinen nosto mahdollistaa myös nuorten, vanhojen tai vajaakykyisten (esim. lievästi selkävaivaisten) työntekijöiden käytön nostotyössä. Lopuksi tarkasteltiin paljasjuuristen ja paakkutaimien kustannuskehitystä. Kovin suurta eroa näiden taimilajien kustannusten kehityksessä ei liene odotettavissa.

HARSTELA, P & TERVO, L. 1983. Technology of the production of bare-root seedlings. Seloste: Paljasjuuristen taimien tuotannon teknologia. Commun. Inst. For. Fenn. 110: 1—51.

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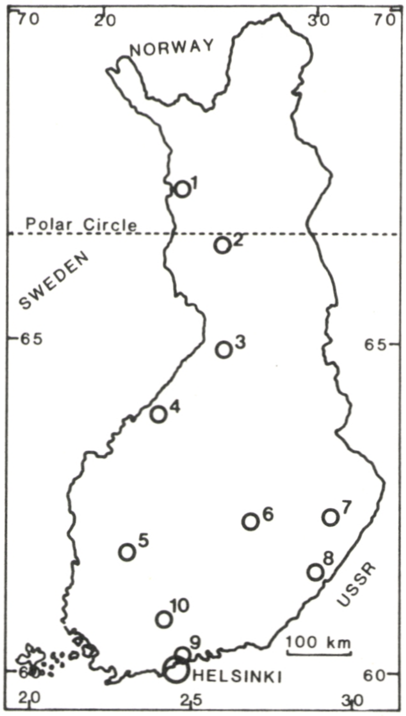

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FACTS ABOUT FINLAND

Total land area: 304 642 km^2 of which 60—70 per cent is forest land

Mean temperature, °C:	Helsinki	Joensuu	Rovaniemi
January	-6,8	-10,2	-11,0
July	17,1	17,1	15,3
annual	4,4	2,9	0,8
Thermal winter (mean temp. <0°C):	20.11.—4.4.	5.11.—10.4.	18.10.—21.4.

Most common tree species: Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens

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