Rationalization of the Production of Bareroot Plants in Finland

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New developments in mechanization of lifting and root pruning of tree seedlings in Finland are reviewed with emphasis on working condition improvement.

Approximately 80 percent of Finland's regeneration area is restocked by planting and 20 percent by seeding. Two hundred million seedlings, of which 72 percent are bareroot plants, are produced for forest regeneration. The remainder are container seedlings (*4*).

Most of the transplant production, especially in South Finland, is with bareroot plants. Use of container seedlings is limited. This makes it worth developing methods for bareroot transplant production further. Some of the nursery considerations are (*3*):

- Economic—Transplant price is an important factor in forest regeneration costs. The transplantation and the lifting and sorting of transplants are especially costly types of work.
- Biological—The physiological condition of the regeneration material is decisive for the success of regeneration. Nursery costs are a small part of the total regeneration costs. Unsuccessful forest regeneration, even if the transplants are cheap, is a waste of time and effort.
- Ergonomical[1]—The main ergonomical problems of nursery work are poor physical working positions, the seasonal nature of the work, and exposure to pesticides and weather conditions (*1*).
- Labor policy—Production of bareroot plants is highly seasonal by nature. Lifting in particular causes an employment peak of short duration. There may be a shortage of labor in the future. Indeed, there is already such a shortage regionally. Furthermore, it is necessary to use unskilled workers. Improvement of the ergonomics of the work will increase job satisfaction.

Experience shows that there is still room for improvement in the production of bareroot transplants and that production can be mechanized to a fairly great extent.

Rate of Mechanization

Many mechanized production innovations have already become practical, routine methods. Soil preparation, fertilization, irrigation, seedbed preparation, seeding, spreading of pesticides, and transplanting have been mechanized in varying scales. Automation has been implemented in the plastic house technique. Mechanized methods have been developed for weed control.

Transplanting and the lifting, sorting, and sacking of transplants, which are the most labor-intensive parts of the regeneration schedule, have been only partly mechanized. In lifting, mechanization has previously been limited to undercutting and vibration before manual lifting and manual operation of sacking devices. The experiments of the Department of Forest Technology of Forest Research Institute in Suonenjoki have shown that the resistance of transplants to freeing from the soil is distinctly reduced with spruce if sidecutting is performed before undercutting with a disk cutter developed for the purpose.

The labor input for transplanting machines is still high. This has been reduced in some large nurseries with level ground by combining three transplanting machines into a single unit. The transplanting machines in use were not originally designed to conform to ergonomical requirements, but their seats and dimensions have since been improved.

[1] Ergonomics is the science that seeks to adapt work or working conditions to suit the worker.—Ed.

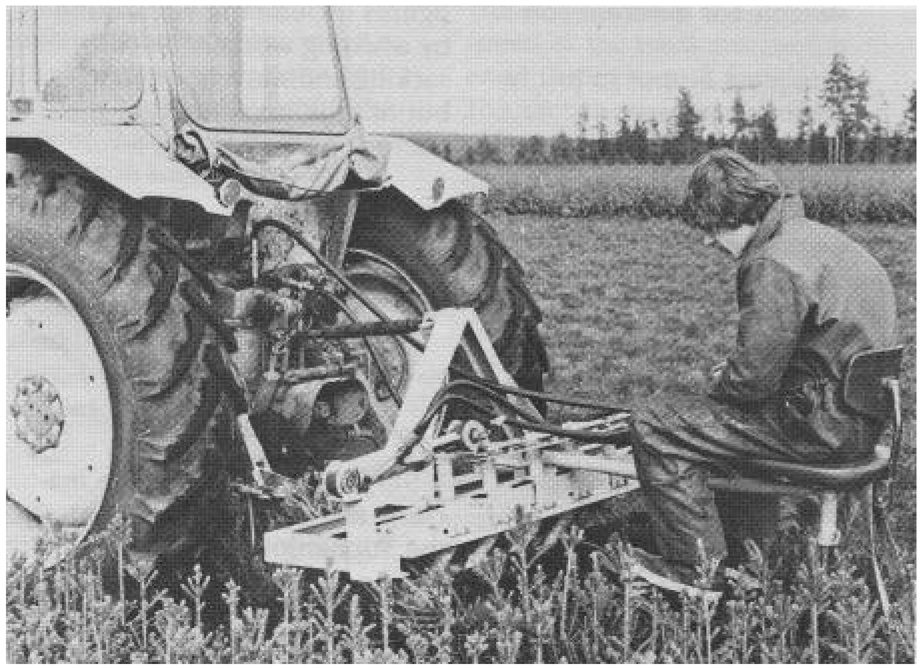

Figure 1.—*Sidecutting device at work*.

Developing of Lifting

The working position in manual lifting is bad, and getting big spruce transplants out of the soil is relatively strenuous work. To ease this load and to speed up the work, a cutter was developed for sidecutting the transplants (figs. 1 and 2) before the undercutting and vibration phase (2). A short lifting test showed that the resistance of transplants to separating was diminished in the following way for spruce 1P+2O[2] and 2P+2O plants.

	Resistance to separating, kg
Undercutting	6.4
Under- and sidecutting	2.7

The heartbeat rate of the workers participating in the test was reduced slightly by the sidecutting process. The productivity of two workers also improved, but that of one decreased. Plant biological factors should also be taken into consideration regarding the time of sidecutting. The best result is achieved if the transplants are cut in the autumn before root growth ends (*5*).

As a commercial machine satisfactory in every respect was not available, a prototype lifting machine, the HARTER-1 (fig. 3), was built by the Finnish Forest Research Institute, Department of Forest Technology, in cooperation with the Suonenjoki nursery, for study of mechanized lifting.

The following factors were desired in designing the machine:

- A modular and simple structure that makes it possible to reduce or increase the operation rate as required.
- The simplest possible structure to ensure reliability of operation, low purchase price, and ample scope for control so the machine would be

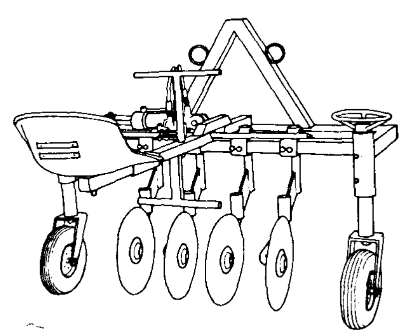

Figure 2.—*Device for sidecutting roots.*

[2]P = plastic house
O = open land

suitable for different conditions.
- Adequate output to justify mechanization.
- Ergonomically correct dimension and the possibility of job rotation for the workers.

The machine was designed to lift every type of transplant, to pick up stones from seedbeds, and to clean peat. Investigation results are presently available only for the lifting of pine 1P+1O plants from peat beds at the Suonenjoki nursery.

The lifting outputs per worker-hour were as follows in mechanized lifting and manual lifting at piece-rate work. The figures include the work done by assisting workers (such as sacking and moving of sacks), but not the work input of the tractor operator.

	Relative output
Mechanized lifting + sorting + bundling + sacking	121
Mechanized lifting direct into the container	317
Manual lifting + sorting + bundling + sacking	100

Studies of the use of the machine are being continued at the Suonenjoki Experimental Station. It is known already that the machine is also suitable for lifting spruce and birch transplants. It is now going into serial production and its price at present is 30,000 to 65,000 Fmk, depending on the standard of the equipment. The machine is manufactured by SUONNE Company in Suonenjoki.

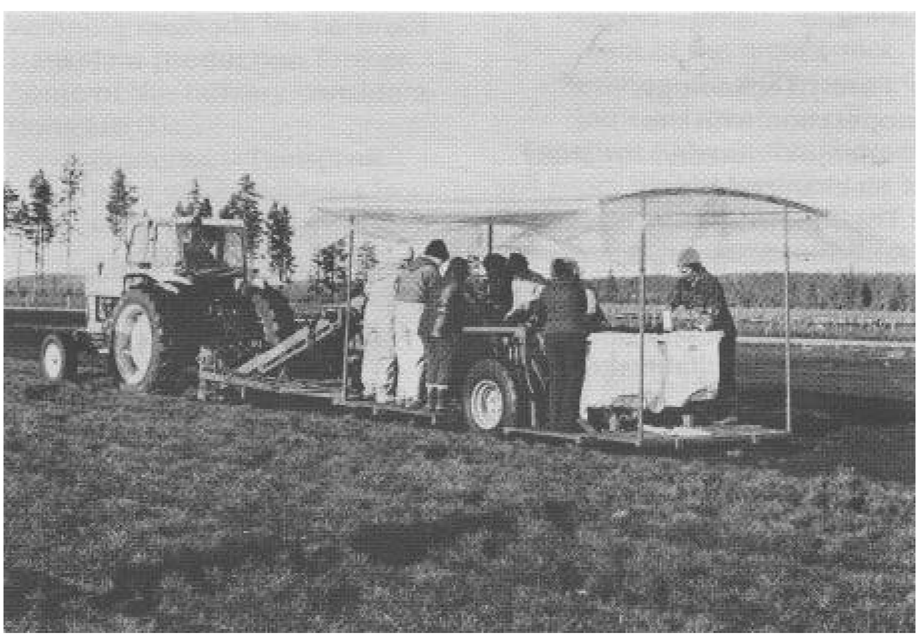

Figure 3.—*HARTER lifting machine.*

The quality of the lifting operation also influences nursery costs. Good transplants are mixed with rejects as shown in table 1 in the different lifting methods.

Incorrectly sorted transplants constitute a relatively large cost item. If the sale price of transplants is 23.5 pennies per transplant, a 1.1 percent difference in lifting costs makes an extra 0.25 pennies per transplant. However, the machine used in the quality test was only a prototype. Modifications have already been made which will improve lifting quality (fig. 4). The most important one is a second vibrator at the front end of the lifting conveyor. It helps the plants rise in a more even flow. It is also probably possible to improve the quality of sorting by reducing the working speed of the machine.

The need to refine the lifting machine further was also illustrated by the working time breakdowns for sorters placed at different positions (table 2).

The waiting time increased distinctly from front to rear sorter. This was partly because, after a jam, there were only

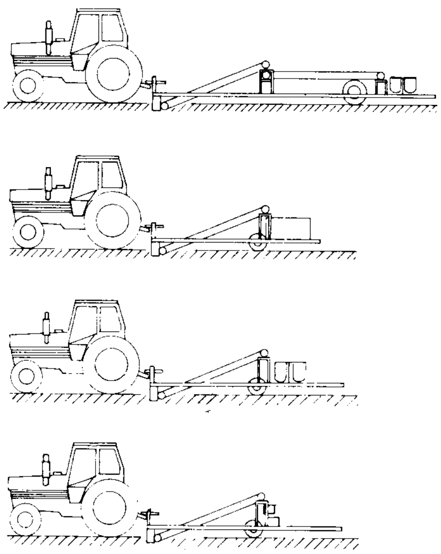

Figure 4.—*Principles of different HARTER versions.*

enough transplants for the first sorters to begin work on. The adding of the second vibrator to the machine should also improve worker productivity and even out the workload. The first experiments with lifting spruce transplants showed an additional vibrator was necessary to adequately clean soil from the roots.

The following ergonomic measurements were made of mechanized lifting. The noise values were:

- First sorter 77 dB (A)
- Last sorter 68 dB (A)

The vertical increase in vibration bearing on the legs was as shown in table 3.

According to current standards, the machine involves no risk of hearing damage and the vibration is not harmful. Because of the plastic lining, the illumination was also good, over 1,000 lux.

The working position in the lifting machine is good except for some reaching. This was reduced by directing the transplants, by means of vibration, to the sides of the sorting track.

The drawbacks of the forced speed of the work can be lessened through work rotation. The sackers work at a considerably lower rate than the sorters, as can be seen from the share of waiting in the following distribution of working time:

	Sacker 1	Sacker 2
Tying of bundle	40.2%	37.2%
Waiting	33.3%	39.0%
Placing in the sack	21.7%	17.6%
Changing the sack	3.1 %	2.6%
Other work	1.1 %	3.5%

Table 1.—*Quality of the lifting operation*

		Percent of accepted plants
Lifting and sorting by machine	Dropped transplants	0.5
	Incorrectly sorted transplants	1.5
	Total	2.0
Manual lifting	Incorrectly handled or dried transplants	0.9

Table 2.—*Working time breakdowns for storters in different positions*

	Place in the machine					
	1[1]/r[2]	1/l[3]	2/r	2/l	3/r	3/l
Counting	91.8%	88.7%	88.1%	86.9%	73.8%	71.2%
Waiting	6.6%	8.1%	10.3%	10.4%	19.2%	23.9%
Removal of rejects	1.6%	3.2%	1.6%	2.7%	7.0%	4.9%

[1] 1-3 = position of the sorter along the machine.
[2] r = the right side of the sorting level.
[3] l = the left side of the sorting level.

Table 3.—*Vibration bearing on legs*

Octave range (Hz)	31.5	63	125	250	500	1,000	
First sorter	0.4	0.8	1.0	0.6	1.3	1.0	(m/s^2, rm^5)
Last sorter	0.2	0.4	1.3	0.5	0.3	0.2	"

In mechanized lifting the transplants were exposed to drying for a shorter time on average than in manual lifting. Direct sunshine was reduced by covering the lifting conveyor with a tarpaulin.

Developing the Cutting of Roots

Cutting of roots has been suggested as an alternative to transplanting. However, the point at issue is a new seedling type whose properties differ from those of either a transplanted or an untransplanted plant. The extent to which cut seedlings become popular depends on their properties and production costs. The cutting technique may influence both.

A "test-bench machine" was constructed for the cutting of roots to study the effects of different technical variables on cutting (fig. 5). Such variables included the basic structure of the machine, cutting knife types, and knife movements (stroke length and rate). The basic structure was designed for high cutting accuracy. The body was fixed to the three-point linkage of a tractor and the steering was hydraulic. A mobile J-knife was decided upon after trying several alternatives, chiefly because it makes it possible to combine side- and undercutting. The root-cutting cost was only 3 to 6 percent of the cost of transplanting.

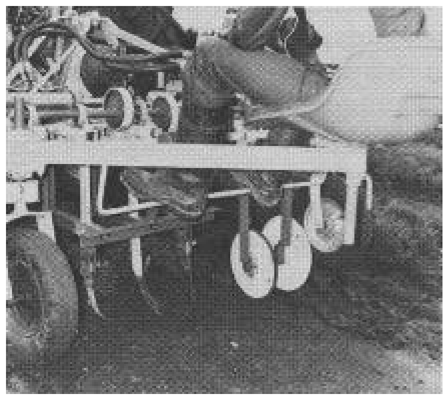

Figure 5.—*Test bench machine for root-pruning.*

Discussion

According to experience gained from the HARTER prototype, mechanized lifting has reduced the need for labor and solved some ergonomical problems of nursery work. The results are based on the lifting of pine. It is possible that the situation may differ for spruce. Judging by the first experiments, the machine is suitable for lifting spruce transplants. The prototype revealed certain shortcomings that have now been remedied. The modifications were designed to improve the quality of work in particular, but also productivity. It seems that other known lifting machine solutions do not offer a more economic alternative if it is assumed that the transplants must still, for biological reasons, be sorted before planting. There is a version of the HARTER which precludes sorting. However, because of the employment situation in Finland, it does not seem appropriate to aim for full mechanization of lifting. Mechanized lifting, in combination with manual lifting, must probably be considered the method of choice.

A cut seedling is a new type of seedling which is cheaper in price than a transplanted plant, but, compared with an uncut plant, more expensive because of cutting costs. In manual lifting, the cost of lifting a cut seedling is greater than that of a transplanted plant because the roots are more intertwined. This is probably not of great significance in mechanized lifting. If the yield of cut plants is 20 seedlings per row metre, the area needed for the production of 2-0 seedlings root pruned twice is 52 percent greater than the area needed for the production of 1 P+1O transplants (transplanting loss 10 percent) and 24 percent greater than that needed for the production of 2O+1O transplants. The area requirement for a yield of 30 seedlings per row metre is 1 percent greater and 18 percent smaller, respectively.

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