Fundamentals of container tree seedling production

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Cover picture: From seeds to seedlings.

Photos (from upper corner) / M. Nygren (2), J. Nerg and T. Saksa

Preface

This guidebook presents the fundamentals of the technology used for growing tree seedlings in containers in Finland and Russia. It was prepared by a group of experts in reforestation from Finnish Forest Research Institute, Forestry Development Centre Tapio, Fin Forelia Ltd. on the one side, and St. Petersburg Forestry Research Institute, Northern Research Institute of Forestry, Forestry Institute of the RAN Karelian Research Center, on the other side.

The recommendations given in the guidebook sum up the experience of growing container seedlings in nurseries of different companies in Finland and Russia: the Republic of Karelia, Arkhangelsk and Leningrad regions.

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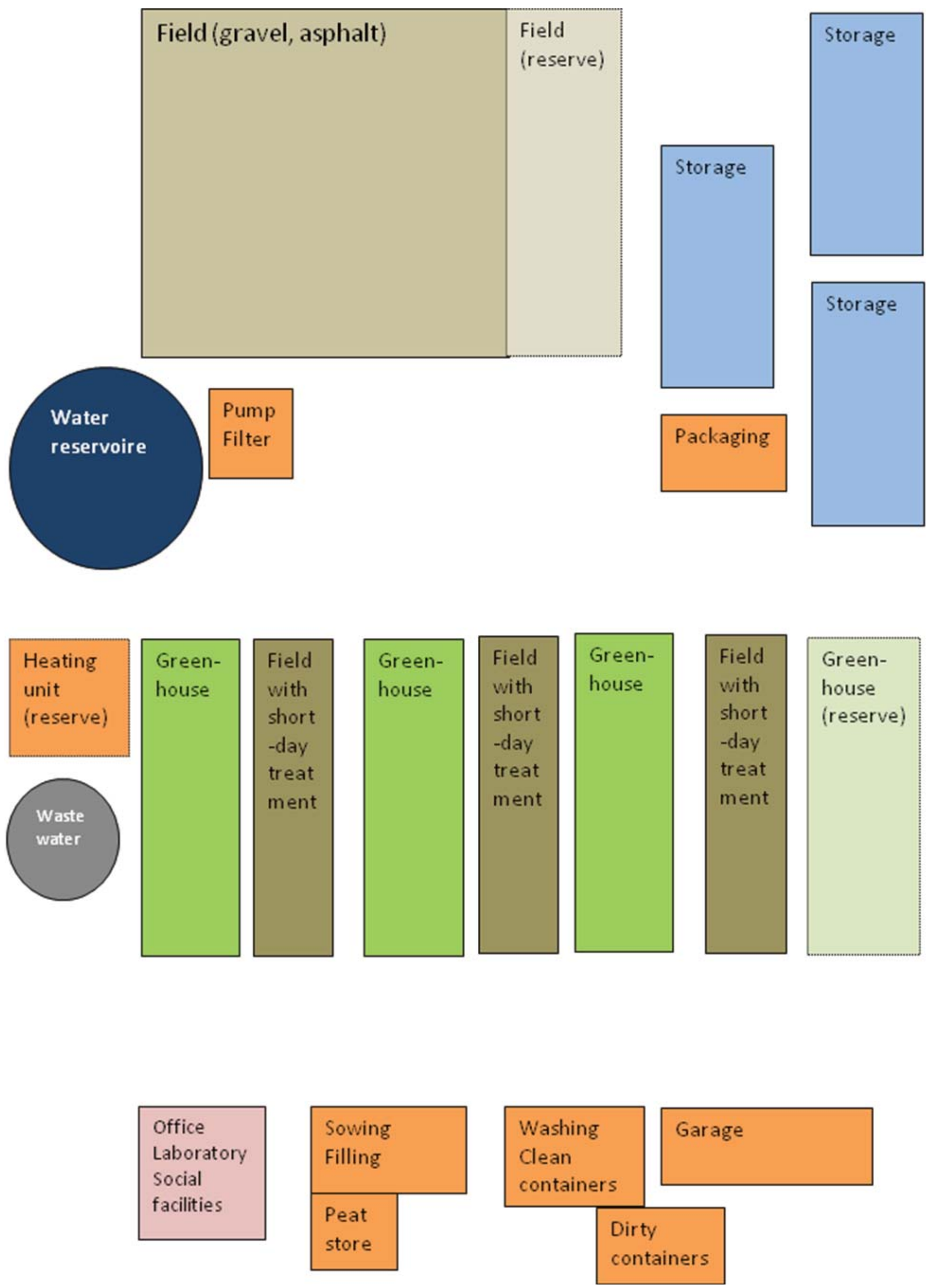
1. Main facilities for containerized seedling production

1.1 Nursery layout: greenhouses, outdoor fields, storages

Containerized seedlings are grown in specialized nurseries. The technological process of containerized seedling production involves the use of greenhouses and outdoor fields. In winter, containerized seedlings can be stored in outdoor fields as well as in special refrigerated storages.

Production of one million seedlings requires about 2 000 – 2 500 m^2 greenhouse area and about 3 000 m^2 of outdoor field area. It is important to make a plan of how greenhouses, outdoor fields and storages will be situated in the nursery area. Greenhouses, outdoor fields and storage / packing facilities should be located logistically clever in order to minimize transportation costs. It is also recommended to have some reserve space for future enlargements, especially concerning greenhouses and outdoor fields.

In addition to the direct production facilities, a container seedling nursery contains facilities for cleaning and filling the containers with growing media as well as a water-handling system and possible heating units for greenhouses. Usually nursery area contains also an office building with a small laboratory and social facilities, a garage and some warehouses. It is also important to locate the nursery so that connections to road network are good. Also, it is not recommendable to locate a nursery on an area where ground water is collected for drinking water.



A schematic picture of container seedling nursery with no exact scale.

1.2 Water source and quality

The containerized seedlings are irrigated with water from open sources and artesian wells. As a rule, mobile spray facilities (booms, sprinklers) are used in greenhouses and outdoor fields. To water seedlings in greenhouses, it is desirable that water should be taken from artesian wells. If the water is available only from open sources, it should be filtered in order to prevent introduction of weed seeds and fungus infections. Water filtration provides reliable operation of sprayers of irrigation facilities. It is important to analyze the chemical and physical (iron, pH and humus) and biological (seeds, etc.) quality of water before large-scale use.

The water resource should be large enough to fulfill the maximum water demand during seedling production. Demand for irrigation water varies depending on tree species, growing phase and weather conditions. The maximum irrigation water demand for spruce and pine is approximately 6 – 8 litres / m^2 per day. This means about 10 litres / 1 000 seedlings with ordinary container volumes. For production of one million seedlings the maximum demand is thus 10 000 litres per day. The mean water demand is about one third of maximum demand.

In addition, irrigation water is also needed to prevent frost damages on outdoor fields and, in some cases, to cool seedlings during the warmest days in greenhouses and on outdoor fields. There is also a need to have hot water for cleaning production facilities and containers in order to keep up high hygiene standards.

1.3 Heating, ventilation and shading systems in greenhouses

As a rule, greenhouses are supplied by manufacturers complete with heating and automatic ventilation systems. The spring sowings can be made somewhat earlier if a greenhouse has a heating system. Often night temperatures fall too low without heating even in April, which can have a negative effect on the seedling establishment. If the target is to produce two seedling crops in one growing season, the first sowing has to be done in March / beginning of April and then auxiliary heat is inevitable also in Southern Finland's circumstances.

Greenhouse with heating and ventilation equipment and short-day treatment curtains (photo T. Saksa).

In most cases in forest tree nurseries greenhouses are heated with oil but if the heating unit provides heat for several greenhouses, then also other energy sources, like bioenergy, is a good option.

Ventilation is important for controlling high temperatures and reducing humidity in greenhouses. Usually ventilation equipment is installed on the roof of a greenhouse and in the lowest part of the walls. Ventilation may be based on free air circulation or it may be operated by different kinds of fans. It is also possible to reduce the incoming heat radiation with shadowing curtains inside the greenhouse or with painting the outer surface of the greenhouse with special paint.

1.4 Containers and other growing equipment

Nowadays there is a wide choice of containers from various manufacturers. The size and the structure of containers depend on the tree species of seedlings and their growing time. On the other hand, the parameters of the future planting site determine what kinds of seedlings are needed.

An empty container (PL81) and a container with 1-year-old pine seedlings (photo T.Saksa).

Nowadays the most used container types in conifer production are hard-plastic containers like Plantek® and BCC® in Finland. Each cell in hard-plastic containers has air holes on each side of the cell, which controls the development of the root system with air-pruning. Containers are usually kept on pallets about 20 cm above the base during the growing period to improve root pruning, and for winter containers are put down onto the ground to avoid frost injuries of roots.

Empty pallets piled for waiting further use (photo T. Saksa).

Containers with seedlings on pallets in a greenhouse
(photo T. Saksa).

The demand for containers is about 1 – 2 times the production volume. The lifetime for the hard-plastic containers is about 5 – 15 years. It is important to clean containers after every seedling crop in order to minimize the risk of spread of harmful fungus and weed seeds. Containers can be washed with hot water (85 °C) with detergents. Cleaned containers should be kept in closed space until the next filling and sowing.

1.5 Growing medium and fertilization

The best growing medium for growing containerized seedlings is light sphagnum peat extracted with a rotary cultivator. Using sphagnum peat with the degree of decomposition of more than 15 %, as well as intermediate and black peats adversely affects the operation of machines for filling containers with a growing medium. Application of other components as a growing medium requires special study and readjustment of mechanisms of the machines.

The growing medium can be prepared at peat-producing plants or directly at a nursery, which requires special mixers. The formulation of mineral supplements introduced into the growing medium depends on the

scheme of fertilizer application. Usually the acidity of substrate aqueous extract is brought to pH 4.5 – 5.0 by applying adequate doses of milled dolomite lime. The full dose of phosphate and potash fertilizers can be applied during preparation of growing medium. In Finland peat producers add about 0.8 kg basic and minor nutrients in one cubic meter of peat. This fertilization dose covers about 30 – 50 % of a 1-year-old seedling's nutrient demand during the growing period.

It is important that growing medium is well mixed and homogenized. The demand for growing media is about 100 – 130 m^3 of peat for the production of one million seedlings.

1.6 Labor and competence

The staff of the nursery should have a proper qualification and receive special training. It is necessary that the staff is able to do routine analyses of the growing medium or plant material and practical diagnosis of the condition of seedlings.

The demand for labor depends, to a large extent, on the level of mechanization and automation in the nursery operations.

2. Preparatory work

2.1 Seed procurement, provenances

Containerized seedlings are grown from seeds improved by genetic selection. The seeds are used in accordance with tree seed zoning. Seeds used in container seedling production should have high germination capability. If the target is one-seed sowing, the germination percent of the seed lot should be more than 95 %.

In commercial container seedling nurseries, the demand for seeds for production of one million spruce seedlings varies from 7 to 8 kilos in one-seed sowing and from 11 to 12 kilos in two-seed sowing. In bare-root seedling production, the result from 100 seeds varies usually from 25 to 45 full-grown seedlings but in container seedling production, it is possible to achieve 80 to 95 full-grown seedlings from 100 seeds.

2.2 Preparation of seed lot

The seeds used for growing seedlings in a nursery are calibrated on seed separation machines and pneumatic classifying tables to bring their germination capacity to 95 %. The seed germination power can be increased by keeping seeds in snow, barbotage and steeping of seeds in a solution of microelements and growth stimulants.

In order to control surface and emergent fungus infections, the seeds are powered or soaked in a solution of certified insecticides.

2.3 Filling containers with growing medium

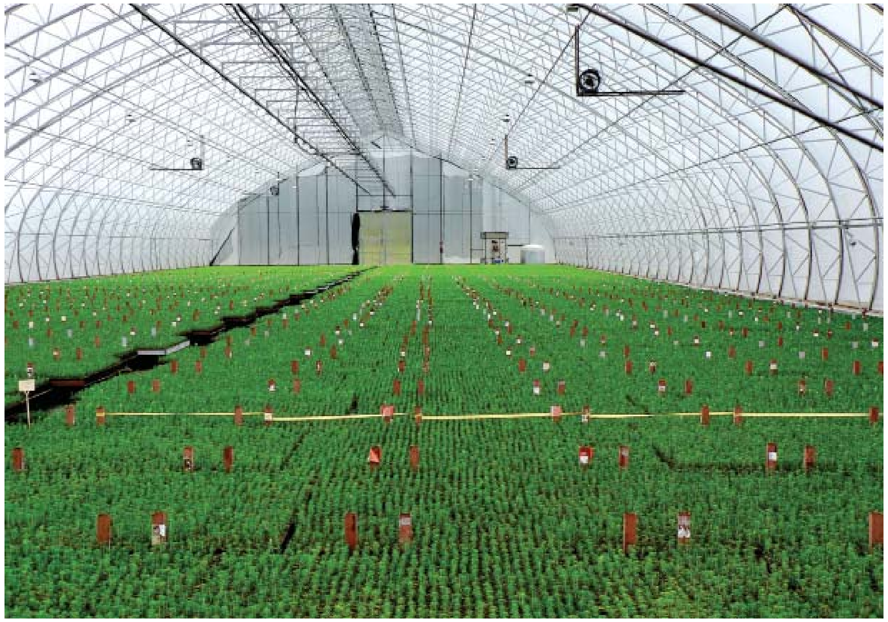
Containers are filled with growing medium on special equipment. The filling machine fills up and compacts the growing medium in containers and makes a small hollow for seed on the centre of each container cell. The target is to get a homogenized structure and level of compaction through one container cell and over the whole container. The container is filled up so that about 0.5 cm from the upper edge of the container is free of growing medium. During the filling operation the weight of a container is measured for control after certain intervals. The weights should be about the same.

3 Growing schedules in container seedling production

3.1 General planning and scheduling

The seedling producer has several tools to control the development of container seedlings. The demand for seedlings in forestry gives the main targets for the seedling production. The most important questions are when the seedlings are needed for planting and what kinds of seedlings will be desired. These requirements from the seedling purchaser create the basis for planning and scheduling the seedling production.

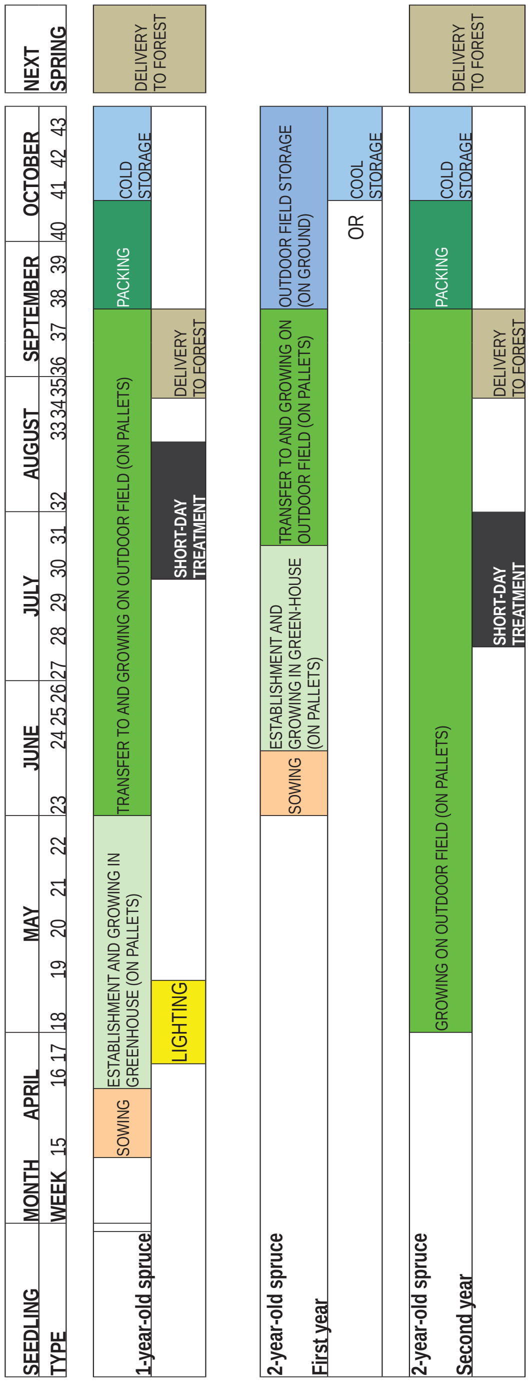
In a modern greenhouse, one to three seedling crops can be produced in one year. In Finland, if more than one seedling crop will be produced, the greenhouse should have a heating system and possibilities for photoperiodic lighting. In more southern climate, there might be possibilities to grow more than one seedling crop without a heating system but photoperiodic lighting will be needed in order to prevent bud formation in the earliest sowings.



Modern greenhouse full of spruce seedlings (photo T. Saksa).

There are several different growing schedules which can be used when producing container seedlings with target biometrical parameters. If the seedling demand can be fulfilled with one seedling crop, the sowing time could be adjusted if the delivery time of seedlings allows, with local natural temperature and light conditions. If two seedling crops are required, the first sowing should be done in March and the second in June. In some cases it is possible to start the third crop which should be sown in the beginning of July. The above-mentioned timetable is suitable for the southern part of Finland.

All growing schedules can be divided in three main stages: establishment phase, rapid growth phase and hardening phase. The establishment phase is the period from seed germination through primary leaf development and root extension throughout the container. The rapid growth phase is the period when seedlings grow in height and increase in weight at an exponential rate. The hardening phase is the period after the bud set when radial growth of the stem and root growth continue and seedlings get cold hardened for outplanting.



General growing schedules for 1- and 2-year-old spruce container seedlings in Southern Finland.

3.2 Establishment phase

3.2.1 Sowing seeds and mulching containers

Seed quality in container seedling nursery should be as high as possible. If the germination capacity is more than 95 %, one-seed sowing can be used. In some cases, the nursery can upgrade the quality of a seed lot. A seed lot can be cleaned and graded with air or water according to the weight of seed. Spruce and pine seeds can also be upgraded with IDS-method (incubation-drying-separation) but nurseries do not usually have any equipment for this procedure. It is not recommended to use the seed lot when its germination is lower than 75 %.

If germination percentage remains low after upgrading and one-seed sowing does not seem to be economical, instead of one seed, 2 or 3 seeds per cell may be sown. If several seeds per cell are sown, cells with multiple seedlings must be thinned after germination is completed.

After sowing, the seeds must be covered or "mulched". The main function of the covering material is to maintain optimal moist conditions around the germinating seed. Because the covering material has a coarser texture than the growing media, upward water flow stops on the surface of the growing media and gives ideal conditions for germination. The covering material also reduces the development of moss, algae, and liverworts. Most of covering materials are light-colored in order to reduce the heating effect of sunlight, which might injure the germinating seed. The seed covering material should also be sterile and it should have about the same pH as growing media. The seed covering material should be evenly distributed and the covering layer should be about twice as thick as the seed's smallest diameter (no more than 3 mm for pine and spruce). There are several mulching materials: perlite, vermiculite, crumb granite, grit, and saw dust.

Different mulching materials used in spruce containers: on the left – perlite (Finnish Forest Research Institute, Suonenjoki), on the right – crumb granite (UPM, Joroinen) (photo A. Zhigunov).

3.2.2 Irrigation and fertilization

The sown containers are irrigated right after they have been transferred to the greenhouse. Within the first 2 – 3 days, the growing medium should be completely saturated throughout the whole container. After that, measuring container weight is the most common way for monitoring the moisture level of containers and deciding on the need of irrigation.

The weight of a container varies according to type and compaction degree of growing medium, so the start and end values for irrigation must be determined for local circumstances. During the establishment phase, the surface of the container may get somewhat dry but the seed should have water contact under the covering material during the first week.

An auxiliary way to control irrigation is to use moisture measurement equipment to determine the moisture content of the growing medium. The decision on the need of irrigation is taken in accordance with these weight and moisture measurements and daily observations in different parts of the greenhouse. Irrigation should be conducted in the morning. During the day, extra moisture will be dried away and the risk of fungus spread during the following night will be minimized.

Example of irrigation guidelines for different Plantek®-containers in the establishment phase in southern Finland

Container type	Fully saturated [1]	Minimum weight / Irrigation needed	Maximum weight / Stop irrigation	Wilting point
	kg	kg	kg	kg
PL256	2.4	2	3	1.6
PL121F	3.8	3.2	4.3	2.4
PL81F	4	3.6	4.8	2.6
PL64F	4.2	3.8	5	2.8
PL49F	4.4	4	5.5	3

[1] Weight on the third day after irrigation started

If the growing medium has been fertilized already by its producer, there is no need to add a fertilizer in irrigation water during the establishment phase. Usually fertilizers added into the growing medium in the manufacturing phase will be effective for six to ten weeks.

3.2.3 Temperature, humidity and light

Seed germination begins after the growing medium temperature rises above 10º. Germination temperatures between 22 and 24 ºC are optimal for many species. It is important to keep the temperature high enough also at night. Depending on sowing time and local conditions, extra heating in the greenhouse may be needed during the germination. If the night temperature falls too low, it has a negative effect on the germination. After two weeks, the temperature can be lowered by a few degrees.

Air humidity in the greenhouse is in the beginning nearly 100 % but it can be lowered to 80 % on the second week after sowing. At the end of the establishment phase the air humidity should be around 60 %.

When sowings are done in early spring (March or April in Southern Finland), photoperiodic lighting is needed in order to prevent bud development. For this purpose, night-break lighting (intermittent lighting) is provided for a 2 – 4 week time period. If the sowing is made in May or later, there is no need for additional lighting at the seed germination phase.

In Finland in some nurseries, lighting lamps are connected to the irrigation boom. In the middle of the night, the irrigation boom is driven (lights on) through the greenhouse after every 30 min during 3-hour time (5-6 drives). The speed of the boom is about 4-5m/minute. Other method is to use fixed lamps and then interrupt the night with a few hours of lighting time. For instance, if the night lasts 16 hours, it should be divided into two parts, seven hours each, and two hours lighting time between them. The third possibility is to use lighting in the evening and morning so that the critical night length will not be crossed. If the critical night length is 8 hours, artificial light should be used from 6 to 9 in the morning time and from 17 to 20 in the evening time.

Example of temperature guidelines for the establishment phase in Southern Finland

Time since sowing	Temperature in the daytime	Temperature at night	Temperature to start heating	Temperature to start ventilation	Air humidity in greenhouse
	°C	°C	°C	°C	%
0-1 week	22	20	20	25	95
1-2 weeks	22	20	20	25	80
3-4 weeks	20	18	18	23	60

3.3 Rapid growth phase

3.3.1 Temperature, humidity and light

At the rapid growth phase, the temperature in a greenhouse should be somewhat lower than that in the establishment phase. The target temperature for pine and spruce varies from 16 to 20 ºC. The temperature in one-meter surface air should not be higher than 30 – 35 ºC.

Example of temperature guidelines for the rapid growth phase in Southern Finland

Time since sowing	Temperature in the daytime	Temperature at night	Temperature to start heating	Temperature to start ventilation	Air humidity in greenhouse
	°C	°C	°C	°C	%
> 4 weeks	16	12…16	12….16	23	60

At the rapid growth phase, greenhouses should be ventilated more intensively than at the seed germination phase. Due to ventilation, the air humidity in the greenhouse should be kept at the level of 50 – 70 %. Additional lighting should not be needed at the rapid growth phase except for the earliest spring sowings (March).

3.3.2 Fertilization and irrigation

Humidity of the growing medium is maintained at the level of 60 – 70 % of the total water capacity. The start of irrigation should be determined by the weight of container. The weight of a container varies according to the type and compaction degree of the growing medium, so the start and end values for irrigation must be determined for local circumstances.

At the moment when irrigation is needed, the upper layer of the growing medium in the cells is somewhat dry and the lower part has about 25 – 30 % moisture content. During the irrigation, the whole container should get wet thoroughly. Before next irrigation, the weight of the container should reach the minimum weight limit. As a result of the above-mentioned variation in moisture, the root development will be balanced in the whole container.

Example of irrigation guidelines for different Plantek®-containers in the rapid growth phase in Southern Finland.

Container type	Minimum weight / Irrigation needed	Maximum weight / Stop irrigation	Wilting point
	kg	Kg	kg
PL256	2	3	1.6
PL121F	3.2	4.3	2.4
PL81F	3.6	4.8	2.6
PL64F	3.8	5	2.8
PL49F	4	5.5	3

Generally, the seedlings are irrigated every third to fifth day in the rapid growth phase, with an average of 6 – 8 liters of water per one m^2 (6 – 8 mm / m^2). Of course, the prevailing weather conditions have a great effect on the need of irrigation. Between the irrigations, the surface of the growing medium should be dry, which hinders the silting of the surface layer and also the growth of moss (especially liverworts).

In the rapid growth phase the most effective nutrient is nitrogen; but usually fertilizers used include potassium and several micronutrients. The fertilization program starts from the third or fifth week from the sowing and continues the whole rapid growth phase. The fertilization program starts from low nitrogen concentrations, continues with higher nitrogen concentrations and ends on a lowered level when the hardening phase starts. The use of nutrients is controlled weekly with measurements of electrical conductivity. The salinity level in the growing medium solution should be in the range of 1.5 – 2.5 mS/cm. The relation between the sowing time and the growing season should be taken into consideration.

Example of fertilization guidelines for spruce and pine seedlings (nutrient concentration in irrigation water mg/l) in early spring and summer sowing in Southern Finland. The growing medium is pre-fertilized. The limed light sphagnum peat and fertilizers used during the growing are products of Kekkilä Ltd

Sowing time April	**Spruce**			**Pine**		
	Nitrogen	**Potassium**	**Phosphorus**	**Nitrogen**	**Potassium**	**Phosphorus**
	mg/l	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
3-5 weeks from sowing	170	180	35	150	160	40
6-8 weeks from sowing	250	270	55	210	220	45
Outdoors in June - July	310	430	85	300	320	65
Outdoors in August	240	540	100	180	410	60
Outdoors in September - November	0	480	100	0	350	75

Sowing time June	**Spruce**			**Pine**		
	Nitrogen	**Potassium**	**Phosphorus**	**Nitrogen**	**Potassium**	**Phosphorus**
	mg/l	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
3-5 weeks from sowing	170	180	35	150	160	35
6-7 weeks from sowing	250	270	55	190	200	45
In greenhouse in August	160	350	65	120	270	50
In greenhouse in September - November	0	300	65	0	230	50

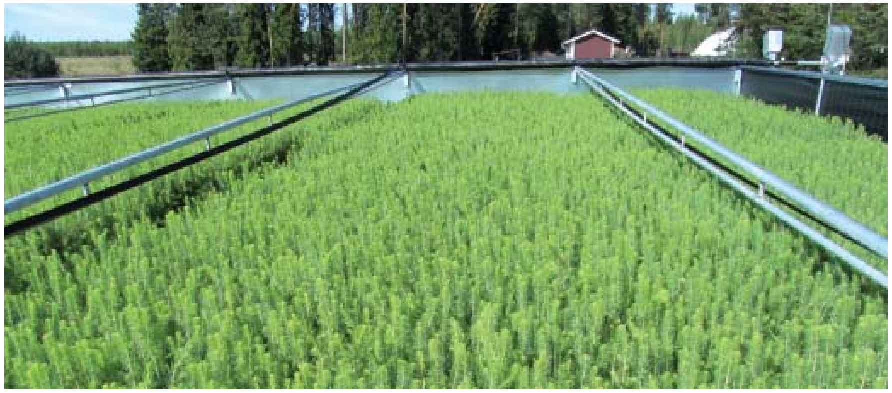
The total amount of nitrogen fertilizer applied during the growing period is 8 – 10 g of nitrogen per 1 m^2. The solution concentration should not exceed 0.4 %. In a greenhouse, it is recommended to use several fertilization times (even with every irrigation time) with lower doses of nitrogen. On the outdoor field, longer fertilization intervals with higher doses may be used.

3.4 Hardening phase

3.4.1 Short-day treatment

In spring sowing (March, April, May), there is no need in short-day treatment to increase the resistance of seedlings to low temperatures in autumn and winter seasons because of natural shortening of the day length from June to September. If one-year-old seedlings are planted in autumn, it is recommended to use short-day treatment in order to ensure that the seedlings will not be harmed in the first autumn frosts.

Summer sowing (June) involves short-day treatment intended to accelerate ripening of the apical bud and lignification of the sprout: light period – 10 – 12 hours (depends on species and origin) for no less than 2 weeks (2 – 4 weeks) in the third decade of July – the beginning of August. If in a good growing season the seedling crop reaches its target height “too early”, short-day treatment can be used to regulate and stop height growth.



An outdoor field with short-day treatment equipment (UPM, Joroinen) (photo A. Zhigunov).

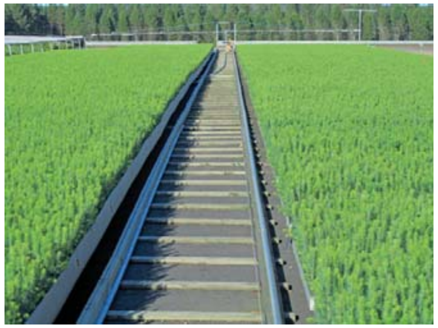
3.4.2 Fertilization and irrigation

Nitrogen fertilizers should not be applied in the hardening phase. Nitrogen fertilization is applied up to September but in smaller doses than earlier in the growing season. In order to enhance the resistance of seedlings, the last potassic fertilization is performed late in September or October.

In the hardening phase, irrigation is performed according to the weight of container. The same weight limits can be used as in the rapid growth phase but the weight of bigger seedlings should be taken into account when calculating the weights for start and stop irrigation. Also, in the autumn time, the weather conditions have a great effect on the timing of irrigation.

3.4.3 Control of weather and other outdoor risks

Seedlings sown early in spring should be transported to outdoor fields for further growing when there is no longer danger of late spring frosts (beginning of June in Southern Finland) or protective (covering) materials and measures, such as water spraying through irrigation units, should be available to protect the seedlings in the case of frosts.



Outdoor fields with irrigation equipment in Joroinen (UPM) (on the left) and (on the right) in Suonenjoki (Finnish Forest Research Institute) (photo A. Zhigunov).

The second seedling crop, seedlings sown in June, should be transported to outdoor fields in August (September). On an outdoor field,

there should be water spraying facilities in case of early autumn frost.

In the case of one seedling crop, seedlings should be kept in a greenhouse when the first autumn frosts come (the end of August). They are transported to outdoor fields at the end of September, when the seedling buds are completely formed and the sprouts become lignified enough.

In order to protect the seedlings from early autumn frosts, it is desirable to apply additional potassic fertilization as well as short-day treatment for early, good and simultaneous formation of apical buds.

In order to protect the seedlings in outdoor fields from low temperatures in October, it is necessary to cover them with artificial snow or covering materials if it has not snowed.

4. Nursery hygiene

4.1 Weed control

First principal idea is to keep nursery area as clean of weeds as possible. Weeds should be weeded away (manually or chemically) from outdoor fields and other areas near to greenhouses. It is important to take weeds away before their seeds ripen.

If peat substrate is extracted and stored properly, it should usually be free of weed seeds. However, during the growing season, containers usually get some weed seeds via air or irrigation water. If the irrigation water comes from open water sources (without filtering), the risk of getting weed seeds is much higher than in the case when irrigation water comes from an artesian wells. If weeds are numerous, they must be weeded away manually or chemically.

For controlling growth of mosses in the establishment phase it is important that the surface layer of the growing medium should get dry between the irrigations and irrigations should be conducted at morning time.

4.2 Disease and pest control

The nursery should be located on a site where air movements are obvious. If the nursery is surrounded by forests, they should be healthy and thinned quite sparse near the nursery in order to enhance air movements. The nursery should not be located on a place where spring or autumn frosts are most typical.

Greenhouses should be kept as clean as possible. They should be cleaned and disinfected regularly between seedling crops. Disease and pest control is performed regularly both in greenhouses and outdoor fields.

Clean environment near greenhouses in UPM nursery (Joroinen) (photo A. Zhigunov).

Damping-off is seldom a problem in peat substrate, but the quality of seeds is crucial. Some of the damping-off fungi are seed borne and thus, hygiene in seed collection and storage is important. If there is a

risk for seed borne fungi, it is possible to treat seeds before sowing with fungicides.

It is important to arrange good aeration for container root systems and avoid excess irrigation. Especially root die-back in containers (caused mainly by *Rhizoctonia* and *Pythium* species) can be a problem if the growing medium is kept too wet and anaerobic (especially if the containers are on the ground level).

In order to prevent the development of gray mold caused by *Botrytis cinerea* Pers., it is necessary to maintain the relative humidity of the air in the greenhouse at the level of 60 – 70 %, remove deteriorated plants, besides, irrigation should be performed always at morning time.

Fungicide treatments are usually needed against gray mold and the seedling lot needs 3 – 4 treatments during the growing period. These fungicide treatments also protect the plants from sclerophoma (*Sclerophoma pythiophila* (Corda) v. Hohnk.), tiphulia, alternaria (v. *Alternaria*), and overwintering diseases (*Phacidium infestans* Karst.).

The plant resistance to diseases can be enhanced by artificial mycorhization, by adding different preparations to the peat substrate.

In the case that rodents significantly increase in number, which happens, on the average, every four years, they may eat up the seeds, shoot and browse on bark. Measures should be taken to exterminate them: use break-back traps, catching cylinders and toxic baits on the territory in the vicinity of greenhouses. It is also allowed to apply various rodenticides. All seedling storages outdoors must have a metal fence around in order protect seedlings from vole or other rodent damages.

5. Quality control

In the process of growing, seedlings must reach the parameters prescribed by the standards for a certain forest zone. In order to follow up the quality of a seedling lot, samples of containers (or seedlings) are controlled several times during the seedling production. The first inventory is made in the sowing phase. One container is sampled, for instance, every second full hour in a working shift. The number of sown seeds, the amount and compaction degree of the growing media and the amount of mulching material will be examined in each cell of that container. Secondly, the number of germinated seeds and number of empty container cells will be inventoried from the same containers after 21 days from the start of seedling production (from the start of irrigation).

The third inventory is made in the autumn time, when seedlings are ready for storage or for autumn planting. At this inventory, the height from a sample of 100 seedlings (200 seedlings if the seedling lot is larger than 1 million seedlings) will be measured. A sample of 100 seedlings is further stratified in 10 subsamples which are randomly located in the seedling lot. The mean height of the seedling lot is the mean height of the qualified seedlings in the sample. The seedlings which are growing in the nursery for the second year will be reinventoried in the second spring and autumn again.

After winter storing in cold or cool storage or outdoors, the Root Growth Potential test is one way to check out the viability of the root system. RGP-test consists of placing a random sample of seedlings into an environment that promotes rapid root growth (temperature about 20 °C, optimum irrigation). After 14 to 28 days, the seedlings are evaluated for new root growth.

6. Sorting, packing and storing

6.1 Sorting routines

In the autumn or spring before shipping, the seedlings are sorted according to quality standards. The seedling must be healthy (no diseases or defects), and it should have a well-formed healthy bud, sound green needles, straight stem with no multiple main shoots and healthy roots binding the whole plug. Also, the height and diameter should be in right relation to the growing density and size of the container cell.

Size classes of conifer container seedlings used in Finnish nursery companies

Size class	Cell volume, cm^3	Growing density, seedlings/m^2	Age, years	Target mean height of spruce seedling lot, cm	Target mean height of pine seedling lot,cm
Mini	15-50	500-3000	0,5	-	5-8
Small	50-90	600-1500	1	12-20	6-14
Medium	90-125	400-800	1,5-2	15-25	10-18
Large	125-225	300-600	2	20-30	14-24
Max	> 225	< 300	≥ 2	30-50	-

6.2 Packing and storing

Before packing and transferring seedlings from outdoors (or in some cases from the greenhouse) to winter storage, it is safe to check the state of cold hardiness of the seedlings. One way to check cold hardiness of shoots is to determine the dry matter content of the seedling. From a sample of shoots, fresh weight is measured and the sampled shoots are dried, for instance, in microwave oven and weighted again. The cold hardiness of shoots is strong enough for packing and storing if the dry matter content is more than 33 – 36 % (spruce and pine). The genetic origin has some effect on development of cold hardiness. There is no practical method for testing cold hardiness of roots.

Winter storage on an outdoor field. 2-year-old spruce seedlings are waiting for snow cower (photo T. Saksa).

Seedlings are stored either in the outdoor under natural or artificially made snow cover, or seedlings are packed into plastic-laminated cardboard boxes or plastic or paper bags and placed in refrigerated storage for the wintertime.

Cold storage full of seedlings in cardboard boxis. (photo J. Nerg).

In a cool storage, the temperature is about 0 to +2 °C and relative humidity is high (80 – 100 %). In a freezer storage, the temperature is a little lower -4 – -5 °C. Freezer storage is a long-term storage (2 to 8 months) and cool storage is better for short times (2 weeks – 2 months).

6.3 Preventive pest control

In order to prevent the seedlings from fungus diseases during winter storage, they are treated with fungicides. If the plants are kept in outdoor fields, preference is given to fungicides that are more resistant to washing off with rain water.

Before the seedlings are transported to a regeneration area, they must necessarily be treated with insecticides (synthetic pyrethrum) to protect the seedlings against the pine weevil (*Hylobius abietis*) damages.

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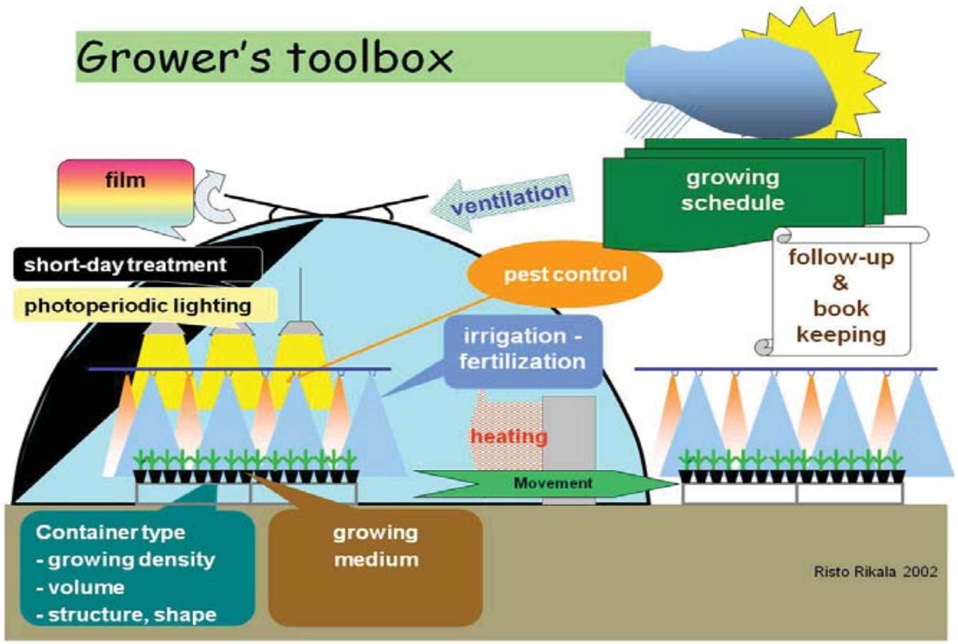
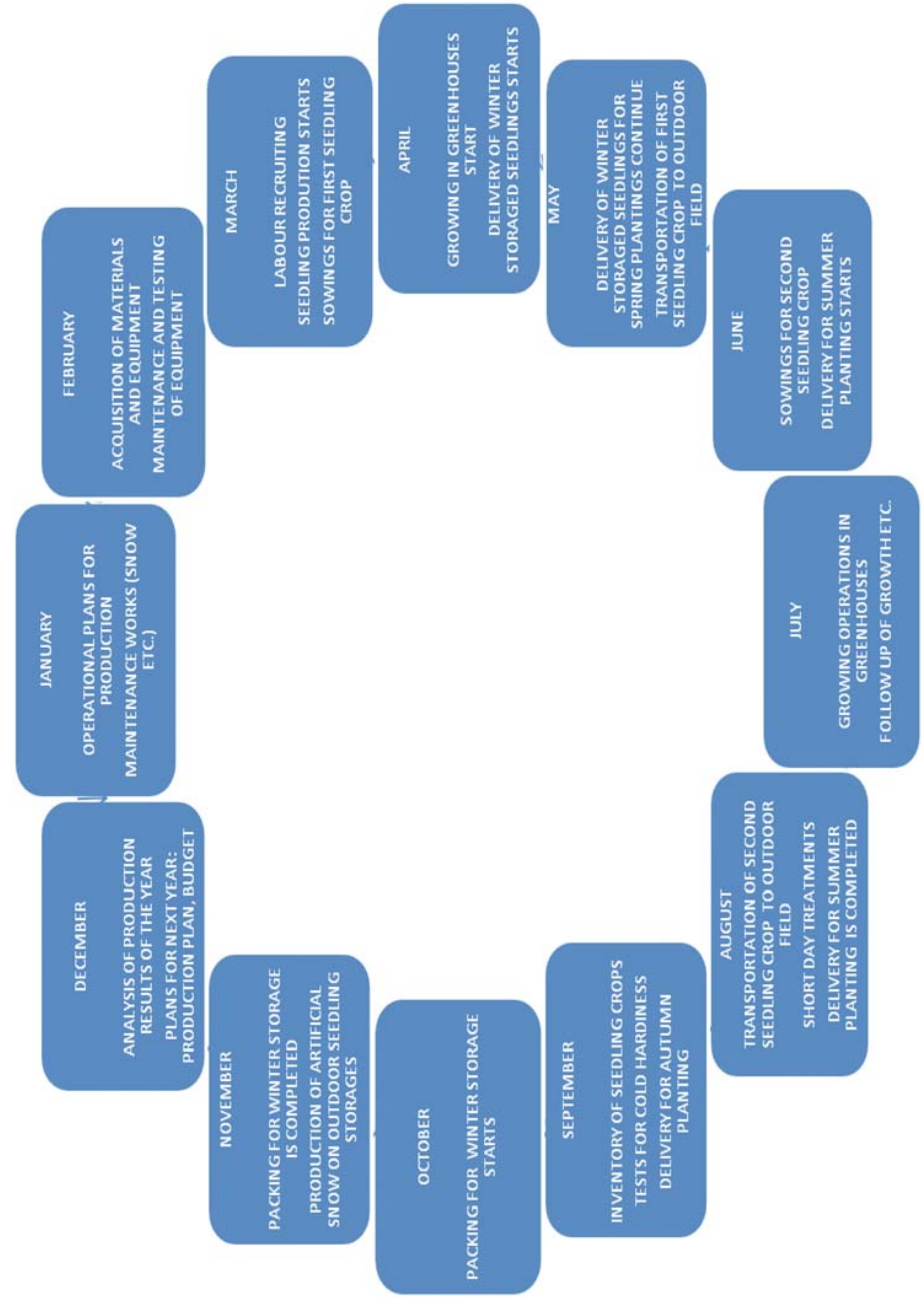
Appendix

The most important equipment and growing operations used in a container seedling nursery





Operations in the seedling production process during the whole year. (Fin Forelia 2011)

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