The Quality of Pine and Spruce Planting Stock in Estonia

HEINO SEEMEN AND ANDRES JÄÄRATS
Department of Silviculture, Estonian Agricultural University, Kreutzwaldi 5, 51014 Tartu, Estonia, e-mail: heino.seemen@eau.ee

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Abstract

The present research is a comparative analysis of how the main quality indices of cell-grown and bare-rooted planting stock - plant height, root collar diameter and their ratio, above-ground biomass, below-ground biomass and their ratio - conform to the existing planting stock standard in Estonia. Data were collected from the nurseries in different state forest regions in the period 2001-2003. Pine and spruce cell-grown plants were grown in Ecopot containers with the density of 400 plants per m^2, bare-rooted pine seedlings and spruce transplants were grown using traditional field-grown technology.

The mean height of the same species container-grown and bare-rooted plants differed relatively little (7-14%). The root collar diameter of pine container-grown stock formed 69% and the corresponding index of spruce container-grown stock 51% from the root collar diameter of the same species bare-rooted plants. The above-ground mass of container-grown spruce stock was on average 4.7 times smaller than the corresponding number of bare-rooted transplants, the relative difference between above-ground mass of pine container-grown stock and bare-rooted seedlings was smaller (2 times). Beside measurements the proportional development of different plant parts is essential as well. It turned out that the root mass of the 2-year-old bare-rooted pine seedlings was relatively small compared with above-ground biomass (above-ground and below-ground dry mass ratio was 4.9-6.4), which may decrease plant establishment in cultivating. Spruce container-grown stock had too high height and root collar diameter ratio (6.6-8.3), which make plants in cultivation less resistant to physical damage factors.

Key words: Scots pine, Norway spruce, bare-rooted plants, cell-grown plants, quality of plants

Introduction

The main forest usage in Estonia is timber production. In intensive forest management region the most rational timber stocking takes place through clear cut. Using clear-cut system the safest and fastest possibility for a new forest generation will be reforestation. The natural regeneration lasts for years, the result of which will be the majority of different aged broad-leaved forests. Considering Estonian climatic and soil conditions, coniferous stands should be preferred. Establishing pine and spruce plantations can only make it possible.

Hitherto mainly bare-rooted planting stock has been used for afforestation in Estonia: as tradition pine plantations are set with the 2-year-old seedlings (sowing is also used) and spruce plantations with the 4-year-old spruce transplants. We have more than 100-years experience in growing bare-rooted seedlings and transplants. Long-running afforestation experiences confirm the successful use of such planting stock. But in Nordic countries (Finland, Sweden, Norway) during the last decades 80-90% of forest planting stock has been taken over by cell-grown planting stock. It has left its effect on the silviculture in Estonia. The first experiment with container-grown stock here was made in the 1980s. During that time at the Estonian Forestry Institute nursery pine and birch paperpot plants were grown and hundreds of hectares of forest plantations were established at least in 9 years. That time the paperpot plants were not approved by foresters and due to additional technical problems the production was stopped. There is little data on cultivation growth of that period. Some initial growth analysis has been made by H. Paal (1991). According to his data during the first decade of planting, paperpot plants grew a little worse than the 2-year-old bare-rooted pine seedlings and much worse than same age plants of natural regeneration. H. Paal has attributed it to poor root system of the paperpot plants. Later H. Seemen (2001) has studied the position of pine cultivations planted with paperpot plants in the 1980s. The author has found only some left cultivations, some of them had totally perished and cultivated the second time or left for natural regeneration, some mostly filled in by repair planting.

In the same period cell-grown planting stock was tried to grow by rolling method. Using the suitable agrotechnology spruce plants up to 70-cm high were grown in two years. Still most of the plants in the cultivations were perished. Their crowns were herbaceous and weakly developed, shoots and needles softer and more elastic than those of open-field grown plants. Therefore wild animals and vermin attacked these cultivations. Their root system was badly deformed (Terasmaa 1981, 1985).

Despite negative results in Estonia the growing of cell-grown planting stock was started again in 1995. By 2007 the production may rise up to 7 million plants per year. Undoubtedly the growing of cell-grown plants has some advantages compared with the growing of bare-rooted plants. The main point is that the plant production can be taken at the industrial level with fully checked growing conditions that will ensure stable production capacity. Planting with such material is very comfortable and fast, but these are initial advantages. The production of planting stock cannot be the goal by itself, it is only the first stage in silviculture. Therefore it is important to know which planting stock qualities will give a new normal forest generation. That is why, at first, the most important growth indices of planting stock types should be found out and compared, the growth and development of forest cultivations established with plants with various quality should be examined, and only then motivated quality standards to planting stock should be set. This helps keep low-quality plants away from a market and estimate plant growers work by the standards.

When Estonia regained independence temporary standards for the estimation of planting stock were used. After passing the law of seed and plant reproduction (1998), the regulation by Minister of Environment laid down requirements for forest planting stock. These were based on the standards valid in the former Soviet Union. The changes in silviculture as well as in forest cultivation technologies force to reconsider the requirements for planting stock. In Estonia new quality requirements for planting stock are being worked out.

The aim of the research work is to find out the differences in main quality indices of spruce and pine plantings and to compare the results with valid standard requirements. The results will be considered in working out the development strategies of forest plant growing suitable for Estonian conditions.

Materials and methods

The material for the analysis of main quality indices of planting stock was collected from 4 different state forest nurseries in Estonia (Koeru, Marana, Reiu, Räpina) during the years 2001-2003. Koeru nursery grows container-grown planting stock on Lännen line, using Ecopot and Plantek type containers. Marana, Reiu and Räpina nurseries grow bare-rooted planting stock on the standard field-grown nursery regime. In the research the growing indices of 1+0 Ecopot pine seedlings, 2+0 Ecopot spruce seedlings, 2+0 bare-rooted pine seedlings and 2+2 bare-rooted spruce transplants are dealt with. All the above-mentioned planting-stock types are used for forest cultivation in Estonia. The data characterising the nurseries are given in Table 1. The open-field nurseries have moderately acid to neutral loam soils with relatively low nitrogen content, but with high phosphorus and potassium content.

To estimate the planting stock quality the following indices of the plants were fixed: height (the last-year height increment of spruce plants was measured as well), root collar diameter, above-ground dry mass, root length and root dry mass. According to measuring results the ratios of height to root collar diameter and shoot to root mass were calculated. The height of seedlings and transplants and root collar diameter were measured on dug-out plants. In field-grown nurseries the plants were dug out along the diagonals on fields with fixed intervals (10-15 m); pot-grown plants were chosen at random. The plant height was measured with 0.1 cm interval from root collar to a top bud, root collar diameter was measured with 0.1 mm interval. The roots of container-grown stock were cleaned from peat substrata, field-grown stock roots from soil and they were washed; the above-ground and below-ground parts of the plants were dried in thermostat

Table 1. Nursery characteristics

Nursery		Type of plant	Soil				
					Nutrient content		
Name	Place		Texture	pH_{KCl}	N %	P_2O_5 mg/100g	K_2O mg/100g
Koeru	58°57'N 26°1'E	cell-grown pine cell-grown spruce	peat peat				
Marana	58°9'N 24°56'E	bare-rooted pine bare-rooted spruce	loam loam	4.6 4.6	0.13 0.13	21.4 21.4	12.3 12.3
Reiu	58°20'N 24°36'E	bare-rooted pine bare-rooted spruce	loam loam	5.5 5.0	0.08 0.1	14.4 10.9	23.5 35.0
Räpina	58°6'N 27°29'E	bare-rooted pine bare-rooted spruce	loam loam	6.7 6.0	0.08 0.1	22.4 31.2	23.0 34.3

up to the constant weight at +60 °C. 30 plants were measured from each treatment. The measuring results were processed by Microsoft Office Excel (Kiviste 1999).

Results

Height of plants

The height of plants is one of the most essential quality indices. By the laid-down standards for forest planting stock in Estonia there are the following requirements for the height: the 2-year-old pine seedling - at least 8 cm, the 2-year-old spruce seedling - at least 8 cm, the 4-year-old spruce transplant - at least 22 cm. The survey about planting stock heights in the nurseries is given in Figure 1.

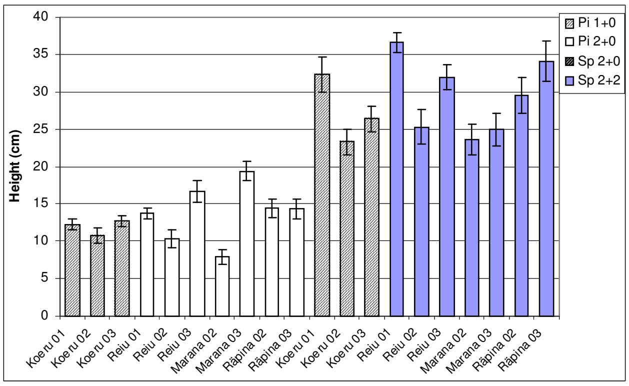

Figure 1. Height of cell-grown and bare-rooted pine and spruce plants

Key: Pi 1+0 - 1-year old cell-grown pine seedlings
Pi 2+0 - 2-year old bare-rooted pine seedlings
Sp 2+0 - 2-year old cell-grown spruce seedlings
Sp 2+2 - 4-year old bare-rooted spruce transplants

The mean height of pine container-grown stock in Koeru nursery in 2001-2003 was 10.8-12.7 cm, the height of spruce plants in the same period was 23.3-32.3 cm. Thus the height of container-grown stock corresponded to the existing standards.

In Reiu nursery the fixed height criterion by the standard for bare-rooted plants was followed with the 2-year-old pine-seedlings as well as with the 4-year-old spruce transplants, the mean height was 10.3-16.7 cm and 25.3-36.6 cm, respectively. In Räpina nursery pine and spruce plants with the standard height were grown too. They had the mean height 14.3-14.4 cm and 29.5-34.1 cm, respectively. The height of the 2-year-old pine-seedlings varied remarkably in Marana nursery. In 2002 the height of pines was 7.9 cm, in 2003 it was already 19.4 cm. The difference in spruce height was not essential (23.6 and 24.9 respectively). In general the plant height in 2002 was less than that in 2001 and 2003, in most cases the difference was statistically important. Probably the reason for that was the hot and dry summer in 2002.

By comparing the mean heights of planting stock with different root system it can be seen that both pine and spruce field-grown stock were higher, although for spruce the difference was not statistically essential (Table 2).

Table 2. Growing and mass average parameters of pine and spruce plants

Key: H - height
D - root collar diameter
H/D - height and root collar diameter ratio
Mabove - shoot dry mass
Mbelow - root dry mass
Mabove/Mbelow - shoot and root dry mass ratio
x - mean value
Sx - standard error
CV - coefficient of variation
P - relative standard error
t - Stat - t-Test value
* - p<0,05

Parameter	Statistic	Pine			Spruce		
		cell-grown	bare-rooted	t-Stat*	cell-grown	bare-rooted	t-Stat*
H, cm	x±Sx	11,9±0,4	13,8±0,6	4,8	27,3±0,9	29,4±1,1	1,4
	CV	21	25		21	21	
	P	3	4		3	4	
D, mm	x±Sx	2,7±0,1	3,9±0,2	12,9	3,6±0,1	7,1±0,2	24,9
	CV	16	31		18	21	
	P	4	5		3	3	
H/D	x±Sx	4,5±0,2	3,7±0,2	6,8	7,6±0,2	4,2±0,1	22,1
	CV	20	25		15	18	
	P	4	5		3	2	
Mabove, g	x±Sx	1,38±0,06	2,76±0,19	11,0	2,52±0,16	11,78±0,82	25,3
	CV	37	49		37	41	
	P	4	7		6	7	
Mbelow, g	x±Sx	0,55±0,03	0,53±0,06	1,2	1,02±0,08	5,23±0,41	24,9
	CV	38	65		46	45	
	P	5	11		8	8	
Mabove/M below	x±Sx	2,8±0,2	5,5±0,3	11,5	2,8±0,2	2,4±0,1	0,2
	CV	45	28		34	27	
	P	7	5		7	4	

The significant index of spruce transplants height dynamics is the increment of the last year. The height increment of 4-year-old bare-rooted spruce transplants measured last year should be close to the height sum of the first three years (Laas 1962). Thus for the 4-year-old spruce transplants the height increment of the last year should form about 50% of the plant height. In this research it was found out that the last-year increment formed about 80% of container-grown spruce height and 25-59% of the 4-years old spruce transplants height.

The proportion of standard transplants in whole production enables to estimate agrotechniques used in plant husbandry. 95-100% of pine container-grown stock and 70-87% spruce container-grown stock had the height required in the height standard. From bare-rooted pine seedlings 70-100% of the plants had the required quality, from the 4-year-old spruce transplants 67-100%.

Root collar diameter

The second essential standard index of plants is root collar diameter. Root collar diameter at the given height mostly depends on growth space during the previous growing period. The minimum requirements for coniferous planting stock root collar diameter in Estonia are the following: the 2-year-old pine seedlings - 1.5 mm, the 2-year-old spruce seedlings - 1.5 mm, the 4-year-old spruce transplants - 4mm. The planting stock root collar diameters grown in various nurseries are given in Figure 2.

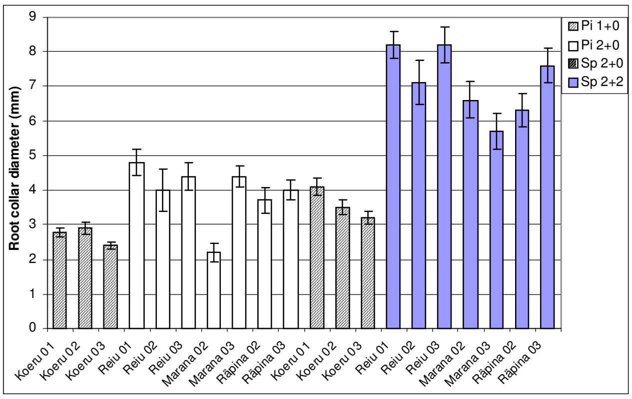

Figure 2. Root collar diameter of cell-grown and bare-rooted pine and spruce plants
Key as in Figure 1

In 2001-2003 the root collar of Ecopot pine plants was 2.4-2.9 mm, at the same time the indices of container- grown spruce stock were 3.2-4.1 mm. Thus pine root collar diameter was about 2 times higher and spruce plants were nearly according to the standard.

In Reiu nursery during 2001-2003 the bare-rooted the 2-year-old pine seedlings had the root collar diameter according to the standard (the corresponding index 4.0-4.8 mm). The same can be seen in Räpina and Marana nurseries in 2002 and 2003 with pine plants (accordingly 3.7-4.0 and 2.2-4.4 mm). The root collar diameter of spruce transplants was higher than the required minimum in all cases. The root collar diameter of spruce transplants exceeded the standard index in Reiu nursery by 78-105%, in Räpina nursery by 58-90% and in Marana nursery by 43-65%.

By comparing the average numbers of root collar diameter of container-grown stock and bare-rooted seedlings it was found out that the according number of bare-rooted both pine and spruce seedlings was essentially bigger than the number of container-grown stock (in case of pine seedlings it differed by 1,5 times; in case of spruce 1,9 times) (Table 2). The diameter conformed 100% to the bare-rooted and cell-grown pine seedlings and spruce transplants standard. Spruce container-grown seedlings conformed 10-54% to the diameter criterion for transplants.

Plant height and root collar diameter ratio

Plant height and root collar diameter ratio is a complex index, which represents the effect of the both important quality indices. The results of this research have shown that Ecopot pine height and root collar diameter ratio on average is a little bigger than that of the 2-year-old seedlings - 3.7-5.4 and 2.7-4.5, respectively. There were some differences between nurseries. Reiu nursery plants had height and root collar diameter ratio 2.7-3.9, Marana and Räpina plants had 3.7-4.5 (Figure 3). The 2-year-old spruce container-seedlings had height and root collar diameter ratio 6.6-8.3 (in 2000 even 8.3-8.8). Thus Ecopot spruce plants had normal height, but the root collar diameter was relatively small. The dealt index of the 4-year-old bare-rooted spruce transplants grown in different Estonian nurseries was 3.6-4.7. The average values of height and root collar diameter ratio of container-grown plants were essentially bigger than those of bare-rooted plants (Table 2).

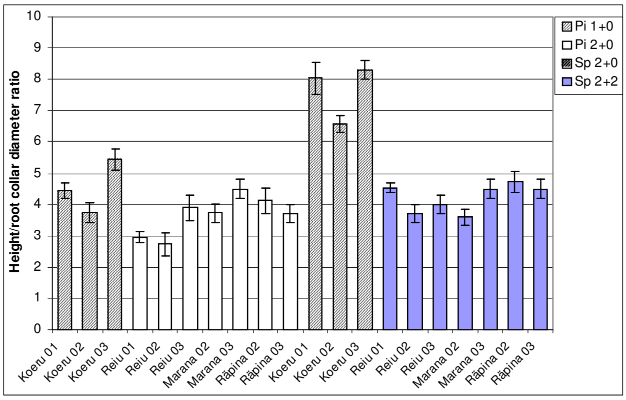

Figure 3. Height and root collar diameter ratio of cell-grown and bare-rooted pine and spruce plants
Key as in Figure 1

Above-ground and below-ground dry mass of plants

The above-ground dry mass of different types of spruce planting stock varies greatly. When the corresponding index of container-grown spruce stock on average was 2.5 g (2.2-3.0 g), the 4-year-old spruce transplants mass on average was 11.8 g (7.2-15.7 g), the difference was 4.7 times (Figure 4, Table 2). The relative difference of the above-ground mass of Ecopot pine plants and bare-rooted seedlings was smaller (2 times), the indices 1.4 g (0.9-1.6) and 2.8 g (0.9-3.9 g), respectively. The root masses of spruce planting stock distributed in general proportionately with above-ground masses: the mean mass of Ecopot plants' roots was 1.0 g (0.9-1.1 g), whereas that of bare-rooted seedlings was 5.2 g (3.6-6.1 g). The mean mass of Ecopot pine roots (0.6 g) did not differ much from the mass of the 2-year-old bare-rooted seedlings (0.5 g) (Figure 5, Table 2).

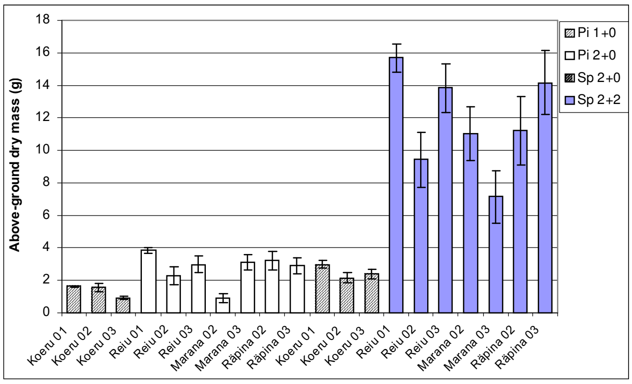

Figure 4. Above-ground dry mass of cell-grown and bare-rooted pine and spruce plants
Key as in Figure 1

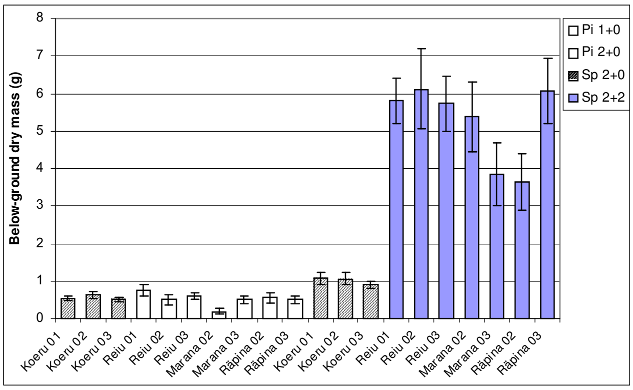

Figure 5. Below-ground dry mass of cell-grown and bare-rooted pine and spruce plants
Key as in Figure 1

Above-ground and below-ground dry mass ratio of plants

According to our data the Ecopot spruce shoot and root ratio was 2.2-3.4 and that of the 4-year-old transplants was 1.6-3.2 (Figure 6). The average values of shoot and root ratio of container-grown and bare-rooted spruce plants did not differ essentially (Table 2). Surprisingly high disproportion could be seen with the 2-year-old pine seedlings, shoot and root index 4.9-6.4. The corresponding index of pine Ecopot plants was 2.1-3.8. The average value of shoot and root ratio of bare-rooted pine seedlings was essentially bigger than that of container-grown seedlings (5.5 and 2.8, respectively).

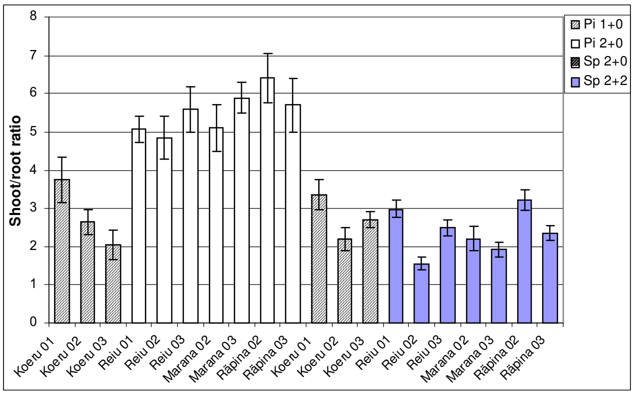

Figure 6. Above- and below-ground dry mass ratio of cell-grown and bare-rooted pine and spruce plants
Key as in Figure 1

Root length

There are no standards set to plant root system length in Estonia at the moment. By the former valid standards root system length was recorded. Pine and spruce seedlings root system length was differentiated by the cultivated soil moisture - in overmoistured soils it could be shorter (10-20 cm), in dry soils longer (20-30 cm) (GOST 3317-77). Thus the root length of spruce transplants should have been at least 20-25 cm.

The root system length was limited by a container volume with cell-grown pine and spruce plants. Pine as well as spruce plants had a main root reaching up to 5-8 cm. The root system of bare-rooted plants was different. The 2-year-old pine seedlings had clearly formed main root, the length of which was 13-19 cm. There was no main root in the 4-year-old spruce transplants. The length of fibrous root system was between 23 and 29 cm. Thus root system length was according to valid standards. Expedience of the root system length of bare-rooted plants was problematic as at preplanting stage roots were cut. Therefore the decisive factor for plant establishment may be not the initial root length, but the extent of root cutting.

Discussion

The quality of planting stock has a strong effect on cultivation establishment and growth in the pre-closing phase. The proper type of planting stock helps to minimise the effect of growth limiting factors during planting and at early growth stage, but it may also affect the stand management in future. Plant competitiveness is estimated by the combination of morphological and physiological qualities.

Growing of bare-rooted planting stock has more than a hundred-year history in Estonia. Good establishment and successful growth of forest cultivations show that these plants are suitable for forest regeneration. But the effect of using container-grown planting stock is not clear, experiences in the 1980s are rather negative. As the production volumes of container-grown planting stock have been small, the quality indices of such plant have not been studied and the requirements have not been worked out. Also there is no suggestion how to use container-grown plants depending on growth site type. As container-grown plants are used in the same conditions as traditional planting material these are estimated according to the same quality indices. In countries where container-grown plants have been used for longer time, special requirements have been worked out.

The size of a plant (measurements and mass) is the most important morphological characteristics of planting stock. The size of plants must make up for the effect of limiting factors in tree growth. A high strong plant is more resistant to various physical damage related factors (snowpack effect, vegetation press, insect and wild animals damages). A bigger trunk diameter help to avoid plant bent. Such trees are less browsed and more resistant to weevil and rodent damages.

In Estonian silviculture it is old wisdom that useage of bigger planting stock on more fertile woodlands will give better results. The advantages of taller planting stock, good quality spruce transplants and disadvantages of the 2-year-old seedlings for spruce cultivation are repeatedly stressed (Laas 1962, 1973, Paal 1962, Paas 1962). In 1954-1955 the transplants use in spruce cultivation was regarded as breakthrough in Estonia. In foreign corresponding literature it is mentioned that taller plants establishment is better and they grow faster than smaller ones (South *et al*. 1985, van den Driessche 1991). By D. South and W. Mason (1993) research smaller plants cannot reach the taller tree growth and in crown association they remain in undergrowth. Long-term growth studies with Norway spruce have demonstrated that size differences at planting can last for 9 years or more. The Estonian research has confirmed that growth preference stays at least for 10-12 years after cultivation (Laas 1984, Margus 1988, Terasmaa 1991). But there can be found the research showing a big plant height may reduce the establishment and growth of bare-rooted as well as cell-grown planting stock due to after-planting water stress. A bigger planting stock has a bigger leaf area. Deformed root system cannot cover the increased transpiration, which, in its turn, leads to transpiration decrease, assimilation decline and establishment and growth worsening (Lamhamedi *et al*. 1998). Thus after 2-3 years of planting the growth increment of taller pine seedlings was less than the corresponding index of smaller plants, the differences in seedling height were levelled (Valtanen *et al*. 1986). In Lithuania for an experimental plot the 1-year-old small (height 4.5 cm and root collar diameter 2.3 mm) and 2-year-old big (height 21.4 cm and root collar diameter 4.2 mm) pine seedlings were used, but their establishment did not differ much. In the first two years after planting the increment of small plant height was more, but due to the greater initial height big plants remained taller (Suchockas 1999). At the same time it has been found the enlarging leaf area increases the plant sensitivity to water stress only in the extreme conditions where air humidity and soil moisture are in deficiency (Lamhamedi *et al*. 1998, Stewart *et al*. 1995). It has turned out when cultivating the loblolly pine, the plant height affects negatively establishment only in unfavourable growing conditions, in good growing conditions the connection is slightly positive (Tuttle *et al*. 1987). Bigger plants have advantage on more humid soils, the plant height has a little influence on its establishment, but taller plants have certain preference in competition with herbs. So the preferring of taller plants compensates its lower vitality. On dry soils taller plants die more in summer and their height increment is less (Stewart *et al*. 1995).

The height of pine and spruce container-grown plants grown in Estonia was only 2 cm smaller than that of bare-rooted plants and comes up to requirements on cell-grown plants' height in other countries (Finland, Canada) (Helenius *et al*. 2002, Provincial…1998, Päätos…1992). But root collar diameter of plants with different root system differed essentially – in case of bare-rooted pine seedlings it was on average 1,4 times and in case of bare-rooted spruce transplants 2 times bigger than that of cell-grown plants. At the same time the root collar diameter of cell-grown pine seedlings exceeded 1.8 times of this given in standard (1.5 mm), the according number of cell-grown spruce plants was close to standard (4.0 mm). According to the literature the root collar diameter is taken even more essential value than plant's height on which the establishment of both cell-grown and bare-rooted planting material depends (Savill *et al*. 1997). D. South *et al*. (1985), who have generalised many research results, concluded the seedlings with bigger root collar diameter have better initial establishment. The conclusion was reached in studying cultivations of loblolly pine and slash pine. But there is lack of information in the literature about the standards on root collar diameter of Scots pine and Norway spruce. In Finland the root collar diameter of bare-rooted pine seedlings of 15 cm high is at least 4.0 mm and that of the 2-years old container-grown spruce plants of 27 cm high is at least 4.0 mm (suggestion is 5.0 mm) (Rikala 2002). In Canada the demanded minimum root collar diameter of the 1-year-old container-grown spruce seedlings is 2.4 mm (Provincial…1998). According to the EEC Standard being valid in former times in European Union the minimum root collar diameter of the 2-year-old pine seedlings of 6-15 cm high was 3 mm; according number of the 4-year-old spruce plants of 25-40 cm high was 5 mm (EEC…1994). Root collar diameter of the 2-year-old bare-rooted pine seedlings grown in Estonia is equal to minimum values of that put into force in different countries for the plants with equal height, root collar diameter of the 4-year-old spruce transplants is probably bigger. Root collar diameter of container-grown spruce plants in Estonia is a little smaller than minimum index valid in Finland. There were no data in the literature for comparison root collar diameter of container-grown pine plants.

The height and diameter ratio (sturdiness) of plants characterizes their resistance to several physical damages. The smaller is ratio's value the stronger are plants and less they suffer under physical damages, vegetation suppression and snowpack effect. If to compare height and diameter ratios of container-grown and bare-rooted pine seedlings in Estonia it can be seen that bare-rooted seedlings are more sturdy (3.7). In Finland 10-15 cm high bare-rooted pine seedlings had height and diameter ratio 3.3 - 3.8 (Rikala 2002). Container-grown spruce plants had very high height and diameter ratio (6.6-8.3) in Estonia, according to the literature it should be between 5.0-5.5. The according average number of the 4-year-old spruce transplants was 4.2. So the container-grown plants were too stretched out. To avoid inappropriate height and diameter ratio, in Finland the maximum height limits are set for container-grown spruce stock, depending on the container type. The height and diameter ratio in Finland is 3.5-4.7 given for container-grown spruce plants based on minimum height and root collar diameter, in case of recommended height and root collar diameter it is 5.4-6.4 (Rikala 2002). In British Columbia (Provincial…1998) on the basis of the standard height and root collar diameter for container-grown spruce stock height and diameter ratio values of the one-year-old seedlings were 5.6-8.0, the values of the 2-year-old plants were 5.3-5.4. The Douglas fir, the lodgepole pine, the white spruce seedlings while growing in 3-12A Styroblock containers (volume 60 ml) height and diameter ratio values of the 1-year-old plants were 6.2-8.6 (van den Driessche 1991).

Besides plants' height and root collar diameter, above- and below-ground biomass and their ratio are considered to be important in cultivating. In Nordic countries the reciprocal value of the mentioned ratio (root/shoot) is used (Vapaavuori *et al*. 1992). For plant characterisation the horizontal projection area root system and shoot mass ratio are used as well (Martinsson 1986). In this research it was found out that bare-rooted both pine and spruce stock had essentially bigger above-ground biomass than container-grown stock. Also the 4-year-old spruce transplants had essentially bigger root mass than container-grown spruce plants. In case of pine with different root system there were no essential differences in root mass.

In accordance with the U.S.A. research data the establishment of Douglas fir and ponderosa pine seedlings with the same height depends on its root system spread. The establishment of Douglas fir seedlings with large root system was 22-26% and the establishment of pine seedlings was 6-16% higher than the plants with smaller root system had. In case of both species the height increment of plants with large root system exceeded 1.2-1.7 times that of plants with smaller root system (Lopushinsky *et al.* 1976).

Obviously the establishment of plants is better when their above-ground and below-ground parts are in balance. Shoot and root ratio is the morphological index, which is used mostly to estimate bare-rooted planting stock, less to estimate container-grown planting stock. Generally smaller shoot and root ratio is considered to be better. In case of a higher index, too large canopy compared with root system may be expected. After planting such plants tend to lose much water from transpiration because a higher proportion of foliage is shade adapted, lacking sufficient cuticular waxes. They are also less sturdy hence more prone to being damaged by vegetation or snowpress. (Provincial…1998). Disproportionate plant above- and below-ground parts are taken as the main reason for planting shock. Experiments with Douglas fir, lodgepole pine and white spruce containerised seedlings showed the shoot and root ratio as 1.77-2.25 whereas a low shoot and root ratio had favoured plant establishment in dry soils (van den Driessche 1991). From the corresponding literature other evaluations to shoot and root ratio as the plant quality index can be found. P. Bernier *et al.* (1995) who have generalised the research results about shoot and root ratio, have found in most cases an increased shoot and root ratio index does not affect coniferous containerized seedlings establishment and growth. In accordance with the U.S.A. research the afterplanting establishment of loblolly pine plants is negatively connected with plant height (r= -0.48- -0.50) and shoot/root ratio (r= -0.75- -0.76) and positively with plant root mass (r=0.63-0.64) (Larsen *et al.* 1986). To ensure proper establishment, it is recommended to use, especially in dry types, the seedlings with the height below 30 cm and shoot/root ratio below 2.5 (Boyer *et al.* 1987). In England there is the current rule of thumb: the shoot/root dry mass ratio should not be greater than 3:1 (Aldhous 1994), ratio 2:1 is taken as ideal (Bernier *et al.* 1995).

If to compare our Ecopot and bare-rooted pine plants height and diameter ratio, the difference was about 20%. Comparing above-ground and below-ground part of same species planting stock biomass, there turned up an essential difference: the bare-rooted seedlings had 2 times higher above-ground part biomass compared with that of Ecopot plants, but the same root system mass. It means bare-rooted seedlings have the root system with relatively small mass. Therefore the shoot and root ratio of bare-rooted pine seedlings was 5.5 and that of cell-grown plants was 2.8. From the literature similar data can be found. So the bare-rooted jack pine seedlings had shoot and root ratio 3.5, cell-grown had ratio 1.6; black spruce plants had ratio 2.0 and 1.4 (Grossnickle *et al.* 1987), respectively. This may cause worse establishment of the 2-year-old pine seedlings. According to the data in the corresponding literature the shoot and root biomass balance seems to be less important to pines than to spruces. The experiments with the 2-year-old bare-rooted ponderosa pine seedlings have demonstrated (Lopushinsky 1976). It is possible that the reason is pine's higher drought resistance. But there have been cases showing the ratio between establishment and height and diameter ratio or shoot and root dry mass ratio has been low in types and in years when soil is humid enough and it is high, when soil humidity acts as a limiting factor (Stewart *et al.* 1995).

Above- and below-ground biomass of the 4-year-old spruce transplants was essentially larger than those of cell-grown plants but the ratio of these indexes did not differ essentially. Therefore high establishment in cultivating with cell-grown spruce plants can be predicted. Due to high height and diameter ratio and less developed canopy cell-grown spruce plants are prone to several unfavourable factors such as competition with herbs and natural regeneration of deciduous, vegetation and snow press, damages of wild animals and insects. To decrease bad results of mentioned factors it is necessary to increase the volume of maintenance works, which makes cultivations established with cell-grown spruce plants more expensive than in using the 4-year-old spruce transplants. Also cell-grown spruce plants are more expensive than bare-rooted plants and it causes the increase in cultivation's cost.

Conclusions

The height indices differed relatively little between the bare-rooted and container-grown plants (7–14%). The root collar diameter of container-grown pine seedlings formed 69% and corresponding index of container-grown spruce planting stock 51% from the bare-rooted planting stock diameter growth. The differences between dry masses were also found out. The above-ground dry mass of container-grown spruce stock on average was 4.7 times smaller than the same number of bare rooted transplants, the relative difference between above-ground mass of pine container-crown stock and bare-rooted seedlings was smaller, 2 times. It was turned out that the root mass of the 2-year-old bare rooted pine seedlings was relatively smaller as compared with above ground biomass (above-ground and below-ground dry mass ratio was 4.9-6.4), which may decrease plant establishment in plantations. Spruce container-seedlings had too high height and root-collar diameter (h/d) ratio (6.6-8.3), which make plants less resistant to physical damages in plantations.

Since 1999 1999/105/EC directive regulates planting stock quality and international planting stock market. There are no concrete numerical quality indices for planting stock given. Presently in Estonia it would be untimely to ignore the quality standards for forest planting stock, but they should be changed - minimum height of bare- rooted pine seedlings should be 10 cm and for spruce transplants 25 cm. The lower limit of pine seedlings root collar diameter should be much raised - from the present 1.5 mm to 3.0 mm, the root collar diameter of spruce transplants to 5 mm. There should separately be worked out quality standards for container-grown stock.

As many researchers have proved the establishment of planting stock can be influenced by plant choice, it would be expedient to divide pine and spruce bare-rooted planting stock by a plant's above-ground and root system measurements. Such division would make it possible to use plants according to soil moisture and fertility in future growing place.

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КАЧЕСТВО ПОСАДОЧНОГО МАТЕРИАЛА СОСНЫ И ЕЛИ В ЭСТОНИИ

Х. Сээмен, А. Яэратс

Резюме

В статье приведен сравнительный анализ соответствия основных показателей качества посадочного материала с закрытой и открытой корневой системой. Соответственно действующему в Эстонии стандарту на посадочный материал рассмотрены высоты, диаметры корневой шейки, соотношения высоты и диаметра корневой шейки, наземные биомассы, подземные биомассы, и соотношения наземной и подземной биомассы растений. Материал для исследования был собран в разных регионах Эстонии в лесных питомниках системы государственных лесных предприятий в период 2001–2003 гг. Растения сосны и ели с закрытой корневой системой выращены в контейнерах Ecopot с плотностью 400 растений на м^2, сеянцы сосны и саженцы ели с открытой корневой системой – в соответствии с традиционной технологией выращивания на открытом грунте.

Средняя высота растений одной и той же древесной породы с закрытой и открытой корневой системой различалась относительно мало (7–14%). Однако, диаметр корневой шейки сосны, выращенной в контейнерных условиях, составлял 69% и соответствующий показатель контейнерных еловых растений 51% от диаметра корневой шейки растений соответствующих древесных пород, выращенных с открытой корневой системой. Масса наземной части контейнерных еловых растений была в среднем в 4,7 раза меньше чем у саженцев с открытой корневой системой. Наземная биомасса контейнерных сосновых растений была два раза меньше посравнении с сеянцами с открытой корневой системой. Наряду с указанными размерами существенным является пропорциональное развитие разных частей растений. Выяснилось, что масса корневой системы двухлетних сосновых сеянцев с открытой корневой системой была относительно малой по сравнению с наземной биомассой (соотношение сухой массы наземной и подземной части составляло 4,9–6,4), что может снизить приживаемость растений при культивировании. У контейнерных еловых растений слишком большим было соотношение высоты и диаметра корневой шейки (6,6–8,3), что делает растения в культуре малоустойчивыми к физическим повреждениям.

Ключевые слова: сосна (*Pinus sylvestris*), ель (*Picea abies*), растения с открытой корневой системой, растения с закрытой корневой системой, качество растений