

## FOREST REGENERATION QUALITY – FACTORS AFFECTING FIRST YEAR SURVIVAL OF PLANTED TREES

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### Abstract

The early stage of forestry is crucial for successful and sustainable forest management. One third of the reforested forest in Latvia is regenerated by planting with different kinds of tree seedlings. The success of forest regeneration by planting depends on correctly prepared soil and choice of the right seedling material. The aim of this study was to evaluate the impact of different soil preparation methods and used type of seedlings on tree survival and growth rate after the first growing season. For this study six young stand sites located in the north-west and central part of Latvia were established in three forest types and in each site soil was prepared in furrows by disc trenching, in mound and left untreated. Reforestation was conducted in the spring of 2017 with four tree species *Picea abies*, *Pinus sylvestris*, *Alnus glutinosa* and *Betula pendula* and three seedling types were used, bare roots, containerized and improved root system. The evaluation of survival and measure of annual increment was conducted at the end of the first growing season in the autumn of 2017. Results showed that overall the highest seedling survival rate provided soil prepared in mound (90%), and seedlings with improved root system, though the lowest survival rate was observed for bare root seedlings. Containerized seedlings have a higher proportional increment if compared to bare root and improved root system seedlings, but differences are not significant yet ( $p > 0.05$ ). In conclusion, the survival rate of outplanted seedlings differs by chosen stocktype and soil preparation method used in forest regeneration and for various tree species impact of chosen stock type on survival rate differs.

**Key words:** soil preparation, stocktype, seedling establishment.

### Introduction

Latvia is located in the boreo-nemoral zone; therefore, forests consist of coniferous and broad-leave tree species (Hytterborn *et al.*, 2005). All together forests cover approximately 52% of Latvia. There are three dominant tree species Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and Silver Birch (*Betula pendula* Roth) that occupy 33.3%, 18.2%, 30.8% respectively, but black alder (*Alnus glutinosa*) occupies 3.2% of forests in Latvia (Valst meža dienests, 2018). The forest management has intensified in the last 20 years (Tērauds, Brūmelis, & Nikodemus, 2011). That is one of the reasons why successful early stage of reforestation is crucial for cost-efficient and sustainable forest management. Reforestation with planting is common practice in forestry that developed in late 19th century and from that time planting methods have been developing. There are two main milestones that will determine the success of reforestation. The chosen soil preparation method and used stocktype (Sutton, 1993). In 1920's Latvian foresters concluded that in successful artificial reforestation soil preparation is one of key elements, that positively changes edaphic factors (Kundziņš, 1939). The aim of soil preparation in forestry is to achieve higher tree seedling establishment and promote their growth and improve C – fixation. Many studies show that mechanical soil preparation methods improve the quality of forest regeneration in boreal forests (Mjöfors *et al.*, 2017). There are many soil preparation methods, but disc trenching is the most widely used one in boreal forests (Henneb

*et al.*, 2015) and in Latvia soil preparation in furrows by disc trenching is also the most popular method although also other methods are used with some advantages in certain conditions, for example, spot mounding has been used in Latvia state forests since 2013 (Lazdina, 2012).

Correctly prepared soil is important because right after planting seedlings are exposed to new environmental conditions that can be stressful for them and chosen method can reduce stress factors. For example, the root growth is essential for successful seedling establishment, because roots provide water for transpiration. Soil compaction, ion concentration, water content, soil temperature, root system size and distribution impact functionality of roots and determines the survival of the seedling (Grossnickle, 2005). Seedling type with larger root volume can increase survival rate in certain environmental conditions (Haase & Rose, 1993). Soil preparation also mixes organic humus layer with mineral soil and exposure of mineral soil reduces seedling damage by pine weevil (Nordlander *et al.*, 2011). Created tilts, mounds and furrows positively stabilize soil moisture conditions by reducing free water content in over-wet sites and raise moisture content at dry conditions (Sutinen *et al.*, 2006). Soil preparation methods can change the C sequestration and N composition in soil (Piiirainen, Finér, & Starr, 2015), and the study represents that soil preparation in furrows and ridges promotes  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{H}^+$  leaching from the upper B horizon compared to the untraded soil (Piiirainen *et al.*, 2009) and reduces the concentration

of F, Br. No<sup>2-</sup> ions (Ring, Högbom, & Jansson, 2013). Scientists have determined the pattern: if the disturbance is higher than ion leaching is also higher and potassium leaching reaches the highest point right after the soil preparation (Piirainen *et al.*, 2009). Soil preparation changes microtopography that causes favorable microclimatic conditions for decomposing organisms, because of changed environmental condition that are higher temperature, moisture, oxygen content, favourable organic and mineral soil mixture for microorganisms compared with untreated soil. All these factors together increase biological activity, including nitrogen releases happen faster in for example disc trenched soil than in unprepared soil (Lundmark–Thelin & Johansson, 1997) and the lack of plant available nitrogen is one of the key factors that determines plant growth (Örlander, Nilsson, & Hällgren, 1996). Mounding especially increases the soil temperature (Sutton, 1993), and increased soil temperature promotes chemical processes and root growth that stimulate nutrient and water uptake (Mellander, Bishop, & Lundmark, 2004), in first years after planting mounding better reduces competition for water between ground vegetation and seedlings than disc trenching in the result of reducing mortality (Archibold, Action, & Ripley, 2000), reduce risk of frost damage (Langvall, Nilsson, & Örlander, 2001). Research carried out by Örlander, Nilsson, & Hällgren (1996) showed that mounding does not increase nitrogen leaching in the first year after clearcut. Research done with Norway spruce and Scots pine seedlings planted on mounds showed a positive effect of this method in the increased survival rate and successful establishment on moist clear-cut forest sites (Mäkitalo, 1999; Hallsby & Örlander, 2004),

and this soil preparation method has a lower negative impact of the surrounding environment (Hallsby & Örlander, 2004).

Although disc trenching is a more commonly used technique, an area of soil prepared in spot mounds increases in Latvia especially in *Myrtilloso – sphagnosa* (Lazdina *et al.*, 2015). Altogether the seedling establishment and their vitality represent environmental conditions like nutrient availability, water content, temperature in different kind of planting spots (Heiskanen, Saksä, & Luoranen, 2013), but there could be one negative effect that scientists have observed that in some cases healthier coniferous seedlings are more browsed and intensity of browsing correlates with the color of the needles (Bergquist, Bergström, & Zakharenka, 2003).

Besides the right soil preparation method also the right choice for stocktype is important. For example, in comparison between bare-root and containerized Scots pine seedlings, a significant higher survival rate at the end of the first vegetation season showed containerized seedlings (Kļaviņa, Gaitnieks, & Menkis, 2013).

The aim of this study was to evaluate the impact of different soil preparation methods and used type of seedlings on tree survival and growth rate after the first growing season.

#### Materials and Methods

The study was conducted at six young stand sites on mineral soils, which were combined into three pairs depending on planting conditions and tree species and seedling type composition (Table 1). Four of these young stands are located in the north-west part of Latvia, in the county of Dundaga. One pair of sites is

Table 1

Tree species and seedling type outplanted in three forest types

Species and seedlings	<i>Vacciniosa mel.</i>	<i>Myrtilloso-sphagnosa</i>	<i>Myrtillosa mel.</i>
Spruce, bare roots	–	×	×
Spruce, containerized	–	×	×
Spruce, improved root system	–	×	×
Birch, bare roots	–	×	–
Birch, containerized	–	×	×
Birch, improved root system	–	×	×
Black alder, bare roots	–	–	×
Black alder, containerized	–	×	×
Black alder, improved root system	–	×	×
Pine, containerized	×	×	×
Pine, bare roots	×	×	×

\* (× variant that was represented in the forest type, – variant that was not represented in the forest type).

drained (*Vacciniosa mel.* forest type) with total area of 3 ha (not all planted area used in this study) located at 57.560735°N, 22.563554°E and 57.558883°N, 22.564405°E, whereas sites of the other pair are with natural water regime (*Myrtilloso-sphagnosa*) with a total area of 3 ha, located at 57.548045°N, 22.537190°E and 57.546587°N, 22.540432°E. Last two young stands are located in the central part of Latvia, in the county of Ozolnieki. The soil in both sites are drained (*Myrtillosa mel.*) with the total area of 2.8 ha, located at 56.722162°N, 23.938307°E and 56.721674°N, 23.941383°E. Each study site was divided into three parts according to what soil preparation method was used and the same methods were applied in all study sites. One part of forest land was prepared with disc trenching, the second part with spot mounding method and the third part between both other methods was left unprepared. The soil preparation was conducted in the autumn of 2016 and all these study sites were reforested by planting in the spring of 2017.

Data collection was conducted from September to November 2017. Four study plots per seedling type were established for data collection at every young stand at mounds and furrows, whereas at unprepared soil every tree was observed. Sampling plots at mounds were randomly established with an area of 25 m<sup>2</sup> (r=2.82 m), and in furrows, the same size sapling plots were established (10 m long and 2.5 m wide). In furrows, sampling plots were distributed in straight lines and the first sapling plot started 10 m

from the beginning of the furrow while the distance between plots was 10 m. The total amount of sample plots at mounds are 146 and 298 in furrows. Total height and annual increment were measured for every living tree in a sampling plot and all died back trees were counted.

The survival rate for each seedling type in each forest type was calculated by dividing count of died back trees with a count of planted trees in sampling plots. The seedling proportional increment was calculated by dividing annual increment with total height. Values were expressed as a percentage and for both parameters standard error (SE) was calculated. Mean values of a seedling proportional increment within one tree species were analyzed by two-way analysis of variance (ANOVA) and Tukey's test. Tests were done with a 95% confidence level and calculations were done by R program for Statistical Computing, Core Team (2017) version 3.4.1.

### Results and Discussion

After the first growing season the highest overall seedling survival rate was determined in soil prepared in spot mounds (90.0 ± 1.03%), in soil prepared by disc trenching survived 86.8 ± 0.83%, but in unprepared soil 88.7 ± 0.84% of all outplanted seedlings and these results confirm previous studies that planting on mounds increase planted tree survival due to favorable nutrient availability and higher soil temperature (Sutton, 1993; Mäkitalo, 1999; Hallsby & Örlander, 2004).

Table 2

Seedling survival rate (%) in three forest types depending on soil preparation method

Species and seedlings	<i>Myrtilloso-sphagnosa</i> mean ± SE			<i>Myrtillosa mel.</i> mean ± SE		
	Dt	M	U	Dt	M	U
Spruce, bare roots	92.5 ± 2.94	94.6 ± 3.71	91.5 ± 3.08	93.5 ± 2.22	94.8 ± 3.53	100
Spruce, containerized	92.7 ± 3.12	97.5 ± 2.48	94.5 ± 2.39	96.1 ± 1.90	93.7 ± 3.52	96.6 ± 3.27
Spruce, improved root system	96.2 ± 2.17	100	96.0 ± 1.96	99.0 ± 0.85	95.7 ± 2.94	100
Birch, bare roots	88.6 ± 5.38	95.2 ± 0.28	89.6 ± 4.41	×	×	80.7 ± 7.72
Birch, containerized	94.4 ± 2.73	97.4 ± 2.53	92.3 ± 0.84	83.6 ± 3.52	81.8 ± 6.71	95.2 ± 2.34
Birch, improved root system	97.2 ± 1.82	100	96.7 ± 1.83	82.4 ± 3.67	91.2 ± 4.86	83.3 ± 8.78
Black alder, bare roots	×	×	×	75.8 ± 7.42	84.2 ± 8.36	87.5 ± 11.7
Black alder, containerized	94.3 ± 2.77	100	94.7 ± 2.56	93.8 ± 4.28	94.7 ± 3.62	92.0 ± 5.42
Black alder, improved root system	100	100	100	88.6 ± 5.34	×	×
Pine, containerized	98.6 ± 1.31	100	93.6 ± 2.77	84.1 ± 4.03	93.8 ± 3.42	95.5 ± 2.52
Pine, bare roots	82 ± 3.66	93.7 ± 4.28	71.1 ± 6.28	79.1 ± 4.5	78.5 ± 6.33	98.2 ± 1.12

\* (Dt – disc trenching, M – mounding, U – unprepared soil, × – variant that was not represented in the forest type).

Table 3

**The seedling proportional mean increment in three forest types depending on soil preparation method %**

Species and seedlings	<i>Myrtilloso-sphagnosa</i> mean ± SE			<i>Myrtillosa mel.</i> mean ± SE		
	Dt	M	U	Dt	M	U
Spruce, bare roots	12.1 ± 0.73 <sup>a</sup>	12.1 ± 0.74 <sup>ab</sup>	17.16 ± 1.1 <sup>bc</sup>	17.9 ± 0.85 <sup>c</sup>	16.5 ± 1.25 <sup>ac</sup>	19.5 ± 1.87 <sup>cf</sup>
Spruce, containerized	23.9 ± 0.9 <sup>ef</sup>	23.1 ± 1.48 <sup>def</sup>	23.4 ± 0.65 <sup>ef</sup>	25.9 ± 1.23 <sup>e</sup>	24.7 ± 1.30 <sup>ef</sup>	19.5 ± 1.35 <sup>bce</sup>
Spruce, improved root system	23.6 ± 0.87 <sup>ef</sup>	20.5 ± 0.87 <sup>cf</sup>	18.8 ± 0.70 <sup>cd</sup>	15.7 ± 0.63 <sup>ac</sup>	17.6 ± 0.86 <sup>bcd</sup>	15.2 ± 0.80 <sup>ac</sup>
Birch, bare roots	20.1 ± 2.01 <sup>ab</sup>	25.2 ± 1.04 <sup>ac</sup>	20.0 ± 1.00 <sup>a</sup>	×	×	24.7 ± 2.91 <sup>ac</sup>
Birch, containerized	25.5 ± 2.16 <sup>ac</sup>	30.1 ± 1.59 <sup>cd</sup>	27.5 ± 1.31 <sup>bc</sup>	34.7 ± 1.33 <sup>de</sup>	39.7 ± 2.58 <sup>e</sup>	22.6 ± 1.81 <sup>ac</sup>
Birch, improved root system	26.0 ± 0.87 <sup>ac</sup>	29.5 ± 1.07 <sup>bcd</sup>	25.9 ± 0.75 <sup>ac</sup>	30.1 ± 1.49 <sup>cd</sup>	25.3 ± 1.93 <sup>ac</sup>	32.8 ± 2.05 <sup>cb</sup>
Black alder, bare roots	×	×	×	45.3 ± 2.62 <sup>f</sup>	65.5 ± 2.99 <sup>g</sup>	44.5 ± 11.95 <sup>f</sup>
Black alder, containerized	19.6 ± 0.95 <sup>ab</sup>	20.6 ± 1.24 <sup>ac</sup>	18.8 ± 0.67 <sup>a</sup>	27.0 ± 1.39 <sup>ce</sup>	30.9 ± 3.93 <sup>e</sup>	40.7 ± 1.07 <sup>f</sup>
Black alder, improved root system	27.0 ± 1.55 <sup>de</sup>	29.3 ± 1.71 <sup>de</sup>	23.8 ± 0.89 <sup>bcd</sup>	25.6 ± 1.76 <sup>bce</sup>	×	×
Pine, containerized	50.8 ± 1.37 <sup>f</sup>	45.6 ± 1.64 <sup>cf</sup>	38.7 ± 1.31 <sup>c</sup>	43.2 ± 1.71 <sup>cde</sup>	46.8 ± 1.38 <sup>df</sup>	48.5 ± 1.69 <sup>ef</sup>
Pine bare roots	31.2 ± 1.14 <sup>ab</sup>	39.2 ± 1.75 <sup>bcd</sup>	29.3 ± 1.78 <sup>a</sup>	40.5 ± 1.57 <sup>cd</sup>	45.4 ± 2.56 <sup>cf</sup>	44.8 ± 1.78 <sup>cf</sup>

(Dt – disc trenching, M – mounding, U – unprepared soil, the different superscript letters represent a significant difference between means within one tree species, by ANOVA and Tukey’s pairwise comparison test  $p < 0.5$ . × – variant that was not represented in the forest type)

The lowest survival rate was determined for pine bare root seedlings in *Vaccinosa mel.* forest type, respectively  $19.6 \pm 5.55\%$  in soil prepared in mounds and only  $12.97\% \pm 3.32\%$  in disc trenched soil and in unprepared soil survived  $13.63\% \pm 3.72\%$  of planted trees, although survival rate of containerized pine seedlings was significantly higher in this forest type, respectively over 95% in both soil preparation methods and in unprepared soil and also in two other forest types scots pine bare root seedlings had a lower survival rate than containerized seedlings (Table 2). Other authors have obtained similar results (Kļaviņa, Gaitnieks, & Menkis, 2013). Disregarding pine containerized seedlings, black alder bare root seedlings in disc trenched soil had the lowest survival rate. Right after outplanting seedlings must adapt to new environmental conditions and overcome stress factors and in volume larger seedling roots can increase survival rate because of providing a sufficient amount of water for transpiration (Haase & Rose, 1999; Grossnickle, 2005). Our study confirmed it as overall highest first year survival was determined for Norway spruce and black alder improved root system seedlings (Table 2).

One of advantages of soil preparation in mounds is reduced competitive vegetation compared to disc trenching and unthreaded soil that not only improves survival (Archibold, Action, & Ripley, 2000) but also reduces the damage rate caused by agrotechnical

care because the planting spot on mounds is easier to find. Overall, 8.4% and 5.2% of seedlings in furrows and untraded soil were damaged compared to 1.4% of damaged seedlings planted on mounds during agrotechnical care.

After the first growing season, the highest proportional increment was calculated for black alder bare roots and pine seedlings (Table 3), except in *Vacciniosa mel.* forest type, where pine bare roots seedlings had a lower proportional increment compared to containerized seedlings, respectively  $19.4 \pm 2.32\%$  against  $46.5 \pm 0.78\%$  in soil prepared by disc trenching,  $22.2 \pm 2.45\%$  against  $48.4 \pm 1.64\%$  in mounds, but in unprepared soil the difference was lower:  $32.9 \pm 3.78\%$  against  $52.3 \pm 0.78\%$ . Other research studies show the same trend that containerized scots pine seedlings have a higher growth rate compared to bare root seedlings (Kļaviņa, Gaitnieks, & Menkis, 2013). The lowest annual increment was observed and calculated for spruce bare roots and improved root system seedlings, and altogether there is a slight trend that bare root and improved root system seedlings have a lower proportional increment compared to containerized seedlings in the first year after outplanting (Table 3). Other researchers report similar results that in the first years after outplanting containerized seedlings have greater growth rate (Renou-Wilson, Keane, & Farrell, 2008).

One of the aims of soil preparation is to enhance a tree growing rate, by providing appropriate environmental conditions (Löf *et al.*, 2012) and evaluating the impact of soil preparation method on seedling growth rate the birch and black alder trees planted on mounds had a higher growth rate up to  $65.5 \pm 2.99\%$  annual increment of total height for black alder bare root seedlings. In the *Myrtilloso-sphagnosa* forest type seedlings planted in unprepared soil had a lower growth rate than those planted on mounds and in furrows, except spruce containerized trees, who produced a similar growth rate in all soil preparation variants (Table 3).

### Conclusions

The survival rate of outplanted seedlings differ by a chosen stocktype and soil preparation method from

lower than 20% survived scots pine bare root seedlings and reaching up to 100% survival rate of spruce, black alder seedlings planted on mounds and altogether soil preparation tend to increase a planted tree survival.

After seedling outplanting from a nursery in the forest land containerized seedling have a higher mean proportional increment ( $35.9 \pm 0.42\%$ ) compared to other stocktype ( $26.6 \pm 0.61\%$  for bare roots and  $23.1 \pm 0.31\%$  improved root system ( $p < 0.05$ )).

Soil preparation method also impacts the damage rate caused by agrotechnical care from 1.4% on mounds to 8.4% damaged trees in furrows made by disc trenching.

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