EVALUATION OF FOREST TREE PLANTING MACHINE EFFECTIVENESS

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Abstract. Soil preparation method – mounding (with varying depth of the pit and the mound height) – may be the solution for establishing new forests when the soil water regime is unfavourable, since the pit serves as a reservoir for water during rainy periods and can retain water for the dry season. Thus, seedlings planted on mounds may obtain water through the soil capillary system when needed. During the last decades extreme weather conditions have occurred more often. And as there is a labour shortage for simple forest management tasks and increased hourly labour cost mechanized planting on mounds could be a promising solution to advance tree planting practices in Latvia. The aim of this study was to compare the productivity, quality and cost of mechanized planting and manual planting in Latvian conditions, where planting density of 2-2.5 thousand seedlings per ha is used. The M-planter was selected for the mechanized establishment of forest sites on mounded soils. During field trials, when 2000 trees per ha were planted, the productivity of the M-planter was 11.2 h ha on drained peat soils, 11.6 h per ha on drained mineral soils and 14.1 h per ha on wet mineral soils. Average mechanized planting time per 1 ha was 11.9 h, while making mounds and manual planting together took 11.2 h per ha. The cost of mechanized planting experiments in Latvian conditions, depending on the number of seedlings planted and planting conditions varied between 450 and 550 EUR per ha. Tree establishment success did not differ between the sites with mechanized or manually planted seedling, but depended more on the local site conditions.

Keywords: silviculture mechanization, forest regeneration, Latvia, mounding.

Introduction

During the last decades forest management in Latvia has been intensified [1]. There are different soil preparation methods used around the globe, but soil preparation in furrows by disc trenching is the most common technique used in boreal forests [2]. This method has one main disadvantage – it is not appropriate for wet forest sites, because the furrows flood in spring and autumn, which causes decay of planted trees. It has been proven that in those conditions the more appropriate method is soil preparation in spot mounds [3;4]. Even though spot mounding is a more expensive method than disc trenching, the results in Fenoscandinavia suggest that total costs in the whole forest regeneration cycle are lower where mounding method was used [5]. Usually soil preparation and planting are separate forest management operations, but it is possible to combine them and currently different kinds of equipment intended for providing high-quality mechanized planting are available on the market. There are two main reasons for the promotion of mechanized tree planting, of which one is economical pressure to decrease silviculture costs and labour shortage, which also increase the total costs of forest management and cause problems in accomplishing forest management tasks [6].

The main reason for mechanized planting not already being widely used is the cost in comparison to manual planting [7]. Studies in Latvia also suggest the same: mechanized planting may be too expensive as a forest management technique [8]. Previous calculations conducted in Finland suggest that mechanized planting productivity should be at least 190 seedlings planted per productive work hour to compete in cost-effectiveness with manual planting [9].

Efficiency of mechanized planting is strongly affected by the technical performance of the machine on which the planting equipment is appendant [9] as well as how efficiently forest regeneration work has been planned. Including such factors as the distance to the seedling stockpile, operator experience, how much logging residue has been left behind [6]. The quality of planting spot can be affected by different factors, such as site conditions, equipment and method used as well as experience and motivation of labour force [10].

The aim of this practical research work was to compare the productivity, quality and the cost of mechanized planting and manual planting in Latvian conditions, where planting density of 2-2.5 thousand seedlings per hectare is used.

Materials and methods

In the central part of Latvia six experimental study sites were established in the spring of 2017 after clear felling. In all sites manual and mechanized planting was conducted. Chosen sites are divided into three groups by water regime and soil properties. Two are on fertile mineral soil with natural water regime (*Myrtilloso-sphagnosa*) located at 56.778349, 24.214402, two sites are on drained forest land with peat layer thicker than 35 cm (*Myrtillosa turf.mel. & Oxalidosa turf. mel*) located at 56.776281, 23.841026 and 56.777830, 23.852595 and the last two sites are on a drained forest land with peat layer less than 35 cm (*Myrtillosa mel. & Mercurialiosa mel.*) Total forest site area for each soil condition group is approximately 3 hectares and all experimental sites were established according to the same principles. Each stand was divided into four substands: two for manual (S) and two for mechanized (M) planting, one for each tree species. In each substand avoiding strip roads five random circular plots with an area of 25 m^2 were established, Fig. 1.

Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) containerized seedlings were selected as the planting material, since these are two of three economically most valuable tree species in Latvia. For mechanized planting the M-planter was chosen, as it has already been previously tested in Latvia [1]. For soil preparation the LSFRI elaborated plating device MPV600 was chosen, as it has a similar blade to the M-planter. Manual planting was done right after soil preparation with a planting tube.

Survival rate and spot mound parameters (the height of the spot mound and the depth of the pit) were observed in the autumn of 2017 and 2018.

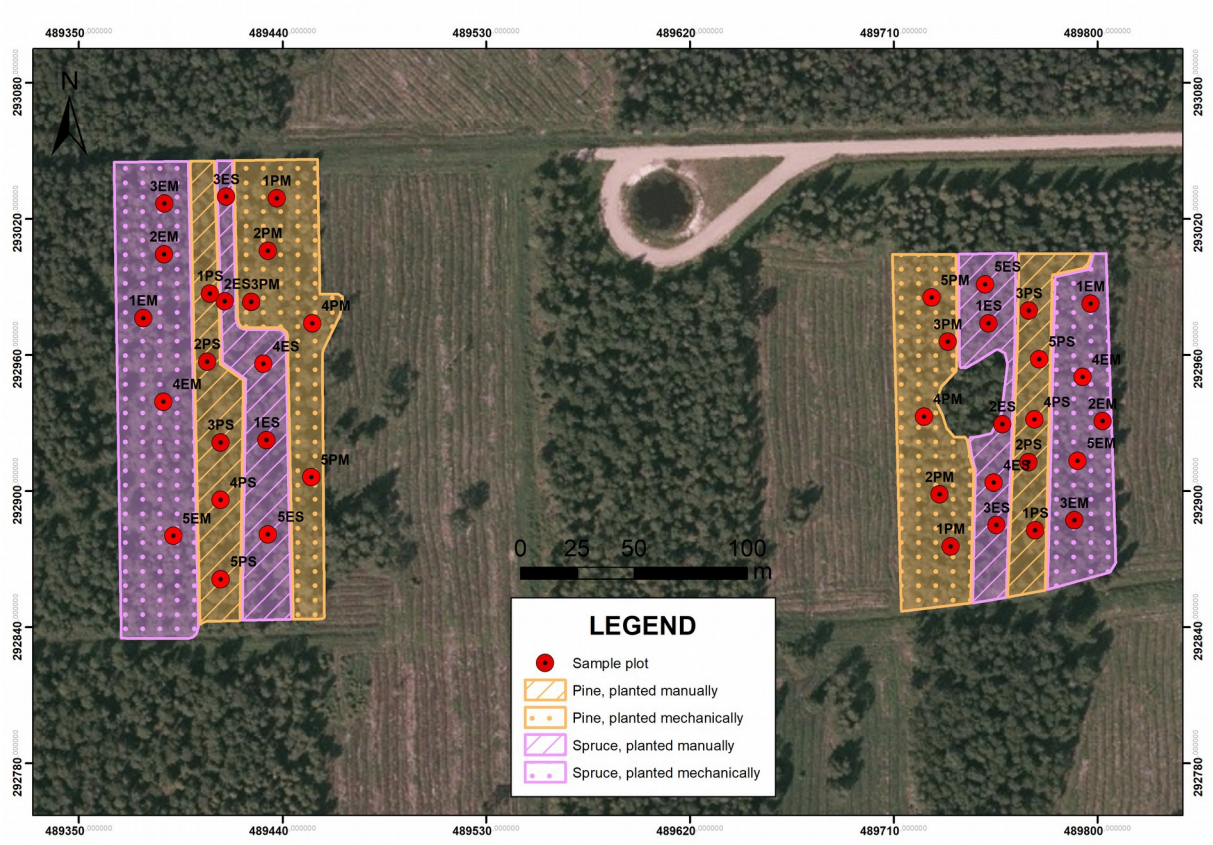

Fig. 1. **Example of study site with distribution of substands and sample plots**

Manual planting was recorded and the planting process was divided into 7 parts – machine movement in the stand, boom manipulations, cleaning the planting spot of felling residue, preparation of mound, planting, other actions in the stand (for example, solving technical issues) and filling the carousel with seedlings. To determine the service costs for one-hectare the forest regeneration operator, machine working time and manual planting time were recorded. For that software SDI 1.2 and Allegro CX field computer were used for time studies. The cost model elaborated within the COST action FP0902 was chosen to evaluate the prime costs of mechanized forest regeneration. It has

been adapted for conditions in Latvia and previously used during the first mechanized planting trials in Latvia in 2007 and 2008 and later in 2012, when the cost efficiency of soil preparation in mounds was evaluated [8]. The main input data used in the model are presented in Table 1.

a) b)

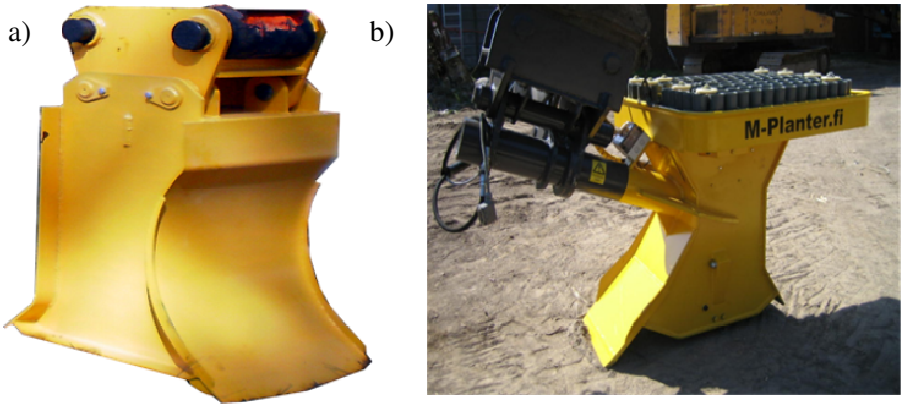

Fig. 2. **Devices used for soil preparation:** a – MPV-600; b – M-Planter

Table 1

Values used in prime cost model calculations

Category	Value	Unit
Cost of excavator	120 000	EUR (without VAT)
M-Planter planting bucket	38 000	EUR (without VAT)
Total number of days operated by planting bucket	252	Days per year
Number of days when planting was done	100	Days per year
Productivity of planting	170	Seedlings per hour
Salary including taxes	9	EUR per hour (one shift 8 hours)
Fuel price	0.88	EUR per litre (without VAT)

The proportions of died trees for each planting technique in each forest type were calculated by dividing the count of died back trees with the count of planted trees in sampling plots and the values were expressed as a percentage. The mean pith depth and mound height were calculated and for both parameters standard error (SE) was calculated.

Results and discussion

During research trial establishment the same excavator was used in all experimental stands and for both methods, so the results are comparable within this research, less so with previous trails, as we encountered technical issues due to limited hydraulic pressure for the excavator, which was the main problem during mechanized planting and decreased productivity in all experimental trials.

Overall planting productivity with M-Planter slightly differed between the forest types – in peatland (peat layer deeper than 35 cm) forest sites the average time spent for one planted seedling was 18.1 seconds, but in drained mineral soil 18.9 seconds. In the forest site with a natural water regime *Myrtilloso-sphagnosa* it took 23.4 seconds to plant one seedling. Results from other studies show a similar pattern - soil properties impact productivity and the average recorded productivity was 13.21 seconds per seedling [9]. Time was also needed to reload the M-planter with seedlings and on average it took 240 seconds per 120 seedlings.

Manual planting consisted of two phases and one of them was soil preparation with the MPV-600 bucket. On average it took 10.5 seconds to prepare a planting spot in drained peat soil and, similar to mechanized planting, slightly more time was necessary on drained mineral soils – 10.7 seconds. In the undrained loamy soil site more time was necessary for the preparation of the planting spot – 12.4 seconds, but planting one seedling took 9.18 seconds.

In the forest law in Latvia it is stated that there must be at least 2000 spruces in a regenerated stand, thus, at least 2100 spruce seedlings ha^{-1} usually are planted. With MVP-600 one hectare of forest land on drained soil was prepared approximately in 6 hours (5.8 needed for peat soil and 5.9 hours on soil with peat layer less than 35 cm), but likewise for mechanical planting more time was necessary to prepare one hectare in spot mounds of loamy undrained soils on average and it took 6.9 hours of work. Thereby, it is possible to prepare up to 1.5 hectares of forest land in one shift. For mechanized planting with 2000 seedlings per hectare with the M-planter on drained organic soils it would take 11.2 hours, 11.6 would be needed for drained soil with peat layer less than 35 cm and for undrained wet loamy soils it would take 14.1 hours to plant one hectare. Overall in average conditions mechanized planting takes more time compared to mounding followed by manual planting, respectively 11.9 hours·ha^{-1} and 11.2 hours·ha^{-1}, but the margin is quite small (0.7 hours), as it can be seen in Fig. 3. The differences could be aligned, if a more powerful and faster excavator had been used, or if the operator had more experience with the specific equipment [9;10].

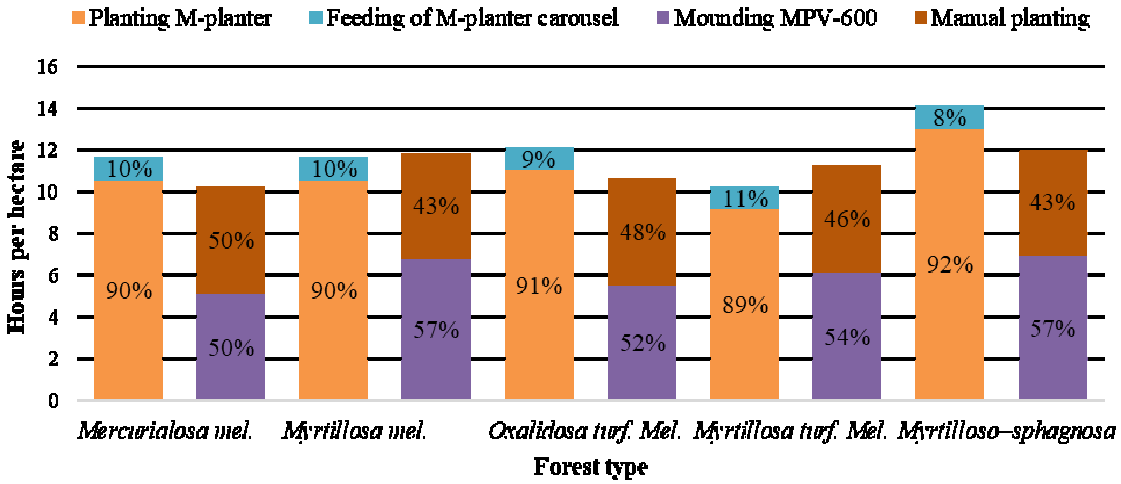

Fig. 3. **Hours needed to regenerate a hectare depending on planting equipment and forest type**

Assuming that average planting productivity is 170 seedlings per hour and in total 2000 seedlings ha^{-1} need to be planted, then in one season 105 hectares could be planted by one M-Planter. In Latvia the situation is similar as described in other scientific works - mechanized planting costs more than manual planting [6]. The reduction of planting density and improvement of planting productivity would decrease the prime forest regeneration costs. If it could be possible to reach the planting productivity that has been recorded in the previous studies [8] (210 seedlings per hour), then the prime cost for one-hectare regenerations would be 447 EUR ha^{-1}, Fig. 4, and that price is close to the actual cost of mounding service alone.

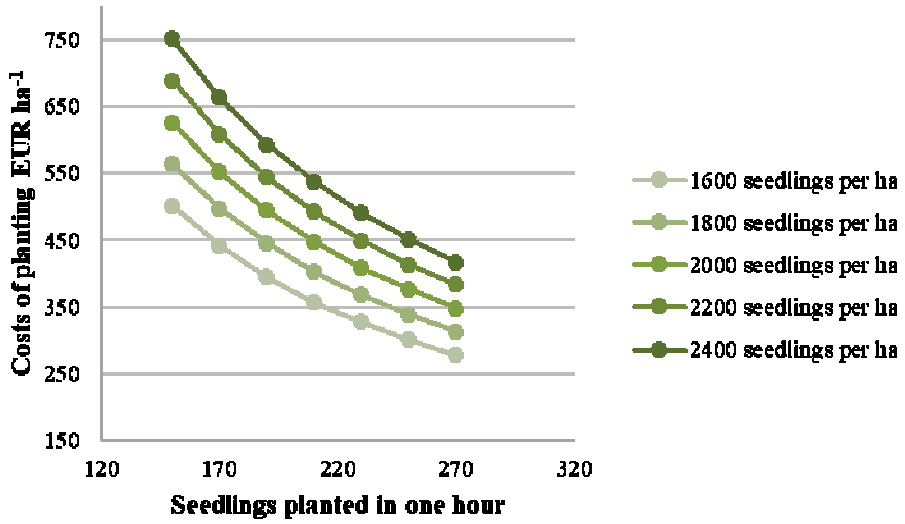

Fig. 4. **M-planter planting costs depending on productivity and planting density**

The results after the second growing season show that the height of spot mound and the depth of the adjacent pit are changing. In all forest types for both methods except *Myrtilloso–sphagnosa* the average height of the mound decreased. Excluding undrained forest sites (*Myrtilloso–sphagnosa* forest type), the spot mounds, which were prepared with the M–planter, decreased from 5 % to 15 %, but the height of the mounds prepared by MPV 600 reduced from 8 % to 22 %. The depth of the pit reduced in all stands and in all variants. On average in those parts, where the M-planter was used, the depth decreased by 18 %, and where MVP 600 was used, the average reduction was 15 %. The largest changes of depth were observed in stand sites on drained mineral soil (*Mercurialiosa mel. & Myrtillosa mel.* forest type). Table 2.

Table 2

Pit depth and mound height after first and second growth season

Forest type	Equipment	Pit depth, cm (± SE)		Mound height, cm (± SE)	
		First season	Second season	First season	Second season
Mercurialosa mel.	M-planter	23 ± 0.9	17 ± 0.6	17 ± 0.7	14 ± 0.7
	MPV-600	31 ± 0.6	24 ± 0.9	18 ± 0.5	15 ± 0.9
Myrtillosa mel.	M-planter	24 ± 0.3	19 ± 0.8	16 ± 0.7	13 ± 0.9
	MPV-600	28 ± 0.7	23 ± 0.9	18 ± 0.7	14 ± 0.8
Myrtilloso–sphagnosa	M-planter	26 ± 0.8	22 ± 0.7	15 ± 0.8	16 ± 0.8
	MPV-600	27 ± 0.5	23 ± 1.1	15 ± 0,7	17 ± 1.4
Oxalidosa turf. Mel.	M-planter	25 ± 0.6	20 ± 0.3	16 ± 0.3	13 ± 0.4
	MPV-600	32 ± 0.9	30 ± 0.6	20 ± 0.7	17 ± 0.7
Myrtillosa turf. Mel.	M-planter	23 ± 0.9	21 ± 0.6	16 ± 0.8	15 ± 1.1
	MPV-600	31 ± 0.6	26 ± 0.8	17 ± 0.7	14 ± 1.2
On average	M-planter	24 ± 0.7	20 ± 0.7	16 ± 0.5	15 ± 0.8
	MPV-600	29 ± 0.5	25 ± 0.9	17 ± 0.6	16 ± 0.9

After the second season of vegetation in all stands spruce had lower survival rate, a similar result was obtained after the first growing season. Overall survival rate for both methods was sufficient and two seasons after planting 85 % of mechanically planted spruce have survived compared to 87 % of manually planted. For pine the survival rate was higher – 97 % for mechanically planted and 92 % for manually planted trees, Fig. 5.

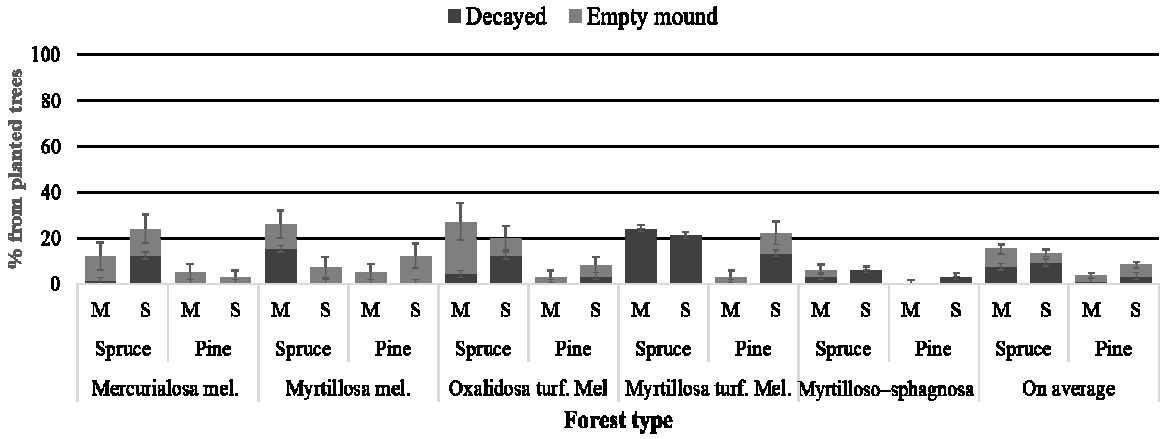

Fig. 5. **Proportion of died trees in different forest types and depending on planting technique used (M-planter, S -manual planting)**

There is no significant difference between the two methods and survival, as described previously, is more affected by the tree location in the stand rather than the planting technique used [11].

Conclusions

1. There was no significant difference in time consumed between mechanized and manual planting (mound preparationand planting).
2. In forest types: *Myrtilloso-sphagnosa, Myrtillosa mel., Mercurialiosa mel., Myrtillosa turf.mel., Oxalidosa turf. mel*. the prime cost of mechanized planting according to the research results varies from 440 to 550 EUR·ha^{-1}
3. The spot mound becomes smaller over time, the average pit depth reduction for the mechanized planting device and mounding head MPV600 was 17 % and on average the mound height decreased by 14 %.
4. Mechanized and manual planting on mounds provide sufficient tree survival rate with no significant difference.

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