BRIEF REPORT

Productivity and Cost-effectiveness of the *M-Planter* Tree Planting Machine in Latvian Conditions

KASPARS LIEPIŅŠ*, DAGNIJA LAZDIŅA AND ANDIS LAZDIŅŠ

Latvian State Forest Research Institute "Silava", Department of Forest Regeneration and Establishment, Rigas 111, Salaspils, LV-2169; Latvia; phone: +371 67942555, e-mail: kaspars.liepins@silava.lv

**Corresponding author: phone: +371 67942555; fax: +371 67901359; e-mail: kaspars.liepins@silava.lv*

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Abstract

Although the first efforts to develop efficient forest planting machines were made already in the mid-20th century, the level of mechanization in reforestation is still very low. The aim of the given study is to assess the productivity and cost-effectiveness in Latvian conditions of the *M-Planter* tree planting machine, recently launched in Finland.

The productivity (E_0) of the *M-Planter* achieved in field tests was 260 seedlings per hour. Considering the current economic situation in Latvia the conventional technologies with mechanized site preparation and manual planting prove to be a viable alternative in forest regeneration.

A number of factors affecting the performance of the said planting machine and prerequisites for introducing fully mechanized forest regeneration technologies in practical forestry in Latvia are discussed.

Key words: mechanical forest planting, productivity, cost-effectiveness, M-planter

Introduction

In Latvia, artificial regeneration, mainly by manual planting and to some extent by seeding, applies to about a half of the forest area restocked annually (11,200 ha in state-owned forests in 2008). Nowadays, soil scarification by disc trenching machines is nearly the only site preparation method used in Latvia in reforestation. In 2008 a research project was initiated at the Latvian State Forest Research Institute "Silava" (LFRI "*Silava*") to study the silvicultural and economical aspects of mechanized forest regeneration in Latvian conditions. Performance testing of novel tree planting machines is set as one of the project objectives.

To improve the working conditions and achieve higher time- and cost-effectiveness in forest regeneration, the earliest mechanized forest planting technologies emerged in a number of European countries already in the mid-20th century. Design of the first tree planting machines envisaged continuous plowing of the site to be restocked. However, for operations in difficult site conditions (heavy terrain, stumps, slash and rock), alternate-furrow planting machines appeared later (Hallonborg 1996).

In Latvia, the first attempts of mechanized forest planting date back to the 1960s, using the prototype tree planting machines developed in the former Soviet republics of Russia and Belarus (Liepa et al. 1981). Large-scale mechanized forest planting, practiced for about fifteen years, was introduced in Latvia in the 1970s with 15-20 % of the total forest plantations established by mechanized technologies. The productivity of mechanized planting was 0.8-1ha per working shift with the costs of forest establishment twice as high as for manual planting. Because of inferior quality in manufacturing the machinery the operation of Soviet-made tree planting machines was problematic (Mangalis 2004 p. 270). At the same time the first pilot forest planting machine *SBS-50* for container stock was developed in Latvia. However, it did not go in production due to low cost-effectiveness of planting (Z. Kariņš personal communication, May 14, 2009).

Nowadays, an interest in forest planting machinery is growing in the Nordic countries as Sweden and Finland (Mattsson 2005). In Finland, according to rough estimates mechanized forest planting accounts for 3 – 4 % of the total with this index about 25 % in the industries-owned forests (Saarinen 2007).

In Sweden and Finland the ongoing development of forest planting machines has resulted in new models which differ substantially from the one-time continuous plowing machines. The new models with the planting head mounted at the tip of hydraulic boom are more efficient in difficult site conditions since the machine operator can evaluate the site conditions and choose each planting spot individually. At present similar tree planting machines predominate in the Nordic countries. The *Bräcke-Planter*, *Eco-Planter* and *Ilves* are now the most common forest planting machines used in Finland, Norway and Sweden (Rummukainen et al. 2003). The *Bräcke-Planter* and *Eco-Planter* simultaneously perform site preparation and planting, while the *Ilves* planter makes no site preparation (Tervo 2000, Rummukainen et al. 2002).

Despite the attempts to achieve an all-round use of machinery in reforestation, the technologies of mechanized site preparation and manual planting still remain a viable alternative (Tervo 2000). Increasing work productivity is currently the major goal in further improvement of forest planting machines. In 2007, Finnish designers presented a new model of forest planting machine, *M-Planter.* The first performance tests of this machine show the *M-Planter* to outperform the *Bräcke P 11a* planter (Rantala et al. 2009). The higher productivity of M-Planter is mainly based on the presence of two mounding and planting units mounted separately to the main frame. In 2009 already five *M-Planter* machines were operating in Finland (L. Tervo personal communication, July 13, 2009)

In efforts to reduce the share of manual planting in forest regeneration the *M-Planter* seems to be hold promise for the Nordic countries. The aim of the given study is to assess the performance and cost-effectiveness of the *M-Planter* in Latvian conditions.

Material and methods

Study sites and planting stock

The field performance of the *M-Planter* tree planting machine was evaluated in October, 2008 in three cutovers in central Latvia, chosen as study sites. Before clear-felling in the previous winter the sites carried conifer-dominated stands. Most of the logging slash was collected and placed on the strip roads arranged for timber extraction. The distance between strip roads (width 4-5 m) varied from 20 to 25 m.

At the study site of Olaine (56˚47' N/24˚04' E, 1 m a.s.l.), the stand logged-over comprised five sub-compartments dominated by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abieas* (L.) Karst) in a mix with hairy birch (*Betula pubescens* Ehrh.) and common alder (*Alnus glutinosa* L.). The mean d. b. h. varied between compartments from 29 to 36cm, and the number of stems per ha – from 220 to 320. The parameters of Norway spruce undergrowth: 324 to 442 stems per ha with the mean d. b. h. 12-14cm.

At the study site of Tome (56˚47' N/24˚35' E, 20 m a.s.l.), the stand cut down was as follows: Norway spruce (68 % of the total stand volume), Scots pine (22 %) with an admixture of birch (both silver and hairy), common aspen (*Populus tremula* L.), and common alder; the number of stems per ha – 668; the mean d. b. h. – 29 cm.

The third study site used for evaluating the planter was a clear-felled cutover next to Viļķene (57˚38' N/ 24˚37' E, 20 m a.s.l.). The forest stand logged over was dominated by grey alder (*Alnus incana* (L.) Moench) (78 % of the total stand volume) in a mix with silver birch (13 %), Norway spruce (6%), and common aspen (3%); the number of stems per ha – 1,295; the mean d. b. h. – 17 cm.

1.5-year-old Norway spruce and 1-year-old Scots pine container seedlings were used for planting. All seedlings were raised in *HIKO V-120 SS* containers (526 cells per m^2, cell volume 120 cm^3). The shoot height of seedlings (mean ± SE) based on the measurements of randomly selected 100 seedlings of each species was as follows: Scots pine – 13.59 ± 0.32cm; Norway spruce – 23.34 ± 0.45cm.

The prescribed planting density for Scots pine was 3,000 seedlings per ha (Olaine), and 2,000 seedlings per ha for Norway spruce (Tome and Viļķene).

Operation of planting machine and the time studies

At all experimental sites the planting machine was operated by one skilled operator who had work experience with *M-Planter* planting machine for more than a year. The planting unit of the *M-Planter* attached to the tip of the excavator's hydraulic boom (in the given study New Holland 175 E) comprises two planting heads which, depending on the accessibility of planting spots, can be operated simultaneously or separately (Fig. 1). The soil preparation (mounding) is done by mounding

Figure 1. The *M-Planter* planting machine (Photo: Dagnija Lazdiņa)

blades attached under each planting head. After the soil is compacted by placing the planting head onto a fresh-made mound, a seedling to be planted out is fed there through a planting tube arranged in the planting head. On the top of each planting head there is a cassette for seedlings comprising means for automatic feeding of seedlings into the planting tube. The holding capacity of the cassette, refilled manually by the machine operator, is 240 seedlings.

In the time studies the operating cycle of mechanized planting was calculated after the following equation:

$$t_{MP} = t_{CM} + t_{SP+PL} + t_{D} + t_{F} + t_{OW} + t_{NW} (cmin) \quad (1)$$

with the following steps of planting cycle: t_{CM} – crane maneuvers; t_{SP+PL} – soil preparation and planting; t_D – driving; t_F – filling the seedling cassette; t_{OW} – other work operations; t_{NW} – no-work operations.

The crane maneuvers include moving the planting head from one planting spot to another; the soil preparation and planting comprise mounding and planting a seedling on the mound. Other work operations include clearing away by crane the logging slash from the planting spot as well as field maintenance of the planting unit. No-work operations include short breaks between the planting cycles and other interruptions of work. To calculate the effective working time (E_0) for the mechanical planting the no-work operations are omitted. The productivity of the planting machine is calculated as the number of seedlings planted per hour of effective working time.

The planting as whole was divided into individual planting cycles which correspond to the time span between individual instances of refilling the seedling cassette. In the time study for the three study sites 29 planting cycles were recorded altogether.

The time required for planting one seedling was calculated by dividing the amount of seedlings planted by the duration of the planting cycle.

Economical calculations and statistical methods

For calculating the prime cost of mechanized tree planting by the *M-Planter* used was the model developed within the research project "Extraction of logging residues at the JSC "Latvijas valsts meži", (LVM). The model was developed jointly with the *Skogforsk* (The Forestry Research Institute of Sweden) and the LFRI "Silava" (Lazdāns et al. 2009).

Factor analysis was performed by ANOVA, using the SPSS (version 16.0) GLM procedure. The data were subjected to the Kolmogorov-Smirnov and Levanie's tests to evaluate the variance normality and homogeneity. To identify statistically significant differences between the data sets treated, the *Post Hoc* procedure was performed, using the Tukey's test.

Results

The bulk (39%) of the *M-Planter*'s total effective working time was devoted to soil preparation and planting (Fig. 2). Crane maneuvers and other work operations accounted for 21% and 16% of the total effective working time, respectively. The time for driving and refilling the seedling cassette made up 12% for each of the operations.

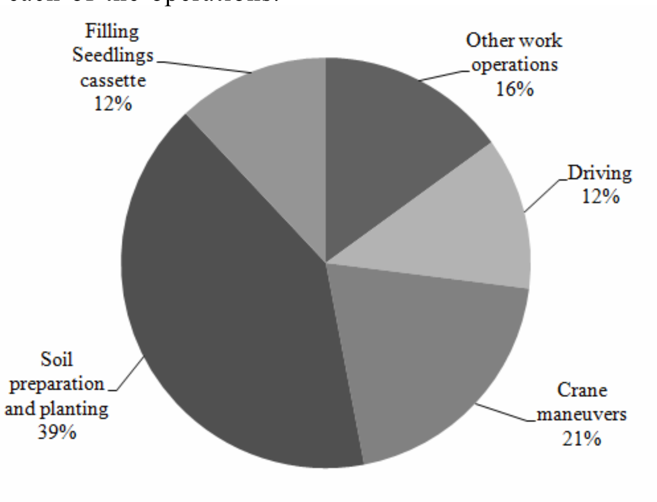

Figure 2. Distribution of the effective working time E_0 of the *M-Planter*

Effective working time as well as the time for separate work operations per planting cycle differed among the study sites (Table 1). Planting on the Olaine site was the most time consuming while the highest productivity was achieved on the Viļķene site (5081.12 cmin and 5484.96 cmin per planting cycle, respectively). Notable differences in E_0 among the study sites are explained by relatively longer time required for soil

Table 1. Average values (± standard error) of work operations on the study sites, cmin per planting cycle

Study site	N	Effective working time (E_0)	Other work operations	Soil prep. and planting	Crane maneuvers	Driving	Filling the seedling cassette	No-work operations
Viļķene	6	5081.12±270.05a*	533.57±106.39a	1852.69±92.24a	1393.52±81.17a	618.26±85.14ab	683.03±2.64a	191.39±48.82a
Tome	5	5484.96±400.77ab	1184.31±289.78b	2121.05±187.85a	991.87±143.78b	502.97±45.44a	684.76±2.29a	321.41±180.76a
Olaine	18	6052.06±127.46b	887.26±96.85ab	2579.87±74.85.24b	1080.45±51.30b	819.41±54.58b	685.07±1.88a	170.39±34.63a

*values with different letters significantly differ from each other at the p<0.05 level preparation and planting in Olaine, 2579.87 cmin, as against 2121.05 and 1852.69 cmin in Tome and Viļķene, respectively. Statistical analyses revealed significant differences between the study sites regarding other work operations too, except for no-work operations and filling the seedling cassette where no statistical differences were found.

Average duration (weighted average among three sites) of the planting cycle (planting of 240 seedlings) with the *M-Planter* was 5539.38 cmin. According to the results of this study the mean productivity (E_0) of the *M-Planter* was 260 seedlings per hour. Following the base scenario (planting density 2,500 seedlings ha^{-1}) the productivity of the said tree planter was 1.66ha daily when working in two 8 hour shifts per day.

Forest planting costs by using the *M-Planter* were EUR 382 per ha or EUR 0.15 per each planted seedling, excluding the costs of planting stock. The planting density appears to be among the factors most strongly affecting the costs of mechanized planting. If the planting density is reduced to 2,000 seedlings per ha, the plantation establishment costs can be reduced by EUR 61 or 16.0%. On the other hand, if the planting density is increased to 3,000 seedlings per ha, the planting costs go up to EUR 67 and 17.5%, calculated with and without the planting stock costs, respectively.

Discussion and conclusions

In the given study the productivity of the *M-Planter* (260 seedlings per hour) was slightly higher than in a similar experiment in Finland where the average productivity of 240 seedlings per hour is reported (Rantala et al. 2009). It could be explained by differences in forest site and working conditions in both countries. In Finland, rocky terrain is regarded as the factor strongly affecting productivity of forest regeneration. In the Latvian experiment the study sites were nearly stone-free. The design of the *M-Planter* machine employed in the given study was somewhat improved compared to the machine used in the Finnish experiment. The improvements in the *M-Planter's* design concerns a higher holding capacity of the seedling cassette which ensured higher productivity of planting in the study discussed.

In field tests the *M-Planter* demonstrated a higher productivity (260 seedlings h^{-1} comparing to 195-199 seedlings h^{-1}) and lower costs of planting (by 23%) compared to the *Bracke P11.a* planting machine previously tested in the Latvian conditions (Lazdiņa 2007).

Forest planting costs by using the *M-Planter* calculated in our experiment reached EUR 382 per ha. It is to be noted that the calculations of forest regeneration costs made in the present study did not include the profit of the company operating the machine. It implies that in practice the costs of mechanized planting can be higher than presented in this paper.

Because of heavy working conditions on forest sites, tree planters with the planting unit mounted on a hydraulic boom is currently the only alternative for ensuring the quality of planting. In order to raise the cost-effectiveness and productivity of tree planting machines research and development in this direction is to be continued. In this respect optimum maneuvering of the *M-Planter* on the site offers certain possibilities for improving its performance. In the present study the direction of driving the planter was parallel to the strip roads. The efficiency of planting can be to some extent improved by moving the planter perpendicular to the direction of strip roads. In such a case the time taken for clearing away the logging slash from planting spots can be reduced. The positive effect of slash removal and stump extraction on the labor productivity in forest regeneration operations is acknowledged too. With the *Bracke* planter, the removal of logging slash resulted in 18% increase in the work productivity of the machine (Saarinen 2006). Combining slash removal and stump extraction with mechanized tree planting seems to hold promise for increasing the efficiency of forest regeneration operations.

With the *M-Planter,* the regeneration costs for one hectare of forest greatly depend on the planting density. According to the Latvian regulations the acceptable minimum density on restocked areas is 2,000 trees per ha for Norway spruce, and 3,000 for Scots pine. In our study the productivity of mechanical planting of spruce was notable higher than for pine despite the fact that planting at bigger density requires less time for driving and maneuvering the machine. The time devoted for site preparation and planting at site Olaine was significantly higher than at other sites. As mentioned before the planting unit of the *M-Planter* comprises two planting heads. The maximum productivity of the machine is ensured if planting can be performed with both planting heads simultaneously. If the planting has to be done at high density on forest site comprising many obstacles (stumps), the time spent by operator to choose the proper planting spot is higher and often just one seedling is planted per operation. However, this statement can be contradicted for the effect of site has to be taken into consideration - pine and spruce were planted on different sites.

Currently, mechanized tree planting cannot be regarded as a viable alternative to manual planting. No denying, the efforts to mechanize forest operations will continue also in the future, especially if the studies on post-planting performance of the stands established by mechanized technologies show up definite silvicultural advantages. As of now, most of the timber harvesting and forwarding operations are mechanized in Latvia. Testing and evaluating the most recent innovations and development results in mechanized forest planting and pre-commercial thinning are of special importance for strengthening the competitiveness of the Latvian forest industry in the long run.

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ПРОДУКТИВНОСТЬ И СТОИМОСТЬ МЕХАНИЗИРОВАННОЙ ПОСАДКИ ЛЕСА В УСЛОВИЯХ ЛАТВИИ

К. Лиепиньш, А. Лаздыньш, Д. Лаздыня

Резюме

Повышение уровня механизации лесных работ является актуальной задачой во многих лесохозяйственно развитых странах. Несмотря на то, что первые попытки выработки эффективных агрегатов для механизированной посадки леса датированы уже в середине прошлого века, уровень механизации до сих пор яиляется низким. Данное исследование было проведено для получения тестовых данных о выработанной недавно в Финляндии лесопосадочной машины M-Planter в условиях Латвии.

Продуктивность лесопосадочной машины M-Planter, достигнутая в проведенном нами эксперименте, составляла 260 саженцев в час. Стоимость механизированной посадки леса значительно превышает стоимость посадки леса вручную.

В статье также проведен анализ факторов, влияющих на себестоимость механизированной посадки леса, и обсуждены предпосылки для введения механизированной посадки в лесную практику Латвии.

Ключевые слова: M-Planter, механизированная посадка леса, продуктивность, себестоимость.

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ERAF
EIROPAS REĢIONĀLĀS ATTĪSTĪBAS FONDS

IEGULDĪJUMS TAVĀ NĀKOTNĒ

EIROPAS SAVIENĪBA