Natural resources and
bioeconomy
studies 8/2016

Proceedings of the OSCAR Workshop:

Mechanized and efficient silviculture

November 25–26, 2015 Natural Resources Institute Finland,
Suonenjoki Research Unit, Finland

Timo Saksa (Ed.)

Luke
NATURAL RESOURCES
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Natural Resources Institute Finland, Helsinki 2016

ISBN: 978-952-326-181-5 (Print)
ISBN: 978-952-326-182-2 (Online)
ISSN 2342-7647 (Print)
ISSN 2342-7639 (Online)
URN: http://urn.fi/URN:ISBN:978-952-326-182-2

Authors: Timo Saksa (ed.)
Publisher: Natural Resources Institute Finland (Luke), Helsinki 2016
Year of publication: 2016
Cover photo: Ville Kankaanhuhta / Luke
Printing house and: publishing sales: Juvenes Print, http://luke.juvenesprint.fi

Abstract

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The workshop took place at Natural Resources Institute Finland (Luke), Suonenjoki Research Unit November 25 – 26, 2015. Workshop was arranged as a joint arrangement between Luke and Latvian State Forest Research Institute "Silava" and the main sponsor was Nordic Forest Research (SNS) / Operating Systems for Centre of Advanced Research (OSCAR2, 2011-2015). This OSCAR Workshop was also promoted by IUFRO Research Group 3.02.00 Stand establishment and treatment. Altogether 28 participants from Estonia, Finland, Latvia, Lithuania and Sweden participated in the workshop.

The objective of the workshop was to present ongoing research concerning mechanized silviculture in Nordic and Baltic countries and to discuss future research needs. State of art reports about mechanized silviculture from Sweden and Finland were presented and discussed. In the Swedish review, inverting; interface from nursery to planting machine; feeding of seedlings in planting device; identification of plantings spots and obstacles as well as planting device development without compactation were covered. In the Finnish part, mechanized planting and mechanized young stand management were discussed. Finally, the differences between the Swedish and Finnish Scots pine management cultures were discussed.

The ongoing research projects concerning forest regeneration, drainage and management of young stands in Baltic countries were presented and discussed. The overview about the management of Latvia's state forests started the session following the state of the art review of the ongoing research activities in mechanization of silviculture in Latvia. Next, the work productivity of wood ash forest fertilization was discovered. Forest regeneration and young stand management in Estonia followed. In conclusion, SeedPAD, as a new and efficient Scots pine regeneration method in Northern Sweden, was viewed.

New ways of young stand management were presented and discussed. At first, the productivity of Vimek harvester and forwarder were scrutinized. Next, Fixteri FX15a small-tree bundlers work processes and productivity in early pine dominated thinnings were considered following an overview of the evolution of innovative systems for small diameter tree harvest in Sweden. In the end, biocontrol methods against hardwood sprouting using *Chondrostereum purpureum* were covered.

In the workshop the need for further Nordic-Baltic co-operation was strongly emphasized. Co-operation in research activities as well as in dissemination of new research findings and in deployment of new innovation were widely discussed. Workshop included also a short field excursion where the PCT operation with "Tehojätkä" (Usewood Forest Master) and young stands treated with Naarva uprooter were demonstrated.

Keywords: silviculture, mechanization, direct seeding, planting, pre-commercial thinning, thinning

norden
Nordic Forest Research
Co-operation Committee (SNS)

Workshop participants during the field excursion. Photo Ville Kankaanhuhta, Luke.

Contents

Session 1

Mechanized silviculture, practice and research, in Nordic countries

Mechanized tree planting in Finland

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On 2014, the information pertaining to mechanized planting activity in Finland in 2013 was updated, since the last survey was conducted by Metsäteho Ltd on 2003. All businesses providing mechanized tree-planting service were interviewed. They were asked to describe their equipment and activities, identify critical success factors, and suggest areas for improvement. In 2013, 31 planting machines (18 Bracke P11.a, 11 M-Planter and 2 Risutec) were operated by 22 businesses planting approximately 4.7 million seedlings on 2,663 hectares. Fourteen businesses operated a single planting machine, seven had two, and one had three. Most planting devices were mounted on the boom of 14–21-ton excavators, with only two operated harvester-based. Businesses had on average 1.7 clients and the main (86%) client group was “large silviculture and forest industry enterprises”. The shares of local forest management associations and non-industrial private forest owners were 8% and 6%, respectively.

The average planting season was 19.9 weeks, starting at the beginning of May and ended late September or the beginning of October. There were stoppages and other excavator works (i.e. soil preparation, ditching and stump lifting), on average, 1.2 and 0.8 weeks, respectively. Base machines provided other services for an average of 2.9 months outside the planting season. Each machine planted an average of 151,242 seedlings in 86 ha. Of the total planted seedlings in 2013, 90% were Norway spruce (Picea abies (L.) Karst.) and the rest were Scots pine (Pinus sylvestris L.). Average productivity was 1,614 seedlings and 0.92 ha per work day. Worksites were on average 4.7 hectares and located <61.5 kilometres from the depot.

Metsäteho reported that, in 2003, the area of mechanized tree-planting work was 1,420 hectares, which covered 1.6% of the total planting area in Finland. Altogether 16 planting machines operated in Finland in 2003. In 2013 the share of mechanized planting was 3.5% of all artificial regeneration. Even though the volumes of mechanized tree-planting work have doubled during the past decade, the increase in mechanically planted areas has still been quite slow. The main reasons for this are low utilization rate of planting capacity and weak cost-competitiveness of the mechanized tree-planting compared to manual planting.

Critical success factors included operator skill, work quality, worksite selection and sufficient work during the planting season. Many businesses were unwilling to increase the area of service, invest in new equipment, or increase the volume of planting work. However, many were willing to network with other businesses and believed that mechanized planting will become more popular in privately-owned forests. Growth of the industry will depend on improved cost-efficiency, appropriate worksites and marketing.

Keywords: Finland, mechanization, planting machines, silviculture, state of the art, tree planting.

Mechanized young stand management in Finland

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In recent years the average young stand management area has been about 160,000 hectares in Finland. Young stand management i.e. pre-commercial thinning (PCT) usually consists of two separate consecutive treatments: early cleaning and later pre-commercial thinning. Nearly all PCT is still done motor-manually with brush saws. The area of mechanized PCT was about 1,300 hectares in 2014 and mechanization rate approximately 1%. The vast majority of mechanized work (1,100 hectares) was carried out in forest industry own forests or private forests managed by agreement. This amount has remained relatively stable. The relative proportion of mechanized early cleaning has slightly increased in past few years (Figure 1). The amount of mechanized PCT in private forests is estimated to be about 200 hectares per year.

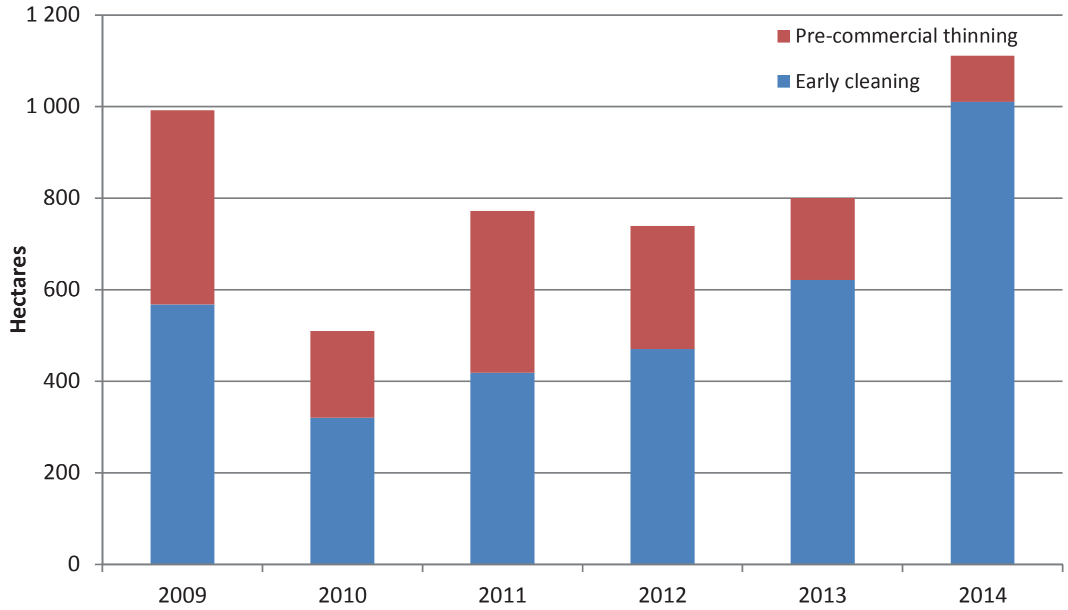

Figure 1. Mechanized young stand management in forest industry own forests or private forests managed by agreement (Metsäteho statistics).

In 2015, about 20 to 25 machines are in active use in PCT operations. Mid-size harvesters and lightweight mini-harvesters (Tehojätkä) are the most common base machines. The most commonly used PCT devices are Naarva uprooter (15, Pentin Paja Ltd), UW Brushwood Cutter (5–10, Usewood Ltd) and MenSe Hedge Cutter (1, MenSe Ltd) (Figure 2).

The lack of cost competitiveness slow down the spread of mechanized PCT. Mechanized PCT is generally not any cheaper than traditional motor-manual work with brush saw. Only mechanized uprooting bring cost savings at the moment. The costs of PCT chain based on uprooting can be up to 20% lower than the conventional motor-manual management chain (Figure 3). This is based on the fact that the method effectively prevents hardwood sprouting in most cases and can avoid the later PCT treatment. Other mechanized methods (methods based on cutting blades), by contrast, are not yet competitive enough in later pre-commercial thinning nor the whole management chain (Figure 4).

Figure 2. The most commonly used PCT devices in 2015: a) Naarva P25 uprooter, b) UW40 Brushwood Cutter c) MenSe RP6L Hedge Cutter

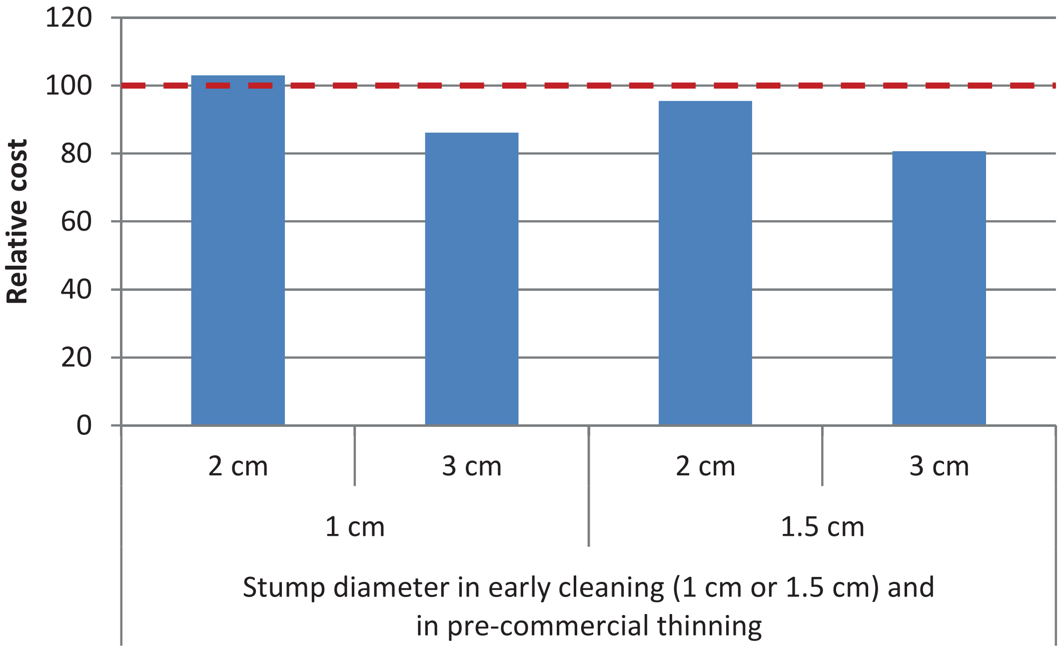

Figure 3. The costs of mechanized uprooting on average conditions (removal 12 000 stems/ha) compared to motor-manual management chain (relative cost=100) (Strandström et. al 2011).

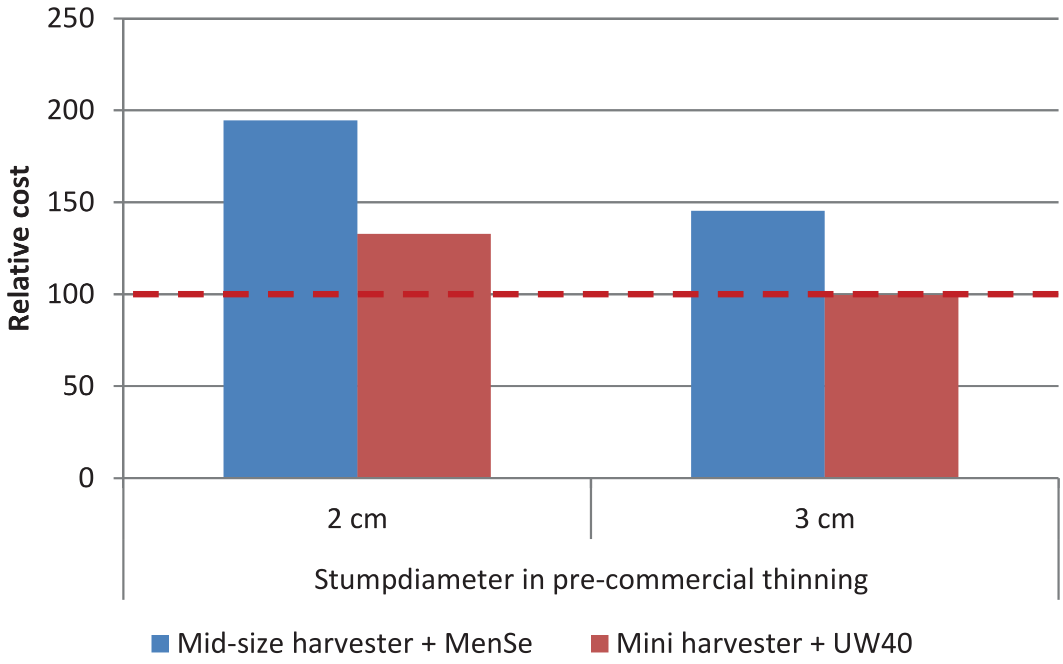

Figure 4. The costs of mechanized PCT in later pre-commercial thinning on average conditions (re-moval 12 000 stems/ha) compared to motor-manual management (relative cost=100) (Strandström et. al 2011).

The research and R&D efforts focus on following topics at the moment when pursuing giant leap in productivity and cost competitiveness of mechanized PCT:

- mechanical or biological methods to prevent hardwood sprouting in early cleaning
- methods to improve productivity through sensor technology and automation
- utilization of Big Data in mechanized young stand management.

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Culture affects management of young scots pine stands today – What is the result after 50 years?

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Silvicultural guidelines concerning management of young Scots pine stands differ markedly between Finland and Sweden. This is especially related to timing of PCT. This phenomenon is independent from the forest owner while forest owners in the same country are quite consistent. SWE 2-4m, FIN 4-7m In Southern Sweden the natural conditions differ from Finland but Norrland and Svealand should be quite equal to Finland, and therefore provide a basis for comparison of silvicultural guidelines and cultural aspects in forest management. Despite of difference in timing of PCT, a strong agreement exists on adequate density of stand independently from timing: 2000-2500 after PCT.

In Sweden, the pricing of Scots pine saw logs conform better to their end use value. In Finland, the price of Scots pine is more or less flat rate with only minor justification according to the log quality. This is contradictory with the aims in young stand management.

Timing of pre-commercial thinning has effect especially on the branchiness quality of pine. The diameter of thickest dead branch in the butt log correlates strongly with the value of lumber pieces. Branchiness quality is also related to the establishment method but the silvicultural methods and seed origins today decrease the problems that appeared earlier with direct seeded and planted stands.

Most extreme recommendations for growing best quality Scots pine suggest postponing of PCT to 7-8 m even in Lapland (Varmola & Ruha 1997). However, later findings of Varmola and Salminen (2004) indicate that postponing PCT over 6 m does not change the branch diameter if stand density is reasonable. These results were obtained in Southern Finland on site indexes H100 = 23 – 26 m. If PCT is postponed from 3 to 6 meters, the diameter of thickest dead branch decreases approximately 3 mm, assuming constant density of stands after PCT (Varmola & Salminen 2004, Fahlvik et al. 2005).

Timing also affects costs of PCT due to diameter increment of stumps of removed trees and the difficulty caused tall felled trees. According to Bergstrand (1986), labour consumption approximately doubles when PCT is postponed from 3 to 6 metres. Uotila et al (2014) show that the proportional increase in time consumption depends strongly on whether the stand is cleaned already once before the operation.

Timing of PCT also has growth and yield effects on stand development. Roberts (1999) reported 7-12% bigger volumes of trees close to first commercial thinning if PCT was done in 3m, instead of 5m. Thus, also stand volumes were higher (2.5-16%) in earlier tended stands.

One has to remember that the stands where PCT is done today will be cut after five decades. Nothing can be forecast about markets. If we think about changes during last 50 years – the basics are the same. Sawmilling industry has already adapted to the change from naturally regenerated pine to logs of direct seeded or planted origin. Developing woodworking technology also allows flexibility – in the future we don’t have to think about quality of log-length pieces of lumber but ready component dimensions for the end use. Glued laminated timber and other EWPs decrease the importance of branch diameter and other quality features of a single piece of lumber.

The diameter of single knots, at least if the variation is within 3 mm, has little effect on bending strength of lumber pieces. Pith-free sawing may be one solution to solve possible problems arising from high proportion of juvenile wood, but its competitiveness is very dependent on the price of the small pieces from the centre of log.

Some concluding views concerning Finland and Sweden related to silvicultural guidelines today and their effect on the wood quality in the future:

Finland

- Better investments available for forest owners than postponing PCT – higher IRR with fertilization, for instance
- Good-quality Scots pine available for sawmilling and other mechanical woodworking in the future
- New chemical pulping capacity built is Southern Finland - wood supply creates pressure on thinning – should or can we react on that?
- Good conditions for the first thinning. Some production lost, however, due to late PCT

Sweden

- Cost-effective PCT
- Some kickback in the 1st thinning conditions concerning technology, however good production in young stands
- A bit lower quality of pine logs than in Finland – does it matter in 2065?

Still today there's a lack of neat and handy model to assess all the most important silvicultural aspects related to the timber quality of Scots pine. Forest regeneration material and technology used today differ markedly from those used in many reports comparing quality of cultivated and naturally regenerated timber. Conclusions and recommendations from different research reports differ from each other and they often do not take cost-efficiency or profitability into account. Silvicultural guidelines are still strongly based on cultural views on quality. The paradox between Finland and Sweden concerning aims in young stand management and log pricing remains unsolved. Diameter difference of 3mm in the butt log knots caused by timing may finally be a small issue; most important is to choose the best trees concerning their growth potential without visible defects. Future market requirements for pine logs are unpredictable but after 50 years remote sensing methods, stand registers, and other data management tools most probably can recognize the best quality stands cost-effectively.

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Session 2

Forest regeneration, drainage and management of young stands

Research objectives for silviculture in JSC “Latvijas valsts meži”

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Latvia’s territory has covered by forest 56.9%. Forest land total 3.35 milj. ha. The half of forests managed by JSC ”Latvijas valsts meži”(LVM).

Main business areas of LVM are roundwood production, silviculture process, forest roads building and maintenance, forest plants and seeds production, real estate, hunting and recreation.

Silviculture process according to knowledge based planning and effective activities should provide healthy and productive stands.

For the next year, our research will be targeted to get more knowledge about young stands management, animal damage risk evaluation depending on accomplished activities, how to promote collaboration with contractors and their quality.

For longer period there are started projects for forest management risk prevention according to global climate changes, to define the prevalence factors of root rot, to determine options to increase productivity of stands by fertilization, to get recommendations for more successful silviculture based on research of various planted stands.

Research activities on mechanization of forest operations in Latvian state Forest Research Institute “Silava”

Dagnija Lazdiņa, Andis Lazdiņš, Igors Gusarevs, Valentīns Lazdāns, Agris Zimelis, Modris Okmanis, Kaspars Liepiņš
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Introduction

The forest regeneration and afforestation research group resumed studies on mechanization of forest regeneration in 2007 after a gap of twenty years since the last activities in this area. Main experimental activities took place nearby Riga in cooperation with “Rīgas meži” Ltd. and Joint stock company “Latvia State forests”, ”Latvijas Finieris”. The first studies were targeted on mechanized planting of coniferous and deciduous container seedlings on mounds. In cooperation with SIA “Intrac” mechanized planting device Bracke P11a was tested productivity of machine in Latvian conditions when seedlings of pine, spruce or birch are planted on various soils (silt, loam and clay). Two methods were compared in the study: direct mechanized planting on mounds and manual planting in area prepared by disc trencher. One year later mechanized planting device M-planter were tested in “Rīgas meži” SIA forests. Results of mechanized planting with the device having two planting buckets, which is able to prepare simultaneously two planting spots, demonstrated better productivity (25 % less time per ha in comparison to Bracke P11.a).

During implementation of several European Regional Development Fund research projects, a set new prototypes of equipment for mechanization of forest operations were developed and some prototypes built up to evaluate the concepts in practice.

Results

The study of Bracke P11a productivity approved that in conditions characteristic to Latvia mechanized planting is more productive, but due of requirement to plant more trees per ha in comparison to Nordic countries, planting of one ha takes more time. Ingrowth of seedling was the same or better in compare to ordinary in late autumn planting (after scarification with disc trencher) (Lazdina et al. 2008).

During last two years remeasurements of forest stands established with Bracke P11a and M-planter were done. First results are very promising, trees planted on mounds are higher and in first two years grove very good, even under ecological or seed trees growth rate were the same (Figure 1). Results of experimental forest stands where M-planter was used are similar – mounds are significantly better for growth of spruce, even late planting of spruce on mounds at autumn (October) gave better results as planting of the same seedlings in early spring a next year in furrows (Figure 2). Trees growing on mounds are more vigorous and results confirm scientific findings of other scientists (Saksa et al. 2005), data of measurements in Latvia are in press.

Considering soil scarification thresholds and productivity of the operation optimal number of mounds is close 1600 trees per ha that were concluded during first experiments (Liepins et al. 2011, Lazdina 2008). Buckets wider than 60 cm are recommended for preparation of mounds just in fertile site types with more aggressive vegetation, where it is enough to plant target trees considering certain percentage of natural ingrowths. In Myrtillosa mel. site type it is necessary to do tending - weed control already during the first growing season (Lazdina 2012) what in most cases is not necessary in Finland and Sweden.

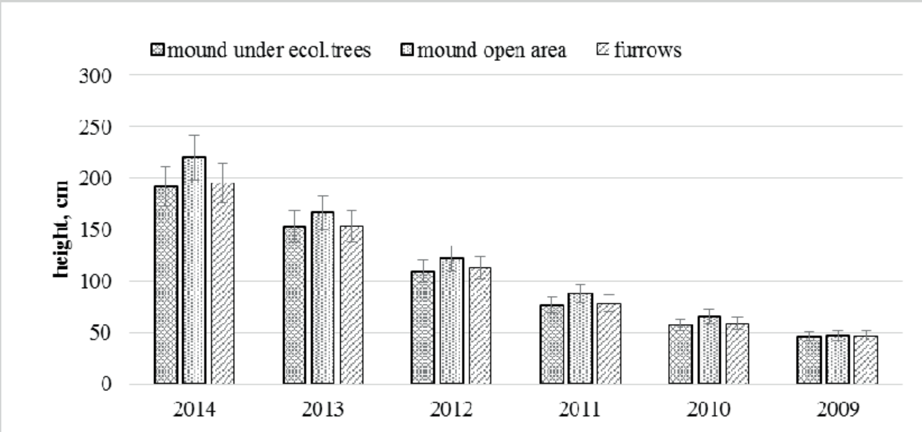


Figure 1. Height (2014) and annual increment (2013-2010) of trees planted 2007 by Bracke P11a at Hylocomiosa forest.

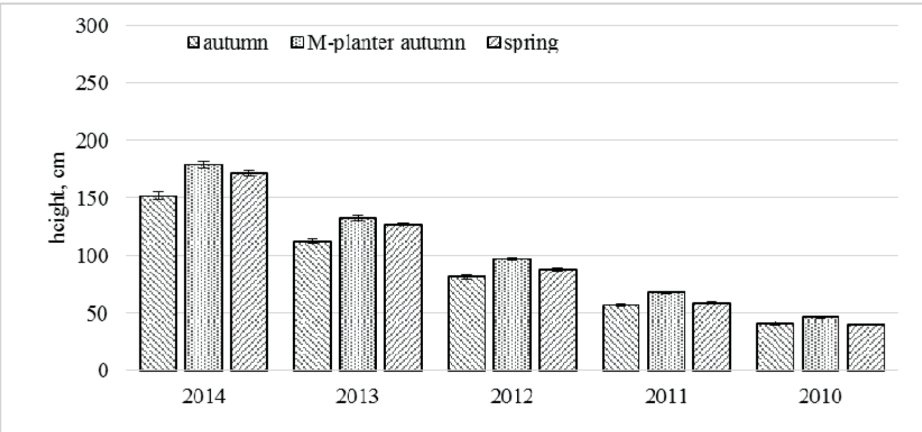
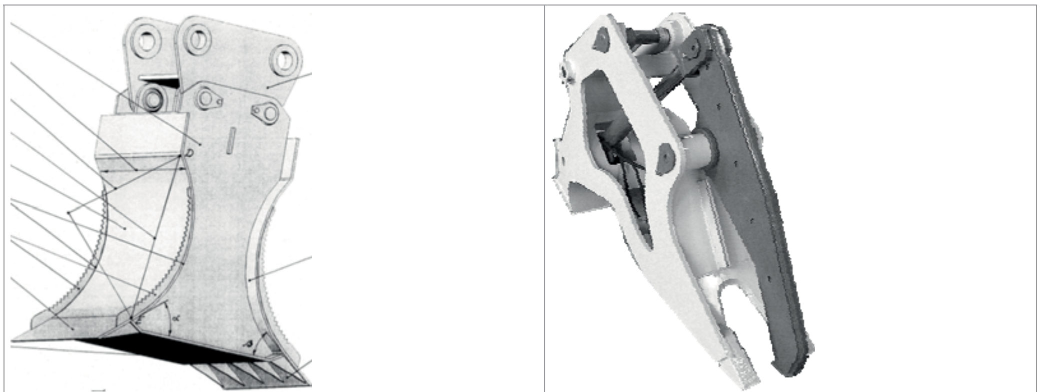


Figure 2. Height (2014) and annual increment (2013-2010) of trees planted 2008 by M-planter at Hylocomiosa & Myrtillosa & Myrtillosa turf. mel forest.

First results of growth of trees at forest sites where mounding were used, encouraged Latvian scientist to elaborate device for soil preparation making mounds. Development and testing a multi-functional prototype machine for soil scarification by mounding and stump extraction were done during 2011-2013 (Figure 3).



for mounding	*for stump extraction and mounding*

Figure 3. Devices elaborated for mechanization of forest operation mechanization during 2011-2013.

Test results of both devices shows, that this soil preparation method were undeservedly neglected in last 20 years (Lazdina 2012).

Minimization of soil scarification is possible by using of two side incurved blade (Figure 4), making “twin mounds” - two mounds from one pit. Twin mounds are easier to found during first tending, because workers at first looking for pit and only then for mound.

Combination of stump lifting and mounding operations allows to remove infected stumps for bioenergy production, and to prepare better planting spots for regeneration of new forest. At least thirty percent of on experimental sites planted coniferous were placed on the best planting spot – mound (Figure 5). According to Latvian legislation - at least 2000 spruces should be planted per ha, so 30 % is 600 trees, what is average number of trees in final felling, it means that it is enough to plant “target” trees on best conditions –mound (Figure 5).

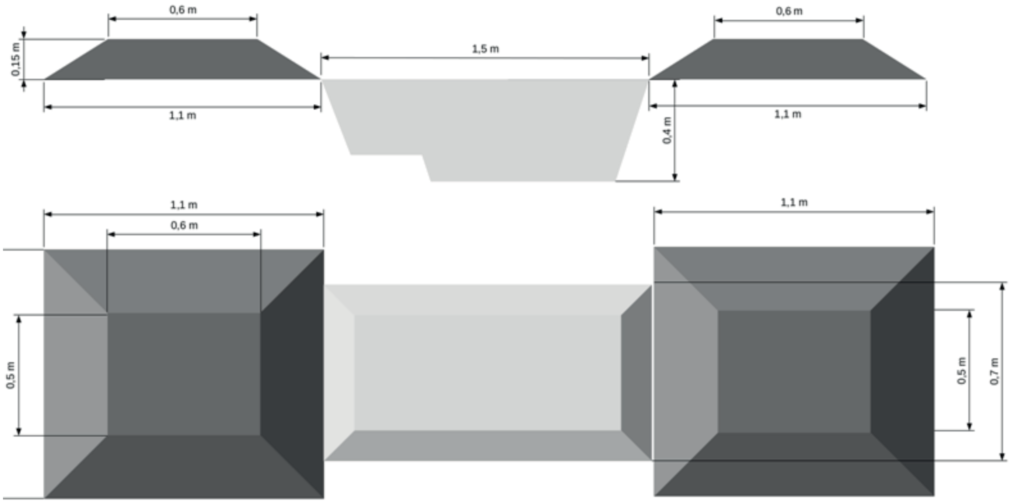


Figure 4. More mounds les pits per ha leads to less scarification of soil (technical drawing of “twin” mound).

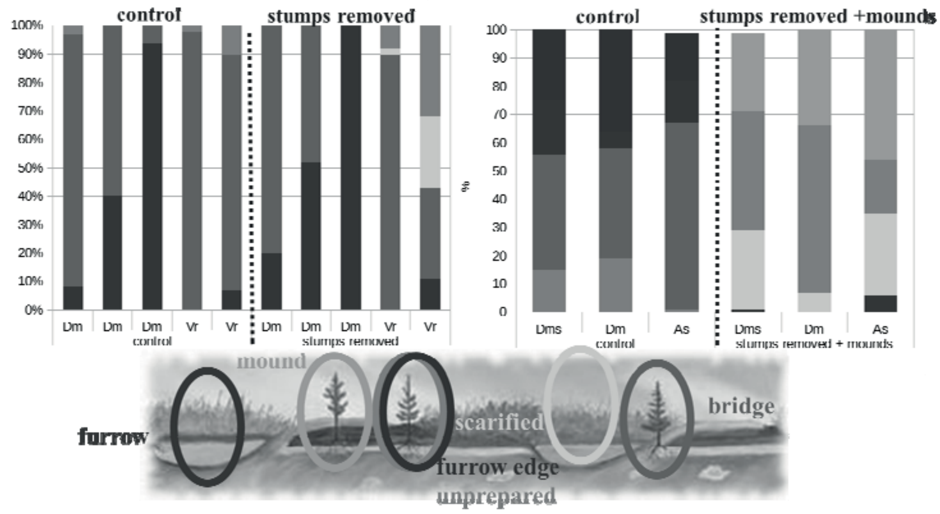
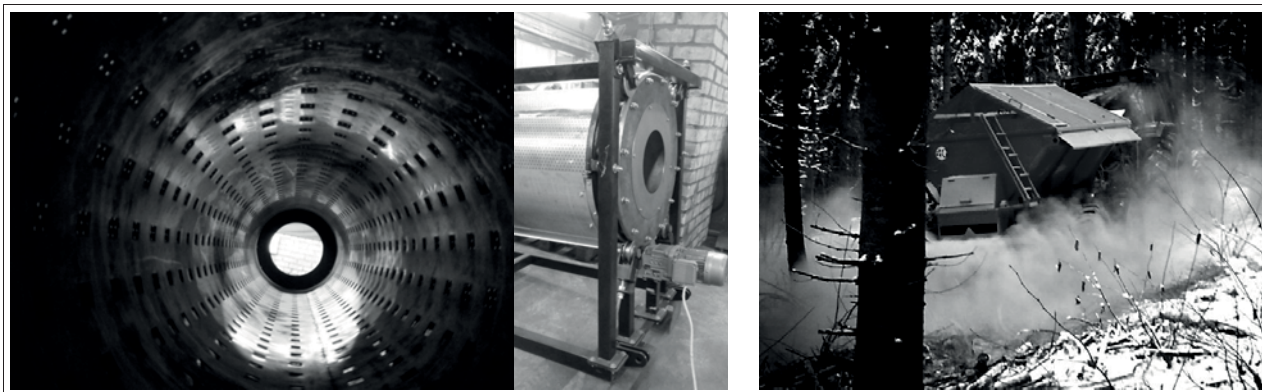


Figure 5. Distribution of different kind planting spots for trees after stump lifting.

Because of increasing of demand of renewable biofuels former recycling of nutrients in forest is changed. After using of removed from forest slash - lignocellulosic materials for green energy production occurring “residue” – wood ash - indeed great source of P, K and micronutrient elements (Okmanis et al. 2015). Results of applying of wood ash for vitalization of damaged spruce stands seamed very promising (Ermane et al. 2012). During last two years researchers and engineers worked on development of technical solutions for utilization of wood ash in forest as fertilizer. Two prototypes of mechanisms aimed to improve wood ash recycling were built (Figure 5).



For wood ash screening | *For wood ash spreading*

Figure 5. Wood ash recycling to forest mechanization in Latvia.

First economical results already are presented (Okmanis et al. 2015, Gusarevs et al. 2015) costs for one hour implements services was 25.00 EUR . Growth curves show positive response of plants to wood ash applying.

Since 2011 till 2015 the excavator bucket for mounding (LV14692), stump extraction device (LV14769), device for ash screening (LV14954) were patented in Latvia[1].

Conclusions

Mound as soil preparation method in wet forests shows promising growth results in young stands - higher spruce trees with vigorous crowns.

Usage of special devices for mounding decreases scarification area of the ground cover.

Combination of soil preparation and infected stump lifting - allows to prepare sufficient amount of good quality mounds for planting of “future trees”

Recycling of wood ash to forest – transport back to forest removed mineral elements should be considered as normal practice. For implementation of wood ash recycling is necessary to develop technologies of full chain of wood ash processing, application or spreading.

Keywords: mechanized planting, mound, birch, spruce, pine, soil, forest regeneration, ash recycling.

Acknowledgements to Forest development fund, SIA “Rīgas meži”, JSC “Latvijas valsts meži”, Ļatvijas finieri“Latvijas Finieris”, SIA “ORVI”, European Regional Development Fund.

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Preliminary data on productivity and cost of wood ash spreading in forest

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Wood ash utilization is essential problem, which is increasing because of policy targets for generating energy from biofuel end decreasing of fossil fuel consumption. One of the wood ash utilization options is spreading in forest for soil amendment. This option is often used in Scandinavia, however in Latvia it is not common practice. To get some steps closer to wood ash use for fertilization implementation in practice, field experiments and assessment of ash spreading should be done. Therefore trial of forest fertilization was carried out using spreading trailer which was connected with tractor Valtra 6350 equipped with wheel loader.

Experiment was held in end of November of 2014. Forest stands are distributed at Joint Stock Company „Latvia's State Forests" Viesite forest district. Experiment of wood ash spreading was made in four (two Hylocomiosa and two Oxalidosa turf. mel.) Norway spruce *Picea abies* (L.) Karst. stands from age of 43 to 48 years which were thinned in last two years. In Total 20 t of wood ash were spread in 10 ha area. To calculate productivity time for all work elements in total productive time consumption were received. Observation of spreading trailer imperfections was made during experiment. Suggestions for spreading trailer improvement were set.

Total time consumed for fertilization was 17 hours and 29 minutes, productivity of ash spreading vary from 0.38 to 0.70 ha h^{-1}. Costs for one hour implements services were 25.00 EUR, total spreading costs were 437.13 EUR or 43.71 EUR ha^{-1}. Main problems faced during operation were related to the ability to overcome difficult obstacles, so it is required to equip rear axle with hydraulic drive.

Keywords: wood ash, spreading productivity

Forest regeneration and management of young stands in Estonia

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Forest regeneration is a key for successful and adaptive forestry in future climate, and the prerequisite for the continued and increasing supply of forest biomass and ecosystem services. Choice of tree species, selection of forest regeneration methods and decisions on young stand management activities shape the future forests.

Mechanical site preparation is one of the main methods to enhance natural regeneration and to facilitate the establishment of seedlings. In State forests different soil scarification methods are used. The dominant methods have been disc-trenching (75%), patch scarification (20%) and mounding (5%). In private forests the most common method is disc trenching, followed by patch scarification, and recently excavators are used to reconstruct forest drainage systems and to make soil scarification simultaneously. However, the latter method is considered to be quite expensive.

In State forests mechanized planting is not practiced and only manual tree planting is used to regenerate the forests. All seedlings are planted with shovels, planting tubes (e.g. *Pottiputki*) or other similar tools. Similarly, in private forests manual tree planting is still the most widespread planting method used today. In State forests mechanized seeding is carried out on 90% of sowing sites. In private forests mechanized seeding in conjunction with disc trenching is used, and partners include State Forest Management Centre (RMK) and some private companies.

In Estonia, motor-manual pre-commercial thinning (PCT) with a clearing saw is prevalent method in young stand management. It is considered as a rather cheap method, with the main costs related to labour and does not require expensive equipment, tools and materials. In some cases chainsaws are also used in PCT.

Seedpad, a new and efficient regeneration method?

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Goals

- Increased seed efficiency
- Only genetically improved material
- Lower costs per established seedling
- Improved performance (mechanization)

Background

Moisture is needed for germination but it’s shifting rapidly in the soil surface depending on weather conditions. Covering of seeds by microsite preparation creates more reliable moisture conditions (Fig. 1).

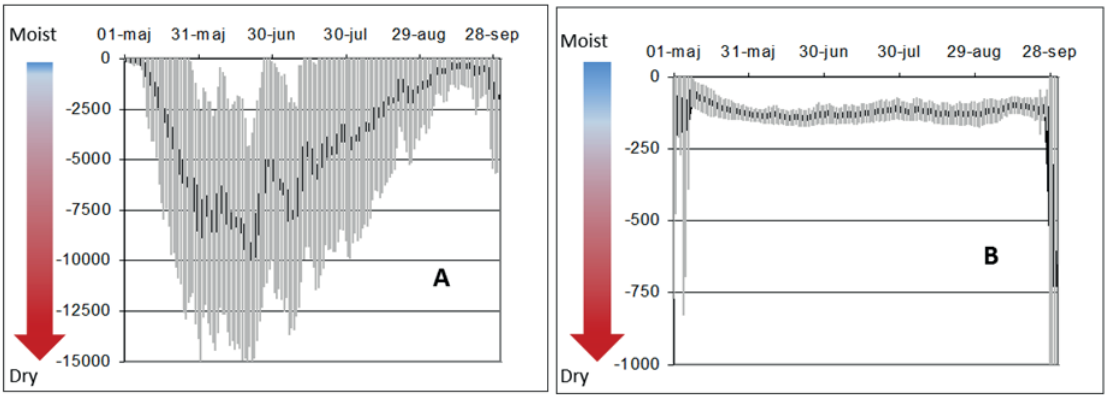

Figure 1. Simulation of moisture conditions (by Harald Grip, SLU) in the mineral soil surface without covering (A) and with covering by 2cm of humus (B).

Seed orchards are established for production of seeds used for seedlings and not for direct seeding. Direct seeding uses about a tenfold more seeds than planting so even if it’s cheaper than planting it will be expensive in a longer perspective if improved seeds can’t be used.

There is a method for mechanized direct seeding including scarification and microsite preparation developed, which makes direct seeding less dependent on weather conditions. However the number of seeds needed is still high, about fivefold compared to planting.

Germination and seedling establishment has to be improved to a level where not more than two seeds are needed.

SeedPAD principle

A unit containing a seed and material that improves germination conditions that could be efficiently placed on mineral soil after scarification was one possible solution.

It started with a paper bag with two seeds glued to the bottom covered with homogenized peat. Today the paper is changed to a polymer; the peat is changed to a disc of compressed vermiculite and one seed is used.

It's very important that high quality seed with almost 100% germination capacity is used because a "blank" SeedPAD is a waste of opportunity.

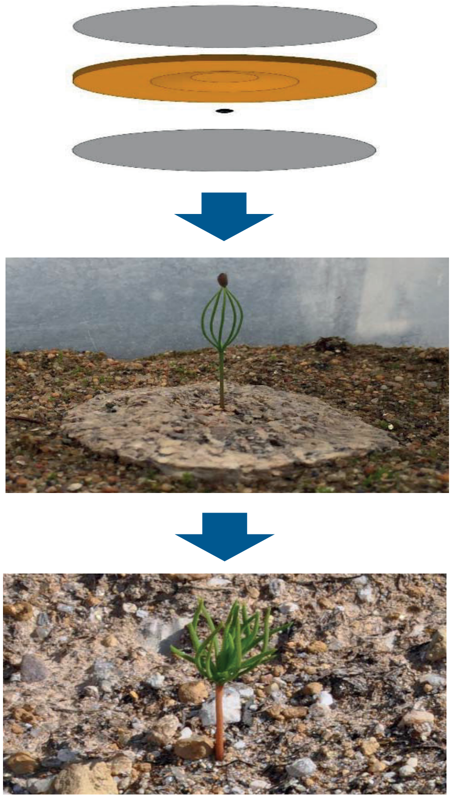

Figure 2. At the top the different parts of a SeedPAD is shown, in the middle a germinant after two to three weeks and at the bottom a seedling after one growing season.

SeedPAD field trials

In Ullatti 2012 different direct seeding methods where compared, including microsite preparation and covering with peat. The combination of them showed the highest germination but the difference to only covering was small.

Paper bags with peat and vermiculite where used in 2013 (about 500 units) and 2014 (about 5000 units). In 2015 about 150' units of compressed vermiculite (Fig. 2 top) with paper and about 500'units with polymer instead of paper was used (Fig. 3).

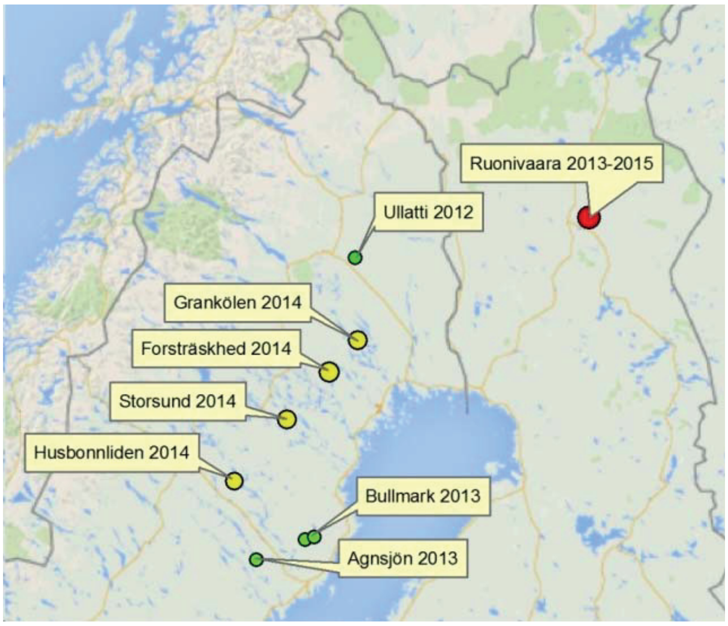

Figure 3. Field trials in Finland and Sweden between 2012-2015, except practical trials by Holmen and Sveaskog during 2015.

Results

Table 1. Results for SeedPAD field trials established in June each year. The first four values for 2015 are for SeedPAD with polymer and the two last are for the paper version used by Holmen. The average result for all trials is 69% seedling emergence.

2012	2013	2014	2015
66	69	76	73
57	73	70	68
	68	69	48
	79	60	66
	75	64	74
		73	82
61,5	**72,2**	**68,0**	**68,5**

In Ruonivaara a three year trial with seeding and placing of SeedPAD:s during six months (June-November) was established.

Results for direct seeding and SeedPAD where better in June, July, October and November than in the other months, the level for SeedPAD was higher than for direct seeding, see fig 4.

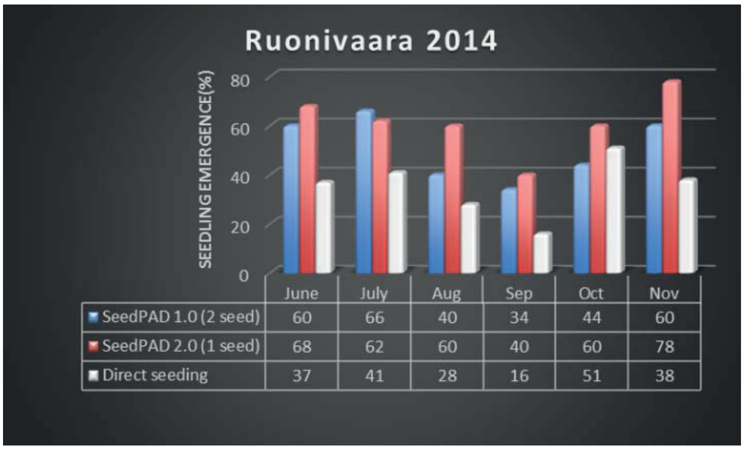

Figure 4. Seedling emergence for SeedPAD and direct seeding at the inventory in July 2015.

During 2015 the results for the version with paper and compressed vermiculite in practical trials at Sveaskog (100'units) was between 32 and 64% emergence and at Holmen (30'units) between 53-77%. In Ruonivaara, where both the old paper bag and the new SeedPAD with paper were used, the bag showed 70% emergence for the June trial and the new showed 40% emergence.

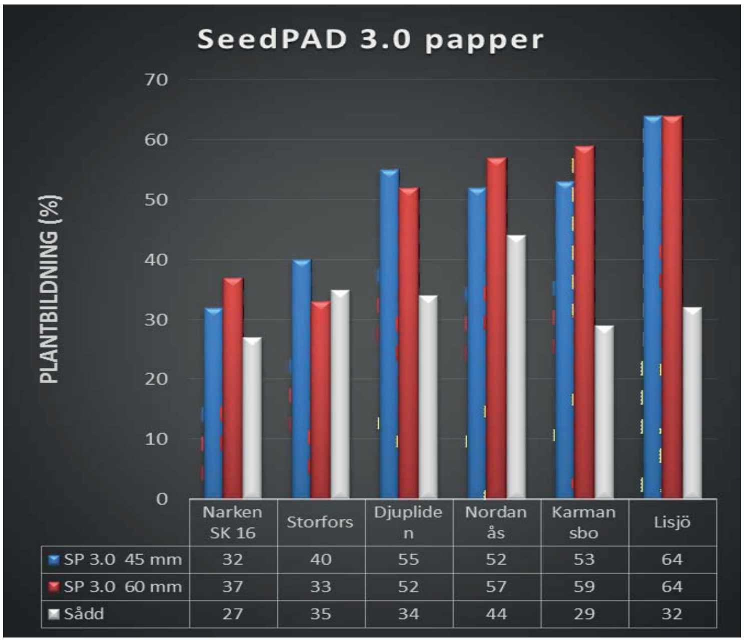

Figure 5. Seedling emergence for field trials at Sveaskog during 2015. Narken SK 16 in Norrbotten is the northernmost site and Lisjö in Bergslagen is the southernmost.

A few units with a polymer coating instead of paper where used on each site and the results where better, see fig. 6.

This and the results from Ruonivaara indicated that the SeedPAD developed for the trials in 2015 was a setback. Investigations during this autumn shows that the glue that was used had made the paper to strong, creating problems for the penetration and also that the seed lot used in Narken and Storfors was not the best.

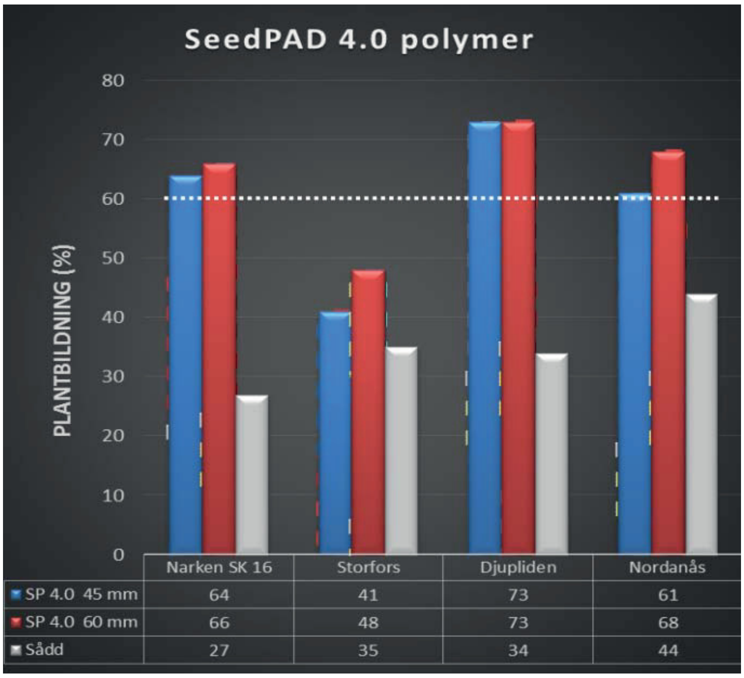

Figure 6. Seedling emergence for SeedPAD coated with polymer instead of paper, in Sveaskog trials in Norr- and Västerbotten.

Further development

SeedPAD shows promising results but there is still a lot of development possible and needed. The unit that will be used in 2016 will consist of compressed vermiculite, polymer coating and one high quality seed (Fig 7.). The plan is to produce 1.5 million units.

Figure 7. SeedPAD version 5.0 for 2016.

Technical development

A tool for placing SeedPAD in the scarified track has been developed and tested (Fig. 8). It should be possible to place out at least 8'units/day with it.

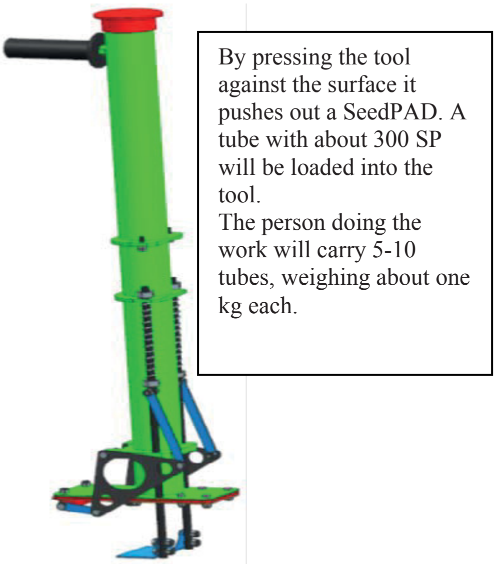

Figure 8. Tool

Fertilizer

It will be possible to insert fertilizers into the SeedPAD and SweTree Technologies are already testing different formulas in field trials.

The increased growth should make it possible to use SeedPAD as a regeneration method on more fertile soils than where direct seeding can be used (Fig. 9).

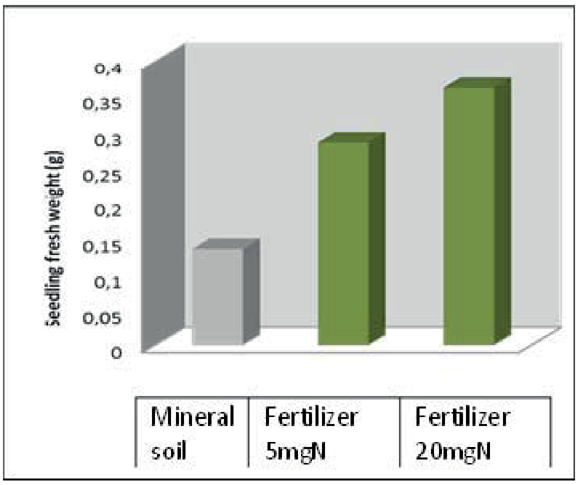

Figure 9. Effects of fertilizer on seedling fresh weight after one growing season.

Scarification

In order to create the best possible germination and seedling establishment conditions scarification has to be adapted.

The SeedPAD has to get in contact with the surface of the mineral soil which gives the needed moisture conditions. If the surface is smooth and even the contact is better than when it is coarse and uneven.

It's probably better with a narrow track after scarification than with a wide, because if the humus layer is closer to the seedling it will get more nutrients and less risk of disturbance due to heavy rain.

A big problem for small seedlings is needle ice and frost heaving. If the scarification is very shallow, just removing the humus layer and leaving an intact bleached horizon, the risk is reduced a lot.

Figure 10. A picture from Ruonivaara in November 2015 showing effects of needle ice on different layers of soil. The bleached layer (E-horizon, ash layer) is intact, to the left. The rusty soil (B-horizon) is heavily impacted by needle ice, to the right.

Session 3

New ways of young stand management

Case study of productivity and quality of early thinning using Vimek 404T6 Harvester and Vimek 610 forwarder compering with experience in Latvia

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The regulations in Latvia do not permit use of small machinery like Vimek 404T6 harvester and Vimek 610 forwarder in thinning due to limitations of area of the strip-roads. According to the Latvian legislation it may not exceed 20 % of the stand area. The small-size machinery makes an up to 2.5 m wide strip-road (technological corridor) every 10th meter (using the maximum extension of the crane). In practice, Swedish operators do not use the maximum extension of the manipulator and the distance between the corridors is even smaller. In Sweden, the strip-roads made by small-size harvesters and forwarders are not accounted as corridors because no trees of the dominant species should be extracted additionally to make the reads, i.e. not 20 % of the stand irrelevantly to to width of the strip-road like in Latvia. According to Swedish regulations the part of a stand under these narrow roads is considered as properly tended and is not separated as a road.

Scientists from the LSFRI Silava took part in time studies of Vimek 404T6 harvester and Vimek 610 forwarder in Sweden in the beginning of 2015. The trial was kindly organized by Sales Representative of Vimek company, Urban Lundström, who consulted Latvian researchers and shared experience about the use of the small-size machinery in Sweden. The issues relating to forestry and quality requirements in Sweden were explained by experienced manager of Swedish logging company participating in trials with their machines.

The work time was accounted using shock- and humidity-resistant field computer Allegro CX with time tracking software SDI. During hauling, the driving speed of the forwarder was determined using GPS measurements.

The time studies did not include accounting of fuel consumption, and the average figures provided by the manufacturer were used. The work time of the harvester was matched with accounting of the engine hours, i.e. the time study was stopped when the engine was switched off and resumed when the engine was started again.

The time study of thinning was done during one shift per day. The duration of a shift was 8-12 hours working. The consumption of work time was determined per every crane cycle recording also the average diameter of the gripped trees (at the cutting height visually) and quantity of trees processed per crane cycle. The work time elements are shown in Table 1). Volume of every load forwarded to roadside was estimated by operator.

The air temperature during the tests was 3-8 ^{o}C during daytime and -2-0 ^{o}C during night-time. On 23 February there were small precipitations (10 mm per day). During other days the weather conditions were optimal and did not affect the productivity.

Table 1. Work time elements in harvesting and forwarding.

Harvesting		Forwarding	
Category	**Explanation**	**Category**	**Explanation**
Informative fields	working time accounting cycle number	Informative fields	various notes, inter alia on breaks, passages, change of corridor etc.
	average diameter of gripped trees d1.3, mm	Effective work time	driving to stand
	qty. of gripped trees		reaching logs when loading
	felled half-trunks		gripping logs when loading
	various notes, inter alia on breaks, passages, change of corridor etc.		loading logs in the bunk
Productive working time	reaching tree		arranging logs in bunk
	time for gripping tree		driving during loading
	cutting tree		putting logs and slash into strip-road
	drawing the trunk and placing in the assortment stack		driving out of stand
	clearing the undergrowth		reaching log when unloading
	bucking the tree		
	time consumed to enter the stand		unloading logs – from gripping till releasing in the yard
	time consumed to exit the stand		gripping logs when unloading
	other non-standard operations, inter alia clearing the undergrowth and machine service		moving when unloading
Non-productive time	activities not related to work		other work-related operations
		Non-productive time	activities not related to work

Results

The stands were surveyed before and after thinning, including assessment of thinning quality and the stand parameters (diameter and height of trees in circular sample plots). Due to thinning the average tree diameter in Stand 1 increased from 9.7 cm to 10.3 and in Stand 2 from 10.9 cm to12.1 cm (Table 2), the remaining basal area decreased to 17 and 23 m^2 ha^{-1} respectively. According to the measurement data the felled volume in Stand 1 was 73m^3 ha^{-1} and in Stand 2 – 89 m^3 ha^{-1} (Table 3).

The number of trees remaining in the stands after thinning is comparatively high (also according the Swedish standards). Recommended thinning intensity in the experimental stands would be to extract 500 trees ha^{-1} more so that remaining number of trees is 1,500 trees ha^{-1} in both stands.

Table 2. Characterisation of the stands after thinning.

Stand	Number of trees ha^{-1}	Average tree diameter, cm	Average tree height, m	Trunk volume, m^3 ha^{-1}	Basal area, m^2 ha^{-1}
1	2025	10.3	10.9	115	17
2	2000	12.1	14.3	206	23

Table 3. Parameters of extracted trees.

Stand	Number of trees ha^{-1}	Trunk volume, m^3 ha^{-1}	Basal area, m^2 ha^{-1}
1	1600	73	10
2	1500	89	10

Most of the trees in both stands after the thinning are 9-12 cm thick; the proportion of the trees with diameter below 8.1 cm after the thinning does not exceed 10% (Figure 1). The largest reduction during thinning took place in diameter group 5-8 cm.

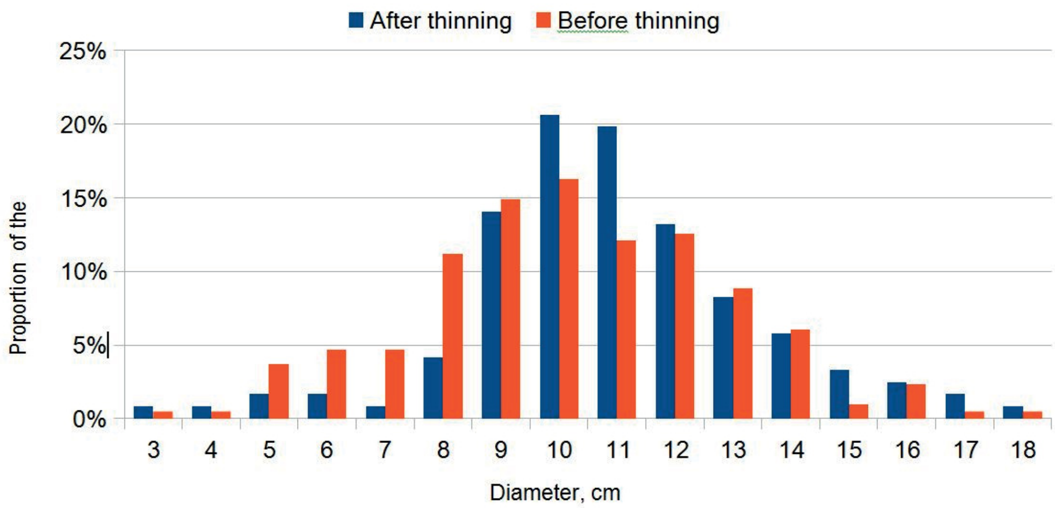

Figure 1. Distribution of the numbers of trees by diameter classes.

The time studies of harvester continued 2 days. The most of the work time was used to delimbing and bucking operation (Figure 2); driving in and out from the stand, as well as the work cycles that did not resulted in produced pieces of roundwood took 9 % of the working time (time when the engine was on). Bucking, delimbing and driving in stand altogether consumed 66 % of the productive time.

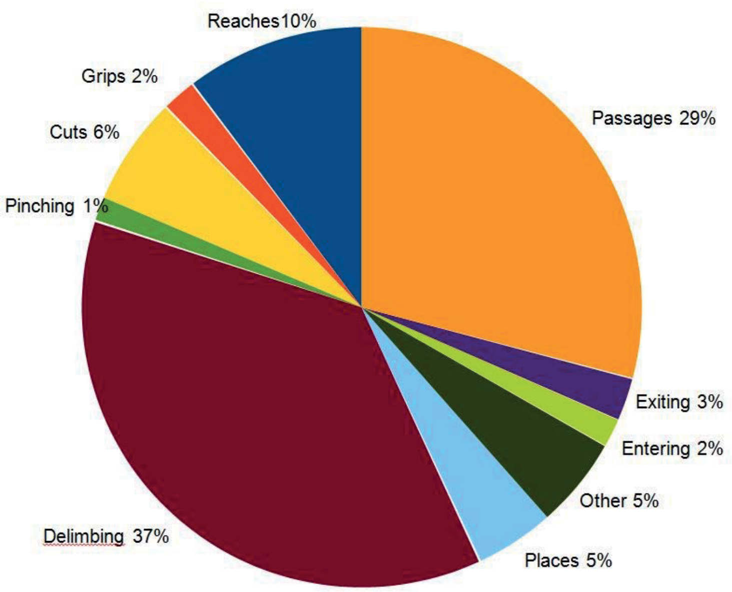

Figure 2. Distribution of Working Time Elements in the Total Duration.

Trees with diameter above 8 cm dominated in extracted stock (Figure 3). Their proportion in the number of the felled trees was 79 % and their volume was 85 % of the produced roundwood and biofuel (Figure 4). Operator avoided cutting trees with diameter below 8 cm; however, considering the high initial density, it was impossible to fully avoid cutting small trees.

The diameter distribution of the extracted trees significantly differs from similar tests in Latvia, where the most of the trees extracted in early thinning have diameter below 8 cm. The reasons for the difference are influence of the undergrowth, which is extracted to improve visibility and accessibility, and considerably higher number of types of assortments to be produced in thinning. Swedish experience can provide solution for this problem, however productivity and economic consequences of the optimisation of the assortments' structure should be evaluated in further studies. Another Swedish experience to expand to Latvia is getting rid of strict requirements for length of timber and switching to variable length (2.2-5.5 m for pulpwood or biofuel logs).

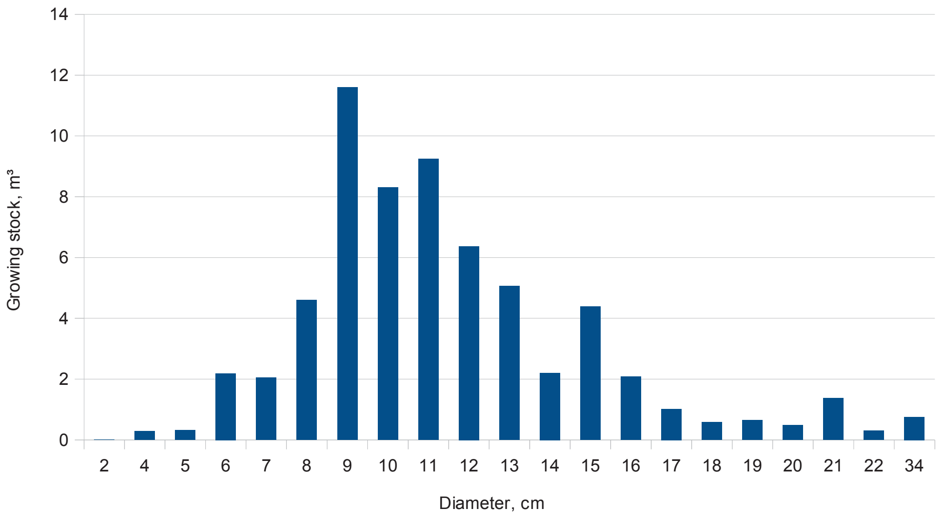

Figure 3. Distribution of the Number of Felled Trees by Diameter.

On average, in 5.7 m^3 of roundwood and biofuel was produced during 1 productive work hour (Table 4). The efficient work time (work cycles resulting with logs) was 94 % of the planned work time. Productivity increase with growth of diameter of extracted trees (Figure 4).

Table 4. Summary of Productivity Figures of Harvesting.

Stand	Productivity, m^3/direct work hour	Productivity, trees/direct work hour	Productivity, m^3/productive work hour	Productivity, m^3/total work hour
1	5.924	105	5.494	5.287
2	4.971	111	4.783	4.638
On average	5.673	107	5.312	5.122

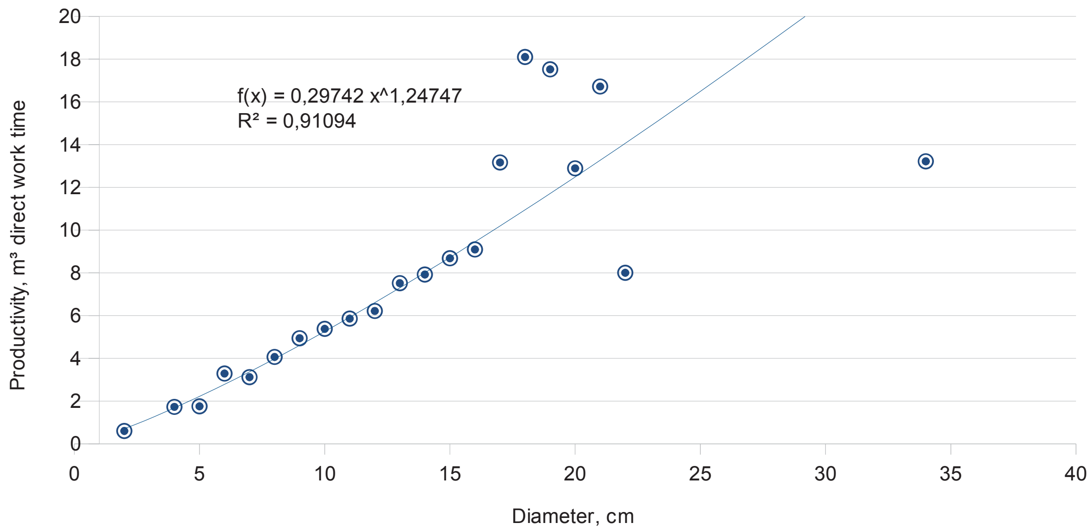

Figure 4. Harvesting productivity (m^3 per direct work hour) depending from diameter of tree.

Productivity of forwarding is shown in Table 5. Loading and unloading time is comparable results obtained in Latvia in trials in similar conditions with heavier machines like John Deere 810D. Driving speed is considerably smaller.

Table 5. Summary of forwarding productivity.

Productivity of loading in, m^3 per productive work hour	Productivity of loading out, m^3 per productive work hour	Productive time from total time	Average driving speed, m $min.^{-1}$
17.9	56.1	99%	22.7

Productive time consumption per load, excluding driving, in trials was 23 min. including 17 min. for loading and 5 min. for unloading, average load was 5 m^3.

Conclusions

1. The productivity figures of harvesting obtained in early thinning in Sweden are at least twice better than the results of similar trials in Latvia. Better productivity can be explained by professionalism of operators (time spent to cut undergrowth trees is negligible); simple structure of roundwood and biofuel assortments in Sweden (not more than 3 types of logs are produced in early thinning, variable length of logs is accepted, all the types of logs are piled in one stack in a stand); optimal choice of work method that makes it possible to make a free network of strip-roads adjusting the pathway of harvester to the actual structure of stand.
2. Damages to the remaining trees and soil in the trials in Sweden were far below the thresholds according to Latvian rules. The forwarder operator had no problems hauling even 5 m long logs following the path of the harvester. It is important to use this combination of machines in early thinning and not the Vimek harvester and a larger forwarder or vice versa, as the benefits come from the use of the combination of particular harvester and forwarder.
3. The revenues from the sale of timber from thinning using Vimek machine set cover the production costs if the diameter of average cut tree is at least 6 cm if biofuel is delivered as partially de-

limbed small logs and at least 5 cm if wood chips are delivered to customer. The work conditions are optimal in stands where the diameter average cut tree is 8-10 cm. In stands with larger trees, in particular in fertile forest types, the productivity is hindered by the increasing time consumption for delimbing.

4. The harvester's control system makes it possible to account the timber according to the requirements of Joint stock company "Latvia state forests"; consequently, there are no organisational obstacles to using this set of machines in thinning and other logging works in the state forests.

Keywords: Vimek, forwarding, harvesting, productivity, thinning

Productivity, work processes and development potential of small-tree bundler Fixteri FX15a from early thinnings

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Introduction

In the Nordic countries several different cutting techniques have been launched, during the last decade, to increase harvesting productivity in young stands (Bergström 2009; Belbo 2011; Laitila 2012). So far, the most successful small diameter wood thinning supply chain has been multi-tree harvesting with a two-machine chain. In this system, a harvester or feller-buncher cuts and bunch the trees along strip roads, and a forwarder hauls them to the roadside storage (Kärhä et al. 2005; Iwarsson Wide 2010). In multi-tree handling, the accumulating felling head is capable of felling and bunching several trees in each boom cycle (Bergström 2009; Iwarsson Wide 2010; Belbo 2011; Nuutinen et al. 2011). However, first thinnings still constitute an operational dilemma in Europe: they should be carried out to improve the development of the future stand, but are often neglected due to high harvesting costs. The causes of the high harvesting costs are the small stem size and low biomass removals per ha. In addition, dense undergrowth often weakens the profitability of early thinnings (Kärhä et al. 2006; Oikari et al. 2010). The small-tree bundler Fixteri FX15a (Fixteri Ltd. 2014) was developed in order to rationalize the integrated harvesting of small-diameter energy wood and pulpwood in thinning operations, and to reduce transportation costs through load compaction (Nuutinen & Björheden 2015). The findings of recent studies (Ala-Varvi & Ovaskainen 2013, Bergström et al. 2015, Nuutinen & Björheden 2015) indicate that bundling small-diameter trees from thinnings has become a viable technology with the development of the Fixteri harvester-bundler. The studies also show that the features of the bundles also can reduce the cost of forwarding, storage, road transportation and comminution for early thinnings in comparison to traditional systems were loose materials are handled.

This paper reports productivity and work processes of a small-tree bundler in energy wood harvesting from early pine dominated thinnings. In the discussion, a possible development of supply chains for bundle systems from small diameter stands is presented.

Materials and methods

This study is based on two sub-studies made by Nuutinen and Björheden (2015): 1) time and motion study of cutting and 2) technical function test. The studied whole-tree bundler consists of a Logman 811FC base machine, a Nisula 280E+ accumulating felling head, and a Fixteri FX15a bundling unit (Fixteri Ltd 2014). The machine fells and accumulates small-trees, which are fed into the bundling unit, where crosscutting, compaction, winding, scaling, and output of bundles of approximately 0.6 m^3 solid is performed in an automated process. When ejected from the bundling chamber, each bundle is weighed before it is dropped on the ground. The time-and-motion study (1) was carried out in Central Finland in late winter in March 2013. The productivity level of the new Fixteri FX15a system in small-tree harvesting was studied in different pine dominated stands with a removal of 6-14 cm in breast height diameter (DBH). In the experiments, the Fixteri-bundler opened strip road and thinned trees from below. In the technical function test (2) the capacity of the crane work and the bundling unit was simulated to find out if bottlenecks between them were restricting overall productivity of the whole-tree bundler concept. The simulation was conducted for the range of removed whole-tree sizes with stump diameters ranging from 5 to 17 cm.

Results

In the sub-study 1, the observed productive machine hour, PMh, was 9.7 m^3 in the dense young stand with rich undergrowth (removal 3216 trees per hectare with an average whole-tree volume of 27 dm^3). In the dense stand with no undergrowth, a productivity of 11.9 m^3/PMh was reached (removal 2019 trees per hectare, 44 dm^3/tree). In the first thinning, at an average whole-tree volume of 84 dm^3 and a removal of 1266 trees per hectare, the productivity was 13.8 m^3/PMh.

In the technical function test (2), the productivity of crane work increased significantly when the size of the accumulated trees increased: when the stump diameter/volume of the cut tree was 5 cm/3.0 dm^3, the productivity of felling-feeding was 2.5 m^3/PMh. For the biggest trees, stump diameter 17 cm and size 93.2 dm^3, the productivity increased to 16.0 m^3/PMh. The production capacity of the bundling unit varied from 23.3 to 36.3 m^3/PMh. The bundling unit has a significantly higher capacity than the crane and felling head. The analysis shows that the felling-feeding sub-system restricts the production of the concept. The ideal production capacity of the bundling unit was from 2 to 10 times higher than the possible level of felling-feeding depending on the tree size (Figure 1).

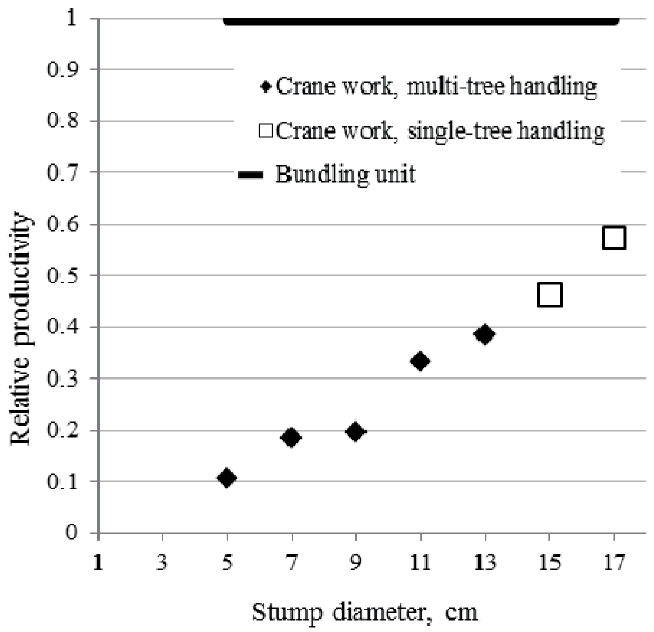

Figure 1. The production capacity of felling-feeding was in the range of 0.1-0.6 of the respective ideal capacity of the bundling unit, based on the technical simulation study.

Discussion

Nuutinen and Björheden (2015) investigated the effects of stand density, undergrowth and tree size on the bundle harvester operation in pine dominated stands when tree size varying from 30 to 85 dm^3. Respectively, in the study on Ala-Varvi and Ovaskainen (2013) the productivity of the studied bundle harvester was in the same level. Also Bergström et al. (2015) studied the Fixteri FX15a bundle harvester in early fuel wood thinnings in the North of Sweden. Their studies of the machine productivity focused on stands with an average harvested tree size below 30 dm^3 (the average tree volume in the time study plots varied from 15 to 43 dm^3). The harvested forest composed mostly of Scots pine, Norway spruce and Birch. The recorded performance is similar to the findings of this study.

Ala-Varvi and Ovaskainen (2013) compared the competitiveness of the Fixteri FX15a small-tree bundler to cutting of undelimbed trees with a traditional harvester equipped with an accumulating harvester head. They determined the costs of cutting and forwarding of both supply chains at an average tree volume of 40 dm^3, forwarding distance of 300 m and harvesting removal of 60 m^3 per hectare. The cost of whole-tree bundling operation was 13.6 €/m^3 and for cutting of undelimbed trees 15.3 €/m^3. The cost for forwarding the bundles was 3.57 €/m^3 and respectively for delimbed trees 5.56 €/m^3. They found the total cost of the wood chip supply chain of whole-tree bundling (46.7 €/m^3) to be lower compared to undelimbed trees (50.2 €/m^3) if the average volume of removed trees was less than 85 dm^3. Kärhä et al. (2009) defined the productivity of forwarding of whole-tree bundles. The productivity of whole-tree bundle forwarding was 23.8 m^3/E_0-hour (bundle size 0.5 m^3, whole-tree removal 60 m^3/ha, and the forwarding distance 300 m; thus the forwarding costs of whole trees were over double compared to whole tree bundles.

Nuutinen et al. (2015) investigated the quality and productivity of five different chippers and one grinder when comminuting bundles produced of small-diameter trees. In the study, the average productivity based on dry mass of chipping the whole-tree bundles was 52 t/E_0h. In the study of Kons et al. (2015), the dry mass chipping productivity for the Fixteri Fx15a whole-tree bundles was 32 t/E_0h whereas the productivities of delimbed whole-trees and logging residues were significantly lower accounting for 16 and 14 t/E_0h, respectively. The higher productivity in comminuting of whole-tree bundles compared to comminution productivities of logging residues and whole-trees resulted from increased size of grapple bunch per crane cycle.

The results of Nuutinen and Björheden (2015) showed that felling-accumulation is an important development target in order to increase the efficiency of multi-tree cutting of small trees of DBH of 2-9 cm and whole-tree volume of 3-45 dm^3. Along improving the performance of the studied bundle harvester a possibility could be to cut trees in narrow strips of boom-corridors along strip roads in dense stands (Bergström 2009). This thinning system has shown to render a development of rational felling and bunching technologies. Bergström and Di Fulvio (2014) show that if the Fixteri bundle harvester system is featured with efficient cutting technology the system would be very competitive in very young dense first thinning stands. In such thinning system the boom-corridors could be about 1 m with a length corresponding to the crane reach (about 10 m) (Figure 2).

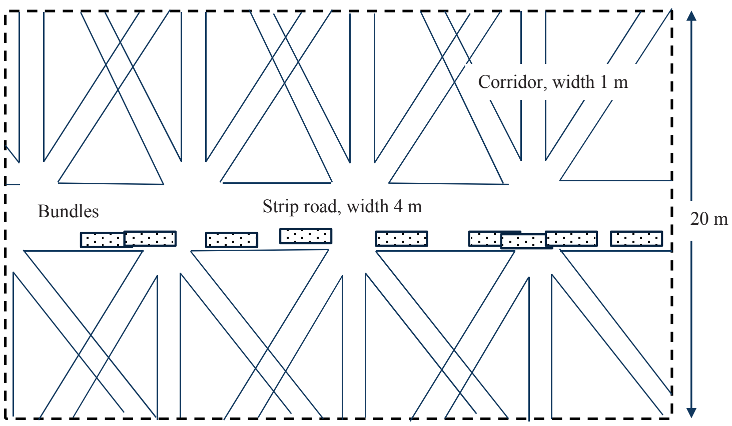

Figure 2. Schematic description of boom-corridor thinning patterns by Bergström (2009) adapted for bundle harvester.

In corridor thinning, using a conventional harvester equipped with multi-tree handling head the loose whole-trees are normally felled towards unthinned stand and bunched along the corridors resulting in time consuming non-linear crane movements in arranging the tree bunches and avoiding future crop trees. However, the bundle harvester feeds the accumulated grapple bunch directly to the bundling unit and drops the finished bundle onto the left side of the strip road. This enables the bundle harvester head operating in a clear, unobstructed working environment and thereby the time required for re-positioning the felling head in each crane cycle should be reduced since trees hindering its movement are removed and bundled as the corridor is harvested. Also for the remaining trees damages would probably be smaller.

Bergström et al. (2010) found that using the commercial accumulating felling head the productivity for boom corridor thinning was 16 % higher compared to traditional thinning below with strip roads. Isomäki & Väisänen (1980), Mäkinen et al. (2006) and Karlsson et al. (2012) investigated the long term effects of systematic corridor thinning and thinning from below harvesting methods on growing stock and on the thinning yield. In these studies no significant differences in volume growth, standing volume and mortality volume were detected. Bergström (2009) states: “Boom corridor thinning systems are focusing on the work method, i.e., the intention is not to create corridors in the remaining stand but to take out trees corridor-wise.” Based on results of the previous studies it can be concluded that the corridor thinning method would be worth studying especially when assuming that the corridor thinning method would be used to better the cost efficiency of the supply chain only in the dense small diameter thinnings.

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Ongoing evolution of innovative systems for harvest of small diameter trees in Sweden

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Introduction

The consumption of forest bio energy has increased dramatically in Sweden over the last ten years. Since the residuals from the saw log industry and pulp mills by now already are used for heat and power production the only way to increase the supply of forest bio energy is to increase the removals from the forest directly aimed at energy production. In 2013 the production of primary forest bio energy was roughly 4 percent (17 TWh) of the Swedish annual energy production. Out of this, 2-3 TWh was removals from (early) thinnings (Anon. 2014a) even though the potential is 20-40 TWh annualy (Fernandez Lacruz 2015).

Since there are neither legal obligations nor subsidies to perform pre commercial thinning in Sweden, these measures are not done in the extent needed for optimal stand development. In 2014 roughly 6 percent of the Swedish forest area (about 1.4 million hectares) was in urgent need of PCT or early thinning operations (Anon 2014b). This silvicultural aspect is more often the reason for measures in these stands since the profitability in general is low. But the combination of great need of measures and the low profitability in early thinning has spawned a lot of research and development over the last decade(s).

Bergström and Di Fulvio (2014) made simulations of the potentials to increase cost efficiency in early thinning using different technical solutions. The greatest potential was found to be in systems using a harvesting head capable of continuous cutting and accumulation in boom-corridors along strip roads and a harvester equipped with a bundling unit. To support this machinery, the most efficient system also included conventional forwarding and road transports.

There is a potential to, at least, double increase harvester performance when performing continuous cutting and accumulation in boom-corridors along strip roads (Bergström 2009). The bundling of small trees has been shown to increase performance in forwarding and truck transport, the challenge is to compensate for the costs of the bundling (Björheden & Nuutinen 2014).

The societal ambition is to increase the removal of bio energy at the same time as the forest sector has a great need to perform early thinnings. On top of that, previous research has shown the most promising trails for development. This makes the options in the technological development quite clear and in response to all the mentioned reasons there are several Swedish technological concepts that may improve this situation being developed. The aim of this paper is to describe the principles and status for these promising technological concepts for early thinning.

Flowcut felling head

The Flowcut felling head is designed to perform continuous cutting and accumulation in boom-corridors. The manufacturer of Flowcut, Mekfab Engineering AB, has made a prototype of the felling head. A first field test of the felling head was performed in 2015 with the purpose of studying functionality, performance and effects on the remaining stand (Grönlund et. al. 2015). The study was done on five dense study plots in harvest of very small trees, the average breast height diameter was between 26 and 41 millimetres and there was between 6 200 and 12 300 stems per hectare.

The Flowcut felling head prototype is at its current stage capable of performing continuous cutting and accumulating the stems as it moves. The performance observed when harvesting the largest trees (average 5.7 kg DM) was comparable to what was observed by Iwarsson and Belbo (2010) when harvesting similarly sized trees (6 kg DM per trees). The maximum speed of the head when harvesting was between 0.6 and 1.0 meters per second, which should be sufficient to at least double performance compared to conventional selective harvest (Bergström 2009). Mainly due to inefficiency in the accumulation, between 90 and 180 trees per hectare were cut but never accumulated and thus dropped in the boom-corridor. Performance would have been 6-17 percent higher if these trees had been gathered. After harvest between 1.1 and 3.5 percent (80-180 stems per hectare) of the remaining trees were damaged.

The felling head was operational but both the cutting and accumulation was in need of improvements to reach the simulated potential. The shearing was not fast enough to cut the trees completely as the felling head moved forward. The engineer's solution is to increase the speed and tension of the chain, which both already were high. Increasing both speed and tension increase the demands on the hydraulics and makes the risks for breaking chain even greater. The accumulation on the other hand was operated semi-manually which in the studied dense pine stands made the accumulation difficult as the sight decreased on full crane reach, this was the main reason for the dropped stems. The operator participating in the study had been involved in the testing of the earlier versions but it is still likely that the number of dropped, up-rooted and partially cut trees will decrease as the operator learns to adopt the speed of the movement to the shearing speed and the functionality of the accumulation.

Cintoc biomass processor

The Cintoc biomass processor is a harvester equipped with a bundling unit. Cintoc is developed by JLO Invest and uses a harwarder base machine equipped with two cranes, one for conventional cutting and one automated crane for processing the trees and delivering to the bundling unit. The system is designed for small tree harvest, the aim is average stem volumes of around 20 dm^3. The concept has thus far been tested through modelling and simulations and the results are promising. The simulator testing suggests that the system is limited by the felling head, at the current a Nisula shearing head. The ambition is that the long (about 5 meters) and relatively loose bundles will be quickly produced and still efficiently handled through the entire value chain. In 2016 in field evaluations will be done of the entire supply chain of the first demonstrator.

Other concepts

There are tests being planned for continued improvement of the Bracke C16, a felling head using a circular saw. The ambition is to adjust the design to be more fitted for intermittently continuous harvest in short (1-2 meters) sections. By utilizing the C16's proven efficient and reliable cutting the ambition is to add a pair of accumulator arms and adjusting their design to better be fitted for continuous movement during cutting. This is an evolution of an already existing product which hopefully would make it into a complete product in 2018.

Bracke's other pioneer project is the Bracke MAMA, a felling very similar to the C16 with the difference that it is equipped with feed rollers, making it more versatile and designed to efficiently perform harvest in everything from pre commercial thinning to conventional first thinning. A prototype of this head has been used in production during 2012-2013 but since then the demand for forest bio energy has decreased and the development of the head has been halted.

Summary

There is a great interest in new technology for profitable harvest in early dense thinning. The Flowcut prototype felling head is promising but in need of improvement of the cutting and accumulation to reach its full potential. The bundling harvester Cintoc has through simulations indicated great potential and in field evaluations will be done in 2016. With only small efforts and increased demand for bio energy the modified Bracke C16 and the Bracke MAMA could prove very competitive. Since the prices on forest bioenergy currently are low, the industry is in great need of cost reductions and it is most likely these systems can contribute to this in the years to come.

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Biocontrol methods against hardwood sprouting: case *Chondrostereum Purpureum*

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After artificial regeneration it is important to secure the vitality of the seedlings doing management of young stands. In Finland both early cleaning and tending is usually needed before first commercial and profitable thinning. Stump sprouting can be prevented chemically with herbicide treatment. In Finland and in many other countries chemical herbicides are not allowed according to laws and certifications nowadays. Then more environmental friendly and acceptable way to diminish or prevent sprouting could be biological method (biocontrol). One promising biocontrol product has been developed based on Chondrostereum purpureum decay fungi.

C. purpureum occur naturally in temperate and boreal vegetation zones of the northern and southern hemispheres (Vartiamäki 2009). It penetrate freshly wounded stump of broad-leaved trees and decays wood (Vartiamäki 2009). Promising C. purpureum strains and formulates for biological control products have been developed in Finland and Canada (Hantula et al. 2012).

In studies the sprouting results varies very much between tree species. Compared to the cutting only (control) treatment, higher mortality on C. purpureum product treatment sites have been reported with birch, maple, hazel, rowan and aspen (Hamberg et. al 2011a, Hamberg et. al. 2011b, Hamberg et. al. 2013, Hamberg et. al. 2014, Hantula et. al. 2013, Smith et. al. 2009). However, poor effect of C. purpureum product to prevent willow has been reported (Lemola 2014). The effect of C. purpureum effect to prevent sprouting is the highest level on springtime and the lowest on midsummer (Hantula et. al. 2012).

C.purpureum treatment with clearing saw mounted dosing and applicator system increase working time compared to clearing saw treatment only, because more work phases is needed to handle and spread C.purpureum product (Roy 2010).

Practical usability and potential of C. purpureum product in forestry was studied. In 2014 founded about 30 practical scale experimental plots in southern Finland. C. purpureum biocontrol treatment was done simultaneously with early cleaning. The work was done with small Usewood Tehojätkä forest machine equipped with boom-mounted UW-cleaning head. The machine was equipped with tank dosing system and applicator for biocontrol product liquid. The control treatment was done without biocontrol product. The material from experimental sites varies by forests, operators, biocontrol mixing ratios and work timings (June-November). The plots were measured in autumn 2015, but preliminary results only from three forest sites have been analysed so far. When the strongest product mixing ratio 1:100 was used, the proportion of dead hardwood stumps was on average about 28%. In addition to the result, on average about 10% of the hardwood stumps were infected by C. purpureum (Figure 1).

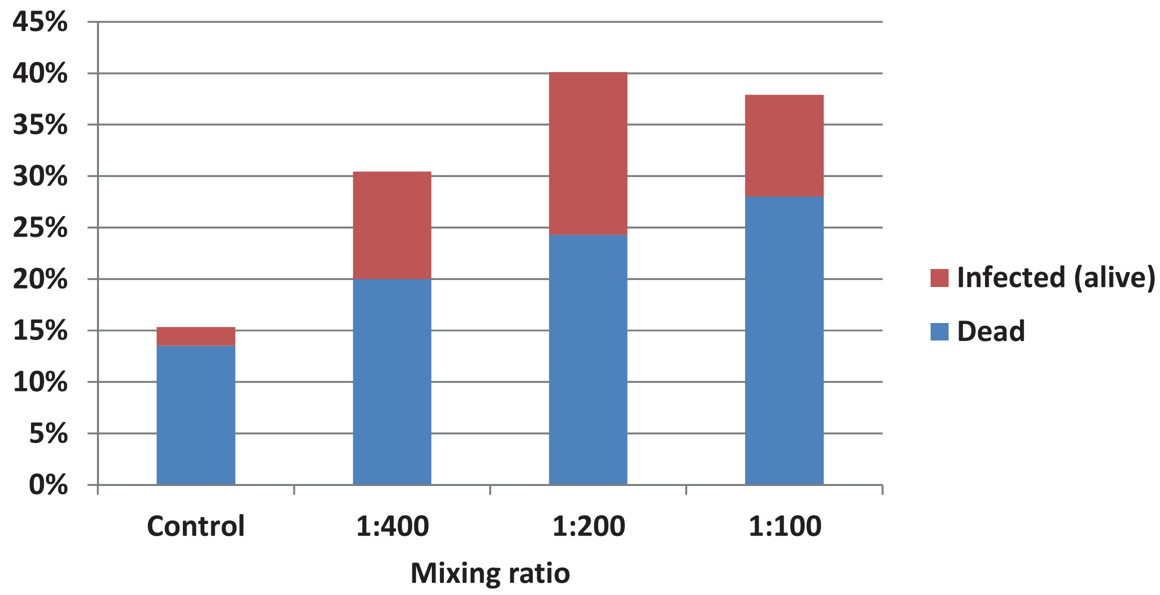

Figure 1. Proportions of the dead and C. purpureum infected hardwood stumps 1,5 growing season after treatment by the mixing ratios.

In 2015 sawing cleaning head Usewood UW40 and cutting Mense RP 6L cleaning heads both with dosing equipments and applicators were tested to clarify the effect of cutting principle on prevention result. Mixing ratio of C. purpureum product was 1:100. Control treatment without was done with UW40 clearing head without C. purpureum. Because the effect of C. purpureum product on sprouting will take at least two years after treatment, the important practical results from the study are not available yet. The consumption of C. purpureum liquid (water+product) was on average 132 litres per hectare with Mense and 186 litres per hectare with Usewood.

The most important answers of the studies will be that how C. purpureum product treatment simultaneously with early cleaning will prevent sprouting and the need of later tending. The effect of blade principle to the prevention result will be interesting. Also the silvicultural state and quality of young forest is important too. Based on the both studies, technical, biological and economical recommendations and instructions for the C. purpureum treatment will be stated.

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