EFFORTE –
'Efficient forestry by precision planning and management for sustainable environment and cost-competitive bio-based industry'

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 720712
Project duration: 1.9.2016–30.8.2019.
Coordinator: Natural Resources Institute Finland (Luke).

Deliverable 2.1. – New solutions for seedling supply chain and enhancement in planting devices; technical report- development and innovations		
Work Package 2 - Increased efficiency in silviculture (Efficient silviculture)		
Task 2.1 Improving productivity of mechanized planting; towards continuously advancing planting machine		
Due date	31.08.2018	
Author(s), organisation(s)	Lars-Göran Sundblad, Skogforsk. Isabelle Bergkvist, Skogforsk.	
Date of publication	30.08.2018	
Dissemination level		
PU	Public	
Nature of the Deliverable		
P	Prototype and Technical Report	

Contents

1. Background

Most forestry operations are mechanised in Swedish forestry. This relates for example to site preparation, thinnings and final harvesting of the mature forest site. Exceptions are mainly related to the regeneration process; i.e. when the clear-cut site should be replaced with next generation forest. Most forest regeneration in Sweden are today made by a combination of site preparation and planting with seedlings. Site preparation are done mechanically; in most cases using either scarification or mounding. Planting, however are almost entirely done manually. Despite many attempts, mechanized planting has yet to make a breakthrough in Swedish forestry. There are many reasons, but the main ones involve technical and logistic bottlenecks that have made it difficult for the mechanized systems to compete with manual planting. However, new technology, new information- and logistic systems provide a potential to remove thees obstacles.

EFFORTE has opened the door to renewed initiatives in this field through the work package on increasing efficiency in silviculture, WP2. The general aim of the EFFORTE projects was to develop a concept for automated mechanized planting of container seedlings, integrated with environmentally sound and efficient soil preparation. The work was to be carried out in several independent projects, each of which generated its own results, development and innovations. The projects involve systematic problem solving, with the aim of finding solutions in three areas:

1. Centre-mounted aggregates for inverse soil preparation.
2. Interface nursery/planter- ways to improve packing and structure of plant boxes with the aim to improve plant logistics from the nursery to the regeneration site (when using a planting machine)
3. Automatic seedling feed in the planter- improvement of the productivity in the planting machine

In this report the two later areas are in focus

2. Interface nursery-planter

The overall aim of this project was to increase the efficiency of regeneration/silviculture. The focus has been on development of concepts regarding the interface between nurseries and existing and potential mechanical planting systems. Focus has both been on assessing potential technical solutions, but also on analyses of how realistic different concepts are, given the development capacity in Swedish nurseries. Two existing plant delivery concepts have been evaluated delivery in cardboard boxes and delivery in containers to examine the potential for developing new delivery systems suitable for mechanical planting.

2.1 Corse of action

The project was executed in collaboration between researchers (Skogforsk), customers (STSG a collaboration group with members from the Swedish forestry) and manufacturers (Bracke Forest and Nurseries with their subcontractors).

2.2 Main problem

In Swedish forestry there is only one concept of planting machine in operational forestry, the Bracke planter with the planting head Bracke p 11 now developed into p12a, figure 1.

Originally the packing line was constructed to pack seedlings from growth-containers to card board boxes for delivery to forest generation sites. This packing concept was/is based on transplanting seedlings from growth containers to unstructured packaging in cardboard boxes. The practical consequence is that seedlings at delivery sites have to be handled individually and manually. This is the situation both for manual and mechanical planting concepts. In both cases the process is time- and cost-consuming.

Figure 1. Original design of the plant storage and feed system on the Bracke P11a.

2.3 Test bench

To test the idea of using a plant packing system that would increase the productivity of mechanized planting based on today present mechanised planting technology a modified seedling packing line in a seedling nursery was constructed. In this packaging line seedlings were transferred from growth containers to cardboard boxes with an internal cell system with defined positions for each seedling. This was done by:

- Modifying the cardboard box feeding line from cardboard boxes for unstructured seedling packaging to a feeding line for packaging designed for structured packaging, figure 2.
- Reprogramming the robot for seedling transfer from seedling growth containers to (originally unstructured) to structured packaging, figure 3.
- Adapting the seedling feeding system on an aggregate for mechanised planting (i.e. Bracke P11) from manual seedling feeding to semi-automatic feeding from cardboard-boxes with seedlings in defined positions.

Figure 2. Cardboard box and internal cell structure for structured packing.

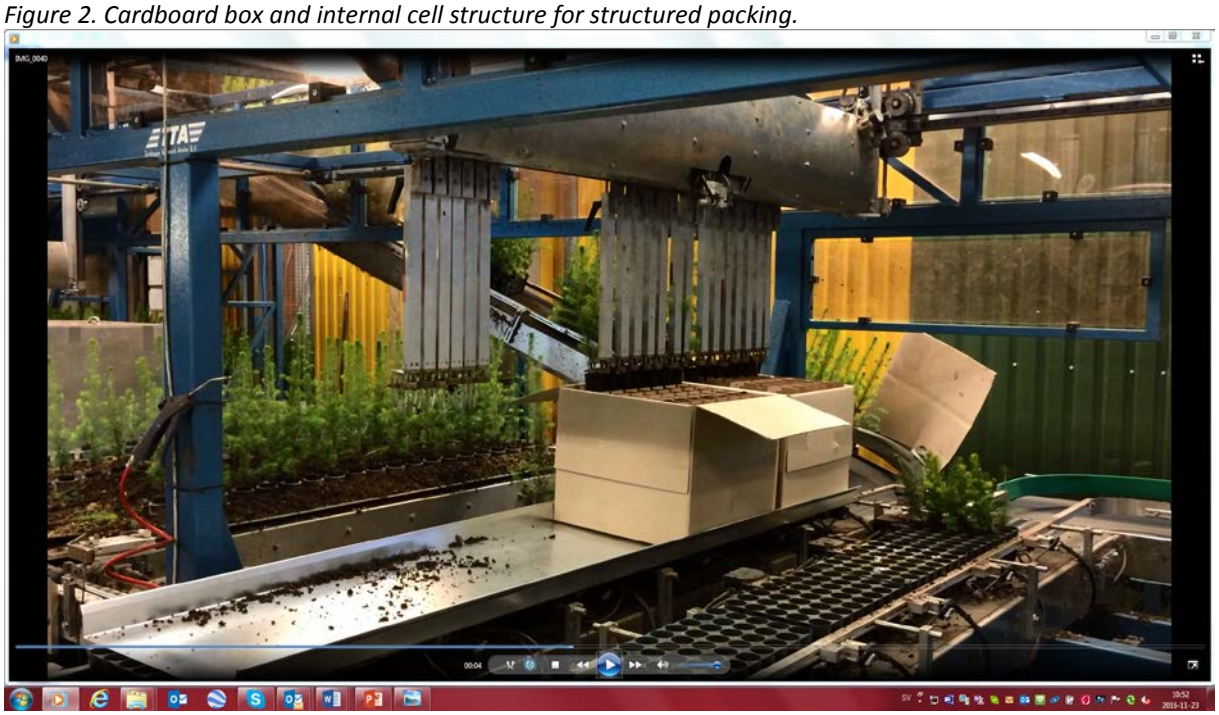

Figure 3. Robotised packing of seedlings in cardboard boxes with internal cell structure.

2.4 Results

The concept of structured seedling packing; as promising as it was on at theoretical level did not work in practise. Seedlings in structured cardboard boxes were found to be not storable for longer times due to problems with drying of root systems. Furthermore, delivery of structured packed seedlings to mechanical planting devises (e.g. Bracke P11) showed to be difficult due to problems related to extracting the seedlings from the cardboard boxes into the plant storage in the planting device, figure 4-5. After storage in the cardboard boxes the seedlings became "glued" to the walls of their structured packaging cells.

In summary; the idea of using structured package of seedlings for more efficient plant handling in combination with mechanised planting were promising in theory but did not work in practise.

Figure 4. New first prototype design of the plant storage and feed system on the Bracke P11a.

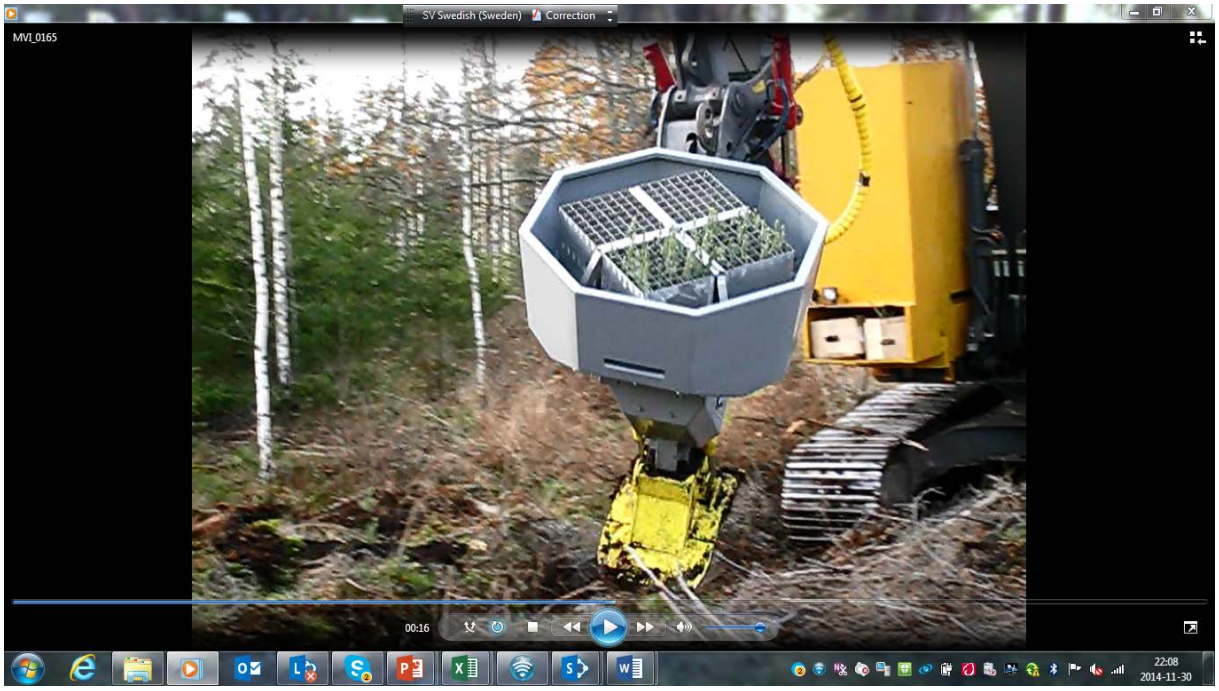

Figure 5. Field test of the first prototype design of the plant storage and feed system on the Bracke P11a.

The overall conclusion therefore was that there was no possibility to develop cardboard-based, structured packing. However, based on the results and development work in the project the initiative resulted in the development of an improved planting aggregate; the Bracke P12a with improved seedling handling systems. Although the P12a likely mainly will be used in tropical conditions it constitutes one step towards large scale implementation of mechanical planting worldwide, figure 6.

Figure 6. The new Bracke P12a planting aggregate.

3. Automatic seedling feed in the planter.

Based on the conclusions from the project on structured cardboard packing, a new strategy was adopted. The fundamental idea was to develop a concept for automatic/semi-automatic plant loading based on seedlings delivered in trays instead of cardboard boxes. Focus was directed towards future possible planters that would advance continuously during operation. An earlier trial, but aimed at boom tip-mounted technology, had been carried out in a collaborative project involving Skogforsk, Swedish University of agricultural sciences, Luleå University of Technology and Skogstekniska klustret (the Cluster of Forest Technology).

In this project, a robot-based plant feed was designed for seedling containers fitted on a Bracke P11 planter (MagMat project). Different variations of the system were built, with different numbers of loaded trays. One conclusion was that trays and plants could be fed when the machine was stationary, but in practice it was difficult to get the sensitive robot technology to work when the machine was advancing and operating, figure 7.

Figure 7. The MagMat seedling feeding system mounted on a P11 planting aggregate.

Based on experiences from all the different trials of mechanized planting (from the time of Silva Nova onwards) and taking into account new aviable technologies a potential concept started to take shape as to how towed mechanical planting devices should be developed and designed. The main developments are technical but include other aspects. The most important points in the strategy are:

- The interface nursery/planter should be based on plant deliveries in containers. Cardboard deliveries are theoretically possible but mean (at least under current conditions) that major development initiatives in nurseries would be too great to be realistic.
- Robot technology for seedling loading should be used with a stationary planter. Technology for this is available and implementable, figure 8.
- During operation, the feed to the planting unit on the planter should be made simple and robust, based on mechanical/hydraulic solutions and using gravity for feeding of seedlings to the planting device (i.e. not robot-based 'plant picking systems'), figure 9.

It was therefore decided that the project focus would be shifted from development of seedling packing systems to development of seedling feed systems on the planter. The project focused on

the ‘missing link’, i.e. how plants are transferred from trays, stored, and fed on the planter while advancing/operating. After consideration of different potential systems, one system was chosen.

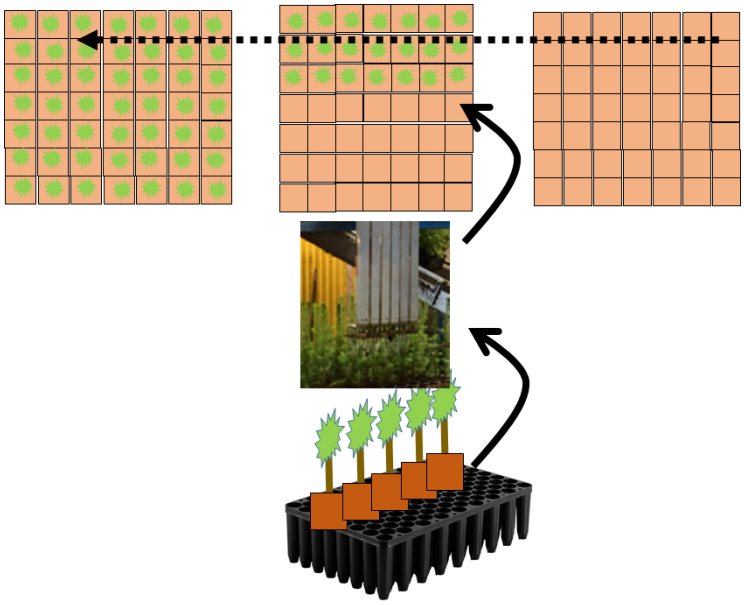

Figure 8. System for transplanting containerized seedlings to storing and forwarding system.

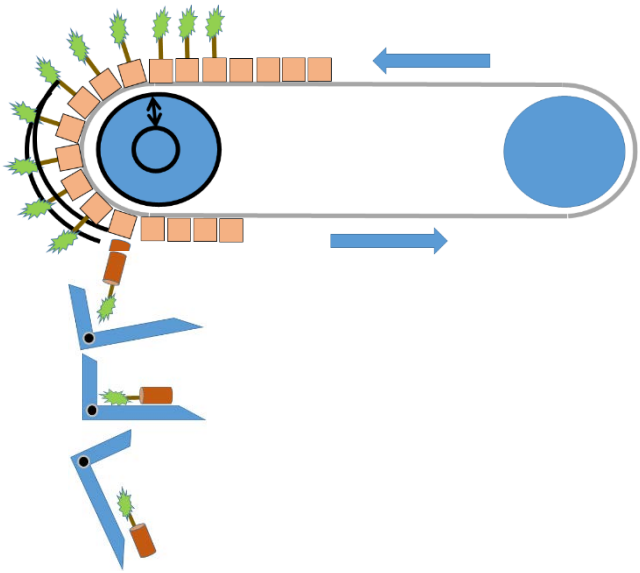

Figure 9. System for feeding of seedlings based on gravity.

A test bench was constructed to visualize how the theorethical system worked in practise, figure 10.

Figure 10. Simple test bench for practical testing of the theoretical system described above.

3.1 Results

In very simple tests (just putting seedlings in the boxes, figure 10) the concept seemed promising and needs to be tested further when a continuously moving planting machine is developed.

In order to increase the productivity of the regeneration process in forestry a new system for mechanised planting has to be developed. This process has to take into account existing presumptions in seedling nursey production systems and also the need for robust seed-handling in a mechanised planting system. The results of the present project indicate that delivery of seedlings in growth containers in combination with simple, robust, semiautomatic seedling feeding-transporting-, planting-systems on planting machines are key factors in this development process.

4. Conclusions

The above principles for developing a towed mechanical planter with special focus on the interface nursery/planter could not be developed to full 'demonstrator' stage. However, the project has showed how such a system should be designed. The concept should be designed in accordance with the following basic requirements:

- Centre-mounted soil preparation machines must produce a high number of high-quality planting spots on all soil types that are currently prepared with a trencher or mounder.
- Seedlings suitable for mechanical planting should be delivered to the planter in containers. This can be done without major modifications.
- Seedlings delivered in containers should be loaded on a stationary planter at the seedling landing. To ensure sufficient productivity in this process, robot-based technology should be used.
- During advance/operation, seedlings should be fed to the planting unit with a simple, robust, gravity based and mechanically/hydraulically driven system. A possible principle for how this can be done has been developed in the project but must be further developed before it can be brought into practical operation.

There are already technical solutions for stages in the development/implementation of towed mechanical planting. What is currently lacking is an assimilation of stages to a coherent functioning concept. The technical/practical conditions already exist but require specific development support from the Swedish forestry sector before they can be implemented.