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

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Implementation of the work study
(Nuutinen & Björheden 2015)

Objectives
- evaluate the performance level of the new Fixteri system in small tree harvesting for different stand types
- investigate the felling feeding sequence and the functions of the bundling unit of the concept.

Two different field tests were conducted (by Metla, Skogforsk and Fixteri Oy in March/September 2013)

Test 1: Time and motion study of cutting
- Moving
- Crane out
- Fell
- Crane in
- Feed (feeding the bunch of whole-trees onto the feeding table)
- Bundling (Grey roters pulling the whole trees into the feeding chamber)
- Cross cutting (the whole trees were cut in feeding chamber)
- Bundling (lifting the cut trees into the central chamber)
- Bundling (compressing and wrapping the cut trees in the compaction chamber)
- Dropping a bundle
- Sorting the felled trees and finished bundles on the ground
- Clearing the undergrowth
- Delays

Test 2: Technical function test of bundling unit

The work process of the whole-tree bundler
The newest whole-tree bundler concept
Work study stands (Nuutinen & Björheden 2015)

25-40 years old Scots pine dominated stands, first thinnings in mineral soils
- young dense, with rich undergrowth, age 25-30 years, removal 6-9 dbh
- young dense, with little or no undergrowth, age 25-30 years, removal 6-9 dbh
- normal first thinning, age 35-40 years, removal 10-14 cm dbh

Young dense rich undergrowth

Young dense no undergrowth

Normal first thinning

<table>
<thead>
<tr>
<th>Before cutting</th>
<th>4033 trees/ha</th>
<th>2836 trees/ha</th>
<th>1999 trees/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-30 years</td>
<td>25-30 years</td>
<td>25-30 years</td>
<td>35-40 years</td>
</tr>
<tr>
<td>Removal, whole trees</td>
<td>3216 trees/ha</td>
<td>2019 trees/ha</td>
<td>1266 trees/ha</td>
</tr>
<tr>
<td>27 dm³</td>
<td>44 dm³</td>
<td>84 dm³</td>
<td>average volume</td>
</tr>
<tr>
<td>After cutting</td>
<td>817 trees/ha</td>
<td>817 trees/ha</td>
<td>733 trees/ha</td>
</tr>
<tr>
<td>57 m³/ha</td>
<td>45 m³/ha</td>
<td>76 m³/ha</td>
<td>stem volume</td>
</tr>
<tr>
<td>Pine/Spruce/Birch</td>
<td>73/2/24</td>
<td>100/0/0</td>
<td>86/5/9</td>
</tr>
</tbody>
</table>

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Field measurements (Nuutinen & Björheden 2015)

- Totally 9 time study plots (20*50 m) in Central Finland (3 time study plots per each stand)
- In the experiments the trees were cut and compacted into energy wood bundles
- Time study: one researcher observing the Fixteri’s performance using a handheld field computer
- Stand data plots of 100 m² from where the stand data after cutting was collected
- The output of the whole-tree bundler was recorded through the machines on-board production statistics (time and weight of each bundle reported from the Fixteri’s computer)

![Time study plot including stand data plots 100 m³](image)
Performance m³ per effective working
(Nuutinen & Björheden 2015)

- 9.7 m³/E₀-h in the *young dense rich undergrowth*
- 11.9 m³/E₀-h in the *young dense no undergrowth*
- 13.8 m³/E₀-h in the *first thinning*

*Average volume of removed whole trees, dm³/stand*
Fixteri productivity leap 2009-2013

- The performance of newest Fixteri FX15a:
  - 9.7 m\(^3\)/E\(_0\)h average removal 27 dm\(^3\)
  - 11.9 m\(^3\)/E\(_0\)h kung average removal 44 dm\(^3\)

Thus, the performance of the new Fixteri FX15a-concept was 2.1–2.3 times higher, depending on the stand density and mean whole-tree volume of the removal.

But this result was only in pine stands.

References:
Linking together the study results of Finland 2013 and Umeå 2014 gave new info about the working area of Fixteri.

The combined results increased the reliability of both studies.

Study results of Finland 2013 (conducted by Metla & Skogforsk)
- Winter harvesting
- Pine dominated early thinnings
- Average removal 27-84 dm³

Study results of Umeå 2014 (conducted by SLU)
- Summer harvesting
- Pine, spruce, birch dominated early thinnings
- Average removal 13-41 dm³

Why lower productivity level in Umeå study 2014
- Cutting in summer
- The stand density after cutting considerabele higher than in Finland study 2013

The Umeå study brings important info about influence of undergrowth to the operation of Fixteri.

References:
- Nuutinen et al. 2011
- Nuutinen & Björheden 2015
- Bergström et al. 2015
Why is the performance increased?
(Nuutinen & Björheden 2015)

- Work process 'cutting of trees' = cutting and accumulating the whole trees and bringing them to the bundling unit
- Crapple bunch = number of trees per crane cycle into the bundling unit

Cutting of trees, average, s/tree

- Fixteri FX15a: 10,6 s/tree
- Fixteri II: 16,3 s/tree

Average size of grapple bunch per crane cycle, trees/grapple bunch

- Fixteri FX15a: 3,2 trees/grapple bunch
- Fixteri II: 2,9 trees/grapple bunch
The suitability of the study stands for multi-tree handling using the studied felling head (Nuutinen & Björheden 2015)

The proportion of multi-tree handled trees:

2 or more trees/grapple bunch:
- Young dense, rich undergrowth 90 %
- Young dense, no undergrowth 94 %
- Normal first thinning 68%

3 or more trees/grapple bunch:
- Young dense, rich undergrowth 78%
- Young dense, no undergrowth 68 %
- Normal first thinning 31%

5 or more trees/grapple bunch:
- Young dense, rich undergrowth 47 %
- Young dense, no undergrowth 19 %
- Normal first thinning 5,8%

The distribution of crane cycles for different number of accumulated whole trees in the study stands
Working technique differences between the study stands
(Nuutinen & Björheden 2015)

- According to field test 1 the operation of the whole tree bundler consists of three main work processes:
  - cutting of trees
  - arrangement of products (felled trees & finished bundles)
  - operation excluding crane work

- ‘Cutting of trees’ decreased from 83% to 61%, when the average volume of the removed whole trees increased from 27 dm$^3$ to 84 dm$^3$

- ‘Arrangement of products’ was at highest in the normal first thinning stand, wherein the arrangement of felled trees increased from level 3% in young stands to over 7% in first thinning
The conclusions of this study so far
(Nuutinen & Björheden 2015)

- The higher performance level of the new Fixteri FX15a is partly a result of:
  - The increased performance of crane work enables more effective feeding of the bundling unit
  - The new felling head was able also transfer more trees at the same grapple-bunch to the bundling unit

- The two youngest study stands (average volume of removed whole trees was 27 and 44 dm³) proved to be a better operating area for the accumulating felling head than the first thinning stand (average volume of removal 84 dm³)

- In the study of Väätäinen et al. (2005), the differences in thinning productivity between the harvester operators in similar conditions varied maximum from 40% to 55% depending on the stem size processed
  - Now the performance increase of the new Fixteri model was from 111% to 133% compared the previous model
  - the new technical features of the Fixteri FX15a whole-tree bundler concept have easily a significant influence on performance leap
THE DEVELOPING POTENTIAL OF FIXTERI IN THE FUTURE.....
THE DEVELOPING POTENTIAL OF FIXTERI IN THE FUTURE......
Finland study 2013: Technical function test (substudy 2)
(Nuutinen & Björheden 2015)

The studied Fixteri whole-tree bundler concept consists of three sub-systems:

1) Machine platform (chassis) providing power (hydraulics) and mobility
2) A felling-feeding system (crane and accumulating felling head)
3) A bundling system (the Fixteri bundling unit)

The potential of sub-systems 2 and 3 were compared. The test aimed to find out the bottle necks between the systems that could restrict the productivity.

The features of whole-trees used in the technical function test:

<table>
<thead>
<tr>
<th>Stump diameter, cm</th>
<th>Brest height diameter, cm</th>
<th>Height, m</th>
<th>Total aboveground solid volume, dm³</th>
<th>Total aboveground fresh weight, kg</th>
<th>Number of trees in full felling head</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2,4</td>
<td>3,9</td>
<td>3,0</td>
<td>2,6</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>4,0</td>
<td>5,9</td>
<td>7,5</td>
<td>6,4</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>5,6</td>
<td>7,5</td>
<td>15,4</td>
<td>13,2</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>7,2</td>
<td>8,8</td>
<td>27,5</td>
<td>23,5</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>8,0</td>
<td>9,9</td>
<td>44,4</td>
<td>38,0</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>10,4</td>
<td>10,7</td>
<td>66,3</td>
<td>56,7</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>12,0</td>
<td>11,5</td>
<td>93,2</td>
<td>79,7</td>
<td>1</td>
</tr>
</tbody>
</table>
Capacity of crane work

- when the stump diameter/size of cut tree was 5 cm/3.0 dm³, the performance of felling-feeding was $2.5 \text{ m}^3/\text{E}_0\text{h}$.
- For biggest trees of stump diameter 17 cm and size $93.2 \text{ dm}^3$ the performance increased to $16.0 \text{ m}^3/\text{E}_0\text{h}$.
- When the stump diameter of trees increased from 13 cm to 15 cm, the trees were processed individually.

Capacity of bundling unit

- In the range of $23.3 \text{ m}^3$ – $36.3 \text{ m}^3/\text{E}_0\text{h}$
- When the length and size of grapple bunch trees increased, the productivity also increased slightly.
- The bundle size had most positive influence on the productivity.
The ideal production capacity of the bundling unit was from 2 to 10 times higher compared to the level that was possible to reach by crane work in the working environment of the sub-study.

**How to better the felling-feeding**

- better features of the felling-head to accumulate, sort and handle the felled trees
- developing the feeding of the tree bunches into the bundling unit
- especially in harvesting trees of whole tree volume under 15-20 dm³ some other technical felling-head solution as the studied head
  - e.g. continuous felling with *Bracke afh-felling head*

**Balance between the bundling unit and felling-feeding**

**FIXTERI IN BOOM CORRIDOR THINNING.....**

- Continuous multi-tree handling in boom corridors
- The accumulated trees are fed directly into the bundling unit
  - enables the bundle harvester head operating in a clear, unobstructed working environment
  - 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

**STUDY RESULTS OF CORRIDOR THINNING:**

- 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) detected no significant long term differences in volume growth, standing volume and mortality volume between systematic corridor thinning and thinning from below harvesting methods
Running in the thinned forest is fun

I agree

Nelli

Nappi

I agree

Nekku

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References:

Kiitos! = THANK YOU FOR YOUR ATTENTION!