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SORTING OF MULTIPLE PRODUCTS WITH A CUT-TO-LENGTH SYSTEM

J.-F. Gingras, F.E.* and M. Soucy**

Abstract

Product separation during harvesting is often necessary to meet the needs of the many users of wood fiber. This report presents the results of a study whose goal was to determine the least expensive method for sorting six products using a harvesting system based on a feller-buncher, a single-grip processor, and a shortwood forwarder. In addition, the study was designed to determine the impact of product separation by the forwarder based on a quality criterion. The results indicated that there was no advantage to species separation with the feller-buncher; on the contrary, it was preferable to carry out all sorting with the processor. Furthermore, it was observed that the forwarder could perform a coarse separation based on quality class (decay content) at no additional cost.

Introduction

The sorting of various products in the woods helps to maximize the value and quality of the resource being harvested. With the cut-to-length system, Gingras (1996) previously demonstrated that the separation of two to four products has little impact on the productivity of single-grip harvesters. However, little information is yet available on the impact on equipment productivity of separating more than four products.

In early 1999, Stora Enso Port Hawkesbury Ltd. (Port Hawkesbury, N.S.) asked FERIC to study the potential advantages of performing initial product sorting with a feller-buncher in an operation where processors and forwarders were also being used. The six target products were as follows: lumber (3.6 and 5.0 m), studwood (2.56 m), and pulpwood (2.56 m), with each product separated by species (fir and spruce).

The study was carried out in an operation of Northumberland Logging, a contractor working for Stora Enso approximately 30 km south of New Glasgow. The machines observed comprised a Timbco 430 feller-buncher, a Rottne SMV Rapid single-grip harvester working as a processor (Figure 1), and a 12-tonne Valmet 646 shortwood forwarder.

Figure 1. The Rottne SMV single-grip harvester working as a processor.

* Jean-François Gingras is a Program Leader, Eastern Division.
** Michel Soucy was a Student Research Assistant, Eastern Division when the fieldwork for this study was carried out.
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The objective of the study was to provide productivity estimates for each machine as a function of the sorting scenarios used in the trial. The following separation scenarios were studied for product sorting based on species, product (lumber, pulp), and quality criterion (decay content):

- Species separation by the feller-buncher, sorting based on end-use by the processor, and preservation of the product separation by the forwarder.
- Species and product sorting by the processor (no sorting by the feller-buncher), and preservation of the product separation by the forwarder.
- Felling and sorting by species and product by the single-grip harvester, and preservation of the product separation by the forwarder.

In addition, the use of the forwarder to produce two separate quality classes was evaluated in the first two scenarios.

Results

The study took place in early March of 1999 in a spruce–fir stand that had been cruised prior to the harvesting phase (Table 1). The terrain was relatively firm, with little or no slope and practically no obstacles (CPPA class 2.1.1).

Feller-buncher

The feller-buncher was observed in two different work scenarios: with or without separation of stems by species. In the first scenario, the operator separated the fir and the spruce (a 64:36 density ratio) into distinct piles. Since the operator alternated between this scenario and one with no separation, the overall average stem volume remained about the same between the two scenarios.

Species separation had negative impacts on the feller-buncher's productivity (Table 2). Even though the total cycle times with or without species separation were similar, the average number of stems accumulated in the head during cycles with species separation decreased. This drop can be explained by interference caused by residual stems of the second species. These stems also caused a slight increase in felling times (0.083 min/stem versus 0.073 min/stem), since the operator had to maneuver the felling head around them. In the scenario with species separation, the feller-buncher's travel time also increased slightly as a result of the back and forth movements required to bunch the stems in separate piles.

The 12% impact of sorting in this study was higher than in a similar study by Gingras (1996), who found that separation of two and three products reduced productivity by 7.5% and 10.6% respectively.

Table 1. Study block stand characteristics

	Balsam fir	White spruce	Overall
Density (merchantable stems/ha)	700	400	1100
Density (unmerchantable stems/ha)	270	30	300
Average DBH (cm)	16.7	21.8	18.6
Average stem volume (m^3)	0.11	0.17	0.13
Average volume/ha (m^3)	77	74	151

Table 2. Effect of sorting of two species on the feller-buncher's productivity

	Without separation	With separation	Difference
Stems harvested	1195	1180	
Stems per productive machine hour (PMH)	317	279	–12%
Volume/stem (m^3)	0.13	0.13	
Volume/PMH (m^3)	41.2	36.3	
Stems per cycle	2.26	1.93	
Average cycle time (min/cycle)	0.43	0.41	
Cost ($/$m^3$)[a]	2.75	3.13	+14%

[a] Based on the cost assumptions in the Appendix, and an estimated direct hourly cost of $113.49.

To reduce the impact of the travel required for bunching, operators could use felling heads with full lateral tilt, which are now common in some regions. To partially alleviate the problem of interference from residual stems, the operator can cut one or two stems of the second species that are blocking movements of the head towards the end of the felling cycle without placing them in the accumulator arms. They can then be released in a separate pile by opening the grab arms prior to bunching the second sort. However, because feller-bunchers are machines designed to fell a large number of stems in a short time, they are better adapted to relatively simple sorting scenarios, such as crude species separation (e.g., softwood and hardwood) or the separation of stems with significant size differences.

Single-grip processor

The results of the study indicate that when the feller-buncher performed species separation before processing, processor productivity decreased slightly (Table 3). The bunches formed by the feller-buncher during species separation were slightly larger than the more "windrowed" bunches of unsorted material, and as a result, the stems in these piles were packed more tightly, with their branches more entangled. This increased the time required to break the stems out of the bunches compared with the time required in the absence of presorting. However, apart from the difference in the time required to pick up stems, other time elements of the processor's cycle were similar.

The productivity decreased by 3% when the processor worked with sorted bunches, in part because the time required to pick the stems out of the bunch was 27% higher. In addition, the operator of the processor found that he lacked adequate room to pile the processed bolts when he worked from bunches that had been separated by species, since the wood was more concentrated. When there was no sorting by the feller-buncher, the stems were distributed much more uniformly along the trails.

Forwarder

Obviously, the greater the number of products to load, the more the forwarder's productivity will be affected as a result of increased time for loading and travelling to obtain a load. During FERIC's study, the forwarder hauled a single product category at a time (studwood or pulp logs) and preserved the species separation by placing one species at the front of the bunk and the other at the back of the bunk. This approach was practical for maintaining product separation, but increased the distance the forwarder had to travel to obtain a full load. There was no productivity difference for the forwarder based on whether the two species had been separated in advance by the feller-buncher.

One objective of this study was to determine whether the forwarder could be used both to preserve the separation already performed and to add a new separation based on quality criteria such as the decay content. In a previous study on product separation by quality class (decay content), FERIC concluded that it was preferable to perform initial sorting by quality class with the single-grip harvester, rather than relying solely on the forwarder. This method slightly reduced the total cost and improved the quality of the separation (Gingras and Godin 1997).

Table 3. Impact of species separation by the feller-buncher on the processor's productivity

	Without sorting by the feller-buncher	With sorting by the feller-buncher	Difference
Stems processed	542	612	
Stems per productive machine hour (PMH)	106	103	–3%
Net volume/stem (m^3)	0.13	0.13	
Volume per productive hour (m^3/PMH)	13.8	13.4	
Cost ($/$m^3$)[a]	9.81	10.10	+3%
Load processor time element (min/stem)	0.125	0.159	+27%

[a] Based on the cost assumptions in the Appendix, and an estimated direct hourly cost of $135.31.

However, with separation by a processor or single-grip harvester, there is a risk of going too far and thereby creating piles with excessive concentrations of rot. As a result, the logs were separated based on their decay content using the forwarder alone, and the sorting was done at the level of entire grapple loads during loading or unloading. During loading, the operator separated the logs into two different classes, based on the presence or absence of decayed wood in the grapple, on each side of the bunk. During unloading, the operator preserved this separation and created two distinct piles at roadside. This method let the operator produce a certain volume of wood with very high quality (less than 1% decay content), which can be very attractive for certain pulping processes (Table 4).

To determine the impact of this sorting on the forwarder's productivity, only the loading and unloading times were considered, as other time elements are not affected by the sorting process. The results suggest that productivity was not affected significantly by separation based on decay class, which was also confirmed by visual observations during the study.

Single-grip harvester

With the single-grip harvester used for both felling and processing, its productivity decreased by around 22% compared with that obtained when using it for processing alone (Table 5). This result is to be expected, since the machine was doing more work than just processing the stems.

When the average stem volume was adjusted to be similar to that in the scenario with processing alone, the cost of using the single-grip harvester proved to be less than that of pairing the feller-buncher with the processor. Thus, the use of a single-grip harvester in place of a feller-buncher and processor can prove to be less expensive in certain situations, such as when undergrowth is not a problem and the average stem volume is sufficiently high. It is thus attractive to have a mix of feller-bunchers, processors, and single-grip harvesters available, since this would let managers adapt their choice of machines and work patterns to suit the stand conditions.

Table 4. Effects of separation by the forwarder based on a quality criterion

Loading and unloading times (min/m³)		
Without sorting	4.27	
With sorting	3.92	
Negative impact of sorting (%)	0	
Amount of decay present in the piles	Proportion of volume (%)	Rot content (%)
Control (no separation)	100	3.7
Rot excluded	73	0.9
Rot included	27	7.3
Average forwarding cost ($/m³)[a]	6.39	

[a] Based on the cost assumptions in the Appendix, and an estimated direct hourly cost of $80.65.

Table 5. Productivity of the single-grip harvester

	Measured results	Standardized stem volume[a]
Number of stems processed	377	377
Stems processed per productive machine hour (PMH)	90	87
Average stem volume (m³/stem)	0.12	0.13
Volume per productive hour (m³/PMH)	10.8	11.3
Cost ($/m³)[b]	12.52	11.97

[a] Adjusted using FERIC's Interface software and the productivity function for single-grip harvesters.
[b] Based on the cost assumptions in the Appendix, and an estimated direct hourly cost of $135.31/PMH.

Discussion and Conclusions

The total direct cost of the wood at roadside was calculated for three different scenarios to create a 6-product sort, with the stem volumes adjusted in the third scenario (Table 6). The assumptions behind the machine costs are presented in the Appendix, and modifying these assumptions (e.g., using more- or less-expensive machines, or used equipment) would give different results and would thus change the relative merits of the scenarios. Only direct costs are included in Table 6, excluding overhead, profits, supervision, etc.

Species separation by the feller-buncher before processing provided no apparent advantage. In fact, the feller-buncher's productivity decreased by around 12% and the processor's productivity also decreased (by 3%). This resulted in a $0.67/m³ cost increase compared with a system in which the feller-buncher performed no sorting. It is possible that using the feller-buncher to perform species separation before processing could prove beneficial under some conditions. For example, species separation before processing could prove effective where two-grip processors were being used. The creation of different bunches with a two-grip processor is more difficult because it requires either back and forth travel by the machine, or rotation of the processing unit. Moreover, the loader on these machines is usually more powerful and the loading grapple is better adapted than a harvester head to picking up stems. Thus, the two-grip processor would be less affected by the tangled stems in the larger bunches.

The cost comparison of the various systems showed that the approach based on a feller-buncher paired with a processor was comparable to that with a single-grip harvester under the study conditions. However, the total cost of using a single-grip harvester can be lower under certain conditions, as shown by the cost (with adjusted stem volume) reported in Table 6. Even so, it's important to remember that stand conditions change frequently, and that feller-bunchers adapt more easily to these changes.

The use of the forwarder to separate pulp logs by quality class had no negative impact on its productivity. Thus, this technique could be used if managers want to produce a certain proportion of high-quality wood for certain pulping processes.

References

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Table 6. Comparison of costs

	Feller-buncher		Single-grip harvester	
	No sorting	Sorting	Unadjusted stem volume	Adjusted stem volume
Cost ($/m³)[a]				
Felling cost	2.75 (0)	3.13 (2)	12.52 (6)	11.97 (6)
Processing cost	9.81 (6)	10.10 (3)	n.a.	n.a.
Forwarding cost[b]	6.39	6.39	6.39	6.39
Total	18.95	19.62	18.91	18.36
Cost difference[c]	n.a.	+0.67	–0.04	-0.59

[a] Numbers in brackets represent the number of sorts created by each machine.

[b] Although we assume that forwarder productivity is the same in all scenarios, it is possible that working with the larger piles provided by the feller-buncher plus processor approach provides some benefits over the piles produced by a single-grip harvester.

[c] Difference compared with the system that includes no sorting by the feller-buncher.

Appendix
Cost Assumptions

	Timbco 430 feller-buncher	Valmet 646 short-wood forwarder	Rottne SMV Rapid single-grip harvester
INPUTS			
Machine life (years)	5	5	5
Scheduled machine hours (SMH)/year	4 000	4 000	4 000
Purchase price ($)	435 000	267 900	595 000
Resale value ($)	43 500	26 790	59 500
Licensing ($/year)	50	50	50
Insurance ($/year)	17 400	10 720	23 800
Interest rate (%)	10	10	10
Utilization rate (%)	80	80	80
Lifetime repair cost ($)	478 500	294 700	654 500
Fuel consumption (L/PMH)	25	12	16
Fuel cost ($/L)	0.45	0.45	0.45
Cost of oils and lubricants ($/PMH)	2.00	1.50	2.50
Operator cost ($/SMH)	25.00	25.00	25.00
FIXED COSTS ($)			
Annual amortization	107 626.71	66 285.19	147 213.55
Other annual costs	17 450.00	10 766.32	23 850.00
Total/year	125 076.71	77 051.51	171 063.55
Cost/PMH	39.09	24.08	53.46
Cost/SMH	31.27	19.26	42.77
VARIABLE COSTS ($)			
Annual cost	138 100.00	81 019.76	161 940.00
Cost/PMH	43.16	25.32	50.61
Cost/SMH	34.53	20.25	40.49
OPERATOR COSTS ($)			
Annual cost	100 000.00	100 000.00	100 000.00
Cost/PMH	31.25	31.25	31.25
Cost/SMH	25.00	25.00	25.00
TOTAL COST ($)			
Grand total per year	363 177	258 071	433 004
Grand total per PMH	113.49	80.65	135.31
Grand total per SMH	90.79	64.52	108.25