Evaluation of Haymaking Equipment to Harvest Switchgrass

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ABSTRACT

The goal of the 1997 Harvest Study was to gather further data on the effectiveness and efficiency of using conventional haymaking equipment to harvest switchgrass in the spring. Specifically, the objectives of this series of experiments were to provide an effective understanding of where losses occur when switchgrass is spring harvested, to identify sources of current losses, and to determine if they could be further minimized. Overwintering losses of switchgrass material were measured again this spring, and ranged between 22.4% and 32.2%, depending on varieties. Losses resulting from the use of a mower-conditioner for cutting the grass were lower this year than in 1996 but were found to be much higher than what can be achieved with a cereal grain swather. The use of the swather led to a 74% reduction of losses over the mower-conditioner (prior to baling). In terms of total harvest losses, that is, losses measured after the baling operation, the swathing/baling system reduced losses by 56% compared to the mowing/baling system in 1997. Overall, both choice of variety and cutting technique proved to be important in increasing delivered mill yields.

Harvest Study
Spring 1997

A series of experiments were established at the Emile A. Lods Seedfarm and at the Ecomuseum on the Macdonald Campus of McGill University to assess harvesting losses of overwintered switchgrass. In the 1996 harvest study, losses of up to 45% of the material resulted. This was due to the material being very brittle at the time of harvest along with the use of a mower-conditioner for cutting the material which was too aggressive. In the spring of 1997, a less aggressive cutting strategy of swathing was compared to the mower-conditioner in order to determine if harvest losses could be reduced. Swathers are used to harvest cereal grains such as wheat. Three separate experiments were conducted as part of this study, which took place on the quasi-commercial field plantations at Ste. Anne de Bellevue, Quebec. These experiments included:

1. Assessment of fall and spring biological yields of overwintered switchgrass;
2. Assessment of mowing and swathing losses prior to baling;
3. Assessment of total harvest losses, including both mowing/swathing and baling;

The objectives of this series of experiments were to provide an effective understanding of where losses occur when switchgrass is spring harvested, to identify sources of current losses and to determine if they could be further minimized.

1.0 Assessments of Losses due to Overwintering Switchgrass

Biological yield losses were compared between three varieties of switchgrass (Sunburst, Cave-in-Rock, Pathfinder) to determine if overwintering losses varied amongst varieties from the fall of 1995 to the spring of 1996 and from the fall of 1996 to the spring of 1997. In each plot, four 1 m^2 quadrats were harvested in the spring and fall at a 10cm cutting height. The two years of data collected from the two sites indicated that overwintering losses did indeed vary depending upon the variety (see Table 1). Average losses of 22.4% were observed for Sunburst switchgrass while losses for Cave-in-Rock switchgrass averaged 32.2%. Pathfinder switchgrass had losses of 25.3%. The losses associated with the Cave-in-Rock material appeared to be the result of its brittleness. It was noticeable at the time of harvest in the spring that the material was susceptible to breakage while the other cultivars remained relatively intact.

Biological yield losses varied somewhat between years. Yield losses in 1995-96 were 23.3% on average compared to 29.9% in 1996-97 (Table 1). This difference may have been due to the fact that the fall harvest in 1995 was quite late (Nov. 13, 1995 at the Ecomuseum site) and that significant amounts of material may have already translocated below ground at the time of harvest.

Table 1: Overwintering Losses for Switchgrass Varieties, Fall 1995 - Spring 1997

Variety	Cave In Rock		Pathfinder		Sunburst	
Location	Seed farm	Eco-museum	Seed Farm	Eco-museum	Seed farm	Eco-museum
Fall 1995 Yield (kg/ha)	10,999	9,618	10,938	9,748	9,492	8,486
Spring 1996 Yield (kg/ha)	7,097	7,550	7,337	8,068	6,867	8,039
Spring/Fall Yield	**64.5%**	**78.5%**	**67.1%**	**82.8%**	**72.3%**	**94.7%**
Fall 1996 Yield (kg/ha)	11,904	12,660	11,267	11,293	10,936	10,125
Spring 1997 Yield (kg/ha)	8,111	7,622	8,351	8,430	8,183	6,935
Spring/Fall Yield	**68.1%**	**60.2%**	**74.1%**	**74.6%**	**74.8%**	**68.5%**

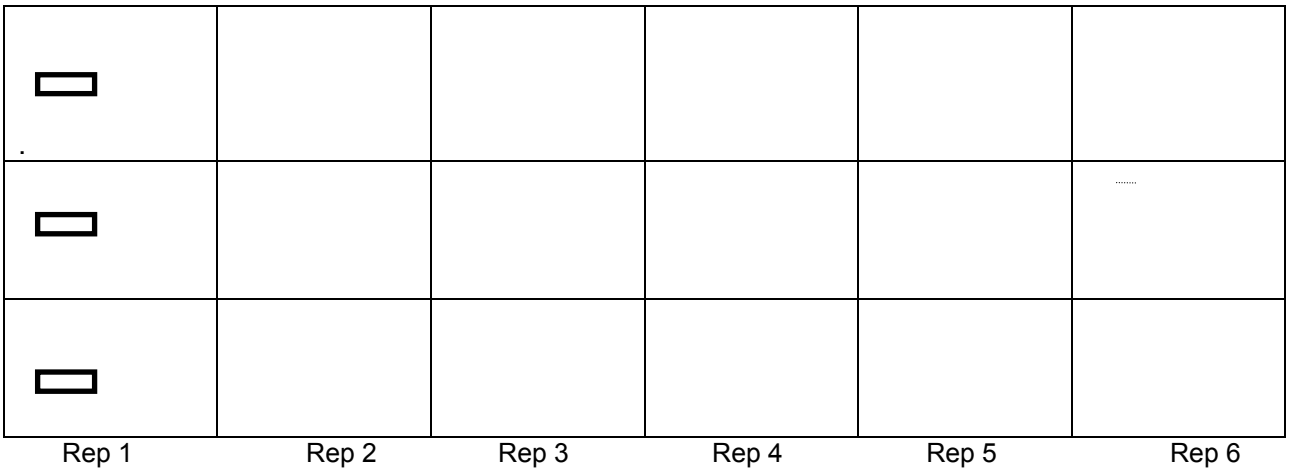
2. 0 Assessment of Losses Due to Cutting Equipment

2.1 Measurement of Background Material

Materials and Methods

Before harvesting losses could be measured, background unharvestable material was assessed in the experimental plot. For this experiment, one plot of switchgrass was divided into two treatments (swathing and mowing), each 10 metres wide and 18 metres long, and replicated six times. Each of the treatments was further subdivided into 3 subplots consisting of different switchgrass varieties. Three 1 m^2 circles were harvested in a line along the centre of each rep, using a sickle and a one-metre quadrat. The cutting height was approximately 10 cm. This harvestable material was then placed in plastic garbage bags for drying and weighing. All unharvestable material from the same 1 m^2 sampling areas was then carefully hand gleaned and placed in separate bags. Switchgrass dry matter weights were determined by oven drying 150 g subsamples of the harvested material.

Plot Layout for Cutting the Mowing/Swathing Study:



Results

The relatively high levels of unharvestable Cave-in-Rock Switchgrass (Table 2) are in line with to the high overwintering losses presented in Table 1. Pathfinder switchgrass had only 53% of the losses of Cave-in-Rock.

Table 2: Unharvestable Switchgrass Residue by Cultivar in the Spring of 1997

Variety	Unharvestable Residues (kg/ha)
Cave-in Rock	2,482
Pathfinder	1,311
Sunburst	1,795
Average	**1,863**

2.2 Measurement of Losses due to Mowing/Swathing

Materials and Methods

Two strips were cut along the length of each of the six main plots, using a cereal grain swather (International 4000) for one, and a disc mower-conditioner (Ford New Holland) for the other. The width of the swathed and mowed strips were determined to be 3.4 and 3.6 metres respectively. Cutting heights for the mower and the swather were determined by measuring twelve randomly chosen stems in each treatment area. Cutting height was determined to be 16 cm for the swather and 9 cm for the mower.

Losses due to the cutting equipment were determined by carefully lifting all harvested material off a sampling area one metre long and the width of the harvested strip (3.4 or 3.6 m).

Unharvested material was then gathered by carefully raking the plot and hand gleaning all switchgrass residue. This material was then placed in plastic garbage bags for drying and weighing. This procedure was repeated three times (once for each variety) in each of the harvested strips.

Results

The data indicate that average losses for mowing and swathing, after adjusting for the background unharvestable material, were 1,770 kg/ha for mowing and 469 kg/ha for swathing (Table 3).

Table 3: Losses Prior to Baling for the Spring Harvest of 1997

	Mowing losses (kg/ha)	Swathing losses (kg/ha)
Cave-in-Rock	1,440	703
Pathfinder	1,826	301
Sunburst	2,043	404
Average	**1,770a***	**469b***

*Means followed by the same letter are not significantly different at the 5% level using Tukey's Studentized Range test.

Mowing losses resulted primarily from breakage of the material upon coming in contact with the conditioner rollers and then falling below the stubble in the swath. Some material was not harvestable due to lodging. In the case of the swather which tended to cut higher (16 cm), the losses were almost exclusively as a result of harvestable material (i.e. material above the 10 cm cutting height) falling below the cutter bar on the swather. Where the material had lodged the swather tended to ride up the downed material.

Overall, swathing appeared to be a very gentle way to harvest the material and a major improvement over the mower-conditioner with a 74% reduction in losses prior to baling (Table 3). If the cutting height of the swather could be reduced below the 16 cm that occurred in our experiment, further reductions in harvest losses would be expected. This could be achieved by removing the rider plate (or using a thinner plate) below the cutting bar.

3. 0 Assessment of Losses Due to Harvesting and Baling Operations

Materials and Methods

In this experiment, mow or swath harvest treatments were randomly assigned to four replications, two at each of the Ecomuseum and Seedfarm sites. One strip was harvested (swathed or mowed) in the middle of each of the three varieties in each plot. The stubble in the middle underneath each windrow was marked with spray paint prior to baling to mark the sampling sites at approximately 10 m intervals. These strips were then baled using the same large square baler as was used in the spring of 1996 study. Each of the sampling sites was 1 metre wide by the operating width of the equipment (3.4 m and 3.6 m). With two sampling sites in each windrow, a total sampling area of 6.8 m^2 and 7.2 m^2 was measured for the swather and mower respectively in each plot. On May 27 and 28, 1997, all unharvested material from these sampling sites was then carefully raked and removed from the site by hand, and placed into a plastic garbage bag. This procedure was repeated twice in each strip, and material from both samples was placed in one plastic garbage bag. Moisture content of the samples was determined by oven drying a 150 g subsample from each of the bags. Aggressive raking was required on these plots as the material tended to be compressed into the soil as a result of the additional wheel traffic from baling. Some of this soil ended up in the samples. After obtaining dry weights from each of the bags, the samples were soaked to remove some additional soil. This soil was then dried and weighed, and this weight subtracted from the switchgrass sample.

Results and Discussion

On average, the swathing and baling system resulted in a material loss of 932 kg/ha versus 2,103 kg/ha for the mowing and baling operation (Table 4). For each of the varieties tested, losses ranged from 10.1-14.0% of the harvestable material for swathing and baling versus 22.7-27.8% for mowing and baling. The swathing and baling system in 1997 reduced losses by 56% compared to the mowing and baling system and by 74% of those recorded in the mowing and baling experiment of 1996. A possible reason for the reduction in losses from the mowing system in 1997 could be that the material was extremely brittle in 1996 as a result of the excessively wet spring.

Based on losses for swathing and mowing assessed in the previous experiment (2.2), baling losses were estimated to be 333 and 463 kg/ha for the mowing and swathing systems respectively. The losses associated with the mower conditioner system appeared to be primarily a result of the material being relatively fine and therefore easily lost in the pick-up and baling action (see photos in Appendix 1). Losses from the swathing system appeared to be related to the wider width of the swath windrow. The baler tractor tires compressed the edge of the swath

into the soil and this caused difficulties for the pickup. Modifying the tire spacing on the tractor to a wider setting would have eliminated much of the problem of the wider swath and reduced baling losses accordingly.

Table 4: Total Losses from Mowing/Baling and Swathing/Baling Systems				
	Mowing/Baling System Total Losses of Harvestable Material		Swathing/Baling System Total Losses of Harvestable Material	
Variety	**(kg/ha)**	**%**	**(kg/ha)**	**%**
Cave In Rock	2,197	27.8%	871	11.0%
Pathfinder	1,905	22.7%	849	10.1%
Sunburst	2,208	28.7%	1,077	14.0%
Mean	**2,103a***	**26.4%**	**932b***	**11.7%**
Estimated Losses Resulting from the Baling Operation Only				
	333 kg/ha		**463 kg/ha**	

*Means followed by the same letter are not significantly different at the 5% level using Tukey's Studentized Range test.

It could be possible to reduce total swathing and baling losses to 5% by making small adjustments to the cutting strategy. Measures such as removing the rider plate below the swather to reduce the cutting height from 16 cm to approximately 10 cm and setting the tractor tires to a wider spacing during baling to avoid compressing the rows would probably keep losses from the harvesting process below 500 kg/ha.

4.0 Analysis and Conclusion

Overall, the delivered switchgrass field yields were improved significantly with the spring of 1997 harvest. The best case scenario, in which Pathfinder switchgrass is grown and harvested with a swather, results in 7.5 odt/ha of material being deliverable to the mill. This is a substantial improvement over 1996 results which indicated that yields of only 4.1 odt/ha would be deliverable to the mill. Both the choice of variety and cutting technique proved to be important in increasing delivered mill yields.

Losses from overwintering were estimated to be twice that of losses from harvesting Pathfinder switchgrass using the swathing and baling method. With small modifications to the harvest equipment in subsequent years, the machine harvesting losses can be kept low. The ideal system would be a self-propelled baler and swather in one unit that would prevent the material from touching the ground after cutting. However, this investment does not appear to be necessary as existing machinery appears capable of doing the work reasonably efficiently. It is

clear that reducing overwintering losses is necessary to further increase the spring delivered field yield above 67% of the fall biological yield (Table 5). Choice of variety appears to play a key role in reducing overwintering losses. For instance, Pathfinder switchgrass had average overwintering losses of only 22.4%, versus 32.2% for the Cave in Rock. Earlier harvesting in the spring could potentially also reduce losses. In both 1996 and 1997 the material could have been harvested in early to mid May had equipment availability not been a limiting factor.

Table 5: Estimated Field Yields of Switchgrass Deliverable to a Plant in 1997

	Swathing and Baling (kg/ha)	**Fall 1996 Biomass Yield (kg/ha)**	**Spring Delivered Yield (swath) vs. Fall Biological Yield**
Cave In Rock	6,995	12,282	**57%**
Pathfinder	7,542	11,280	**67%**
Sunburst	6,482	10,531	**62%**

Agronomically, the spring harvest remains attractive because it:

- provides very reliable weather conditions for harvesting;
- minimizes potential for winter hardiness problems of the stand;
- eliminates the early growth of spring weeds;
- provides a seed source to regenerate the stand;
- maximizes recycling of the nutrients to the soil minimizing fertilizer requirements;
- enables late maturing varieties of switchgrass to be grown which can better use solar radiation available in late fall.

The only disadvantages of this system are that it makes the material brittle (which necessitates the use of a swather) and it can also delay soil warming in the spring and material regrowth if harvesting is delayed.

It would be wise to do some fall harvesting studies to determine the long term yield stability and reliability of fall harvesting . It appears possible that the material can be baled at higher moisture contents than previously thought. Experiments with straw from grass seed crops in Oregon indicate that baling could occur at moisture contents up to 25% with no decomposition of the material. This appeared to be attributed to the low nutrient content of the material that made it less prone to microbial decomposition. The opportunity to bale the material slightly wetter than previously believed may make fall harvesting a viable option.

5.0 Recommendations

Based on the results obtained in this study, our recommendations for future work are:

- To determine if overwintering losses could be further reduced through plant selection;
- To evaluate the effect of fall harvesting switchgrass in eastern Canada on yield stability;
- To evaluate the effect of material moisture content in the 20-25% range on decomposition during storage;
- To assess the potential of earlier spring baling at wetter moisture contents to minimize overwintering losses and reduce material brittleness;
- To further characterize switchgrass biological yield loss to determine if losses are occurring mostly in late fall, winter, or early spring prior to harvest.