CONF-960958--5

Energy Division and Environmental Sciences Division

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Prepared for
7th National Bioenergy Conference
Nashville, Tennessee
September 15-20, 1996

Prepared by
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6205
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract number DE-AC05-96OR22464

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YIELD EFFECTS ON BALE DENSITY AND TIME REQUIRED FOR COMMERCIAL HARVESTING AND BALING OF SWITCHGRASS

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ABSTRACT

Economic projections for harvesting and baling switchgrass as an energy crop are currently derived from budgets for hay making. However, hay yields are less than half those expected for biomass yields, which suggests that this extrapolation may not be valid. Therefore, the objective of this study was to obtain mowing, raking and baling data for switchgrass fields with either a low (hay) or high (biomass) yield. The study involved experiments at two locations. At the Wiregrass Station, near Dothan in southeast Alabama, equipment typically available to small-scale farmers was used to mow, rake and bale switchgrass in 0.2 ha plots with low and high yields, representing the second cut of a 2-cut per season system, and the only cut of a 1-cut system, respectively. At the E.V. Smith Center near Montgomery, Alabama, more powerful equipment typically available in larger farming operations was used under similar field conditions. Bales at the Wiregrass Station were 1.52 m in diameter and 1.22 m long. Corresponding measurements for bales at the E.V. Smith Center were 1.83 m and 1.52 m. For each plot, time taken for mowing, raking and baling was recorded, and all bales were weighed and measured to determine bale density. Subsamples were dried in an oven at 60°C for 48 hr to determine dry matter content. Yield had relatively little effect on bale density, mowing time and raking time. However, bale density was strongly affected by the baler size: density of the small bales averaged 110 kg/m^3, while that of the large bales averaged 134 kg/m^3. In addition, high yields caused considerable difficulty with baling operations, including occasional jamming of the smaller baler at the Wiregrass Station, which amounted to unscheduled down time. This study indicated that data for hay making are not appropriate for harvesting and baling switchgrass when managed as an energy crop. In addition, further research on harvesting and baling switchgrass for biomass with commercial equipment is urgently needed to obtain reliable estimates of costs.

Keywords: herbaceous energy crop, *Panicum virgatum*, energy feedstocks

INTRODUCTION

Several technologies for producing energy from dedicated energy crops appear to be near ready for commercialization. Based on 10 years of research in Alabama, the southeastern

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USA offers considerable economic opportunity to produce switchgrass (Bransby and Sladden, 1995). Yields from test plots in this region averaged 25.8 Mg/ha (11.5 tons/acre) from 1990 to 1994. Yields from commercial fields are likely to be well below this, because of incomplete stands, weak patches in fields and less border effect, compared to small research plots. However, even if yields of 13.5 to 18.0 Mg/ha (6 to 8 tons/acre, or 48 to 30% lower, respectively) are assumed, projected returns/ha were $153 to $242 ($62-$98/acre). Furthermore, this would be very competitive with two major existing enterprises in the region: beef production from pasture, which mostly generates less than $124/ha ($50/acre), and forestry, from which the annual return is about $62/acre).

Published switchgrass biomass cost analyses have been based mainly on hay production data (Cundiff, 1994; Cundiff and Harris, 1995), with some modifications in certain cases. However, without actual data from commercial harvesting of switchgrass for biomass, validity of these projections will remain unknown. Perhaps the most important difference between hay and biomass crops is yield: a standing hay crop is usually about 4.5 Mg/ha (2 tons/acre), while biomass crops would often be more than twice this amount. Consequently, hay making equipment may have to be modified to handle these higher yields. Furthermore, Cundiff (1994) suggested that higher yields reduced bale density, which would increase transport costs, and Cundiff and Harris (1995) indicated that higher yields may require slower forward speeds for baling which could also increase costs. However, some of these projections were obtained from a model developed for alfalfa, which may not apply to switchgrass.

In order to develop reliable cost estimates for switchgrass biomass production, harvesting and transport, it is necessary to conduct studies with commercial equipment and representative yields. Therefore, the objective of this study was to determine effects of yield on bale density, and on the time required to mow, rake and bale switchgrass biomass with commercial equipment.

PROCEDURE

This study involved experiments with 'Alamo' switchgrass (*Panicum virgatum*) at two locations. At the Wiregrass Station, near Dothan in southeast Alabama, equipment typically available to small-scale farmers was used to mow, rake and bale switchgrass in 0.2 ha plots with low and high yields, representing the second cut of a 2-cut per season system, and the only cut of a 1-cut system, respectively. At the E.V. Smith Center near Montgomery, Alabama, more powerful equipment typically available in larger farming operations was used under similar field conditions. Bales at the Wiregrass Station were 1.52 m in diameter and 1.22 m long (5 ft x 4 ft). Corresponding measurements for bales at the E.V. Smith Center were 1.83 m and 1.52 m (6 ft x 5 ft).

For each plot time taken for mowing, raking and baling was recorded. Although plots were small, they were relatively long (about 165 m at each location) and narrow. Time was recorded for each linear pass for each operation separately. Time required for turning due to the small size of the field was not included. It was assumed that this would more closely represent activities on large fields. All bales were weighed separately and measured to determine bale volume. Subsamples were obtained and weighed before and after drying in an oven at 60°C for 48 h to determine dry matter content. Yield and bale density were then calculated on a dry matter basis.

RESULTS AND DISCUSSION

Bale Density

Yield of the 2-cut system corresponded with yields often observed under hay management (Table 1). The high yields obtained from the 1-cut system were more than double those of the low yield treatments at both locations. However, bale density was affected very little by yield, and depended mostly on the baler used. Therefore, these data do not support the projections of Cundiff (1994) which suggested that, based on an alfalfa hay model, higher yields may result in significantly lower density bales.

Table 1. Production Data for Fields and Bales of Switchgrass Harvested at Two Locations in Alabama.

	LOCATION			
EXPERIMENTAL VARIABLE	Wiregrass		E.V. Smith	
Number of cuts/year	2	1	2	1
Dry matter yield (Mg/ha)	5.2	11.3	3.3	10.1
Number of bales/ha	19.7	44.0	6.1	19.9
Bale weight (kg dry matter)	264	257	541	508
Bale density (kg/m^3)	111	109	140	132

On average, bales from the small baler at the Wiregrass Station were 110 kg/m^3, while those from the large baler at the E.V. Smith Center were 136 kg/m^3. This represents 23.6% greater density for the larger baler. Clearly, this will affect the weight of switchgrass that can be loaded onto any transport vehicle, and therefore, the cost of transport. In addition, it could affect damage to, and associated losses from bales which are stored without protection from the weather.

Time Required for Mowing, Raking and Baling

Time required for mowing one hectare was similar for different yields and equipment at both locations (Table 2). Therefore, when expressed on a per bale or Mg basis, results were dependent on the size of bales and yield.

Table 2. Time Required for Mowing, Raking and Baling Switchgrass from Fields with Different Yields at Two Locations in Alabama.

	LOCATION			
EXPERIMENTAL VARIABLE	Wiregrass		E.V. Smith	
Number of cuts/year	2	1	2	1
Dry matter yield (Mg/ha)	5.2	11.3	3.3	10.1
Mowing time				
(min/ha)	41	45	42	41
(min/bale)	2.08	1.02	6.88	2.06
(min/Mg)	7.88	3.98	12.73	4.06
Raking time				
(min/ha)	39	0[1]	48	76[2]
(min/bale)	1.98	0	7.87	3.82
(min/Mg)	7.50	0	14.55	7.52
Baling time				
(min/ha)	45	128	22	64
(min/bale)	2.28	2.91	3.60	3.22
(min/Mg)	8.65	11.33	6.67	6.33
Total mowing, raking and baling time				
(min/ha)	125	173	112	181
(min/bale)	6.34	3.93	18.35	9.10
(min/Mg)	24.03	15.31	33.95	17.91

[1]This field was not raked, but baled directly from the swath.

[2]Windrows in this field had to be compressed with a tractor wheel, which increased this value.

Raking time per hectare was similar for the low yield at both locations. However, at the Wiregrass Station, baling was done directly from the swath with the small baler, without any raking. This approach was taken because more than one swath would have resulted in a very heavy windrow for the small baler. As it was, even with a single swath, the baler jammed several times. The higher raking time recorded for the higher yield treatment at the E.V. Smith Center resulted from he need to compress or flatten the heavy/high windrow in order to ensure easier feeding into the baler, and reduce the risk of jamming. This was done with the rear wheel of a tractor traveling ahead of the baler, thus requiring an extra operation which took 28 min/ha. Therefore, the 76 min/ha indicated for raking the high-yield fields at the E.V. Smith Center in Table 2, is actually made up of 48 min/ha for raking (the same as for the low-yield fields) and 28 min/ha for compressing.

Baling time per hectare was strongly influenced by yield at both locations, and was considerably lower for the large baler at the E.V. Smith Center (Table 2). Time required to complete a bale was higher for the high-yield fields and the small baler at the Wiregrass Station. This is because a slower forward speed was required to reduce the risk of the baler jamming, thus confirming the projection of Cundiff and Harris (1995). However, this was not necessary with the larger baler at the E.V. Smith Center. Consequently, in this case higher yields resulted in heavier windrows and less time for completion of each bale.

Although total time/ha required to mow, rake and bale was higher for the high-yield fields, total time/Mg was lower than for the low-yield fields. At the Wiregrass Station total time required to mow, rake and bale/Mg of switchgrass biomass was 57% (24.03 min vs. 15.31 min) greater for the low-yield fields, while at the E.V. Smith Center the difference was 90% (33.95 min vs. 17.91 min). Once again, these results do not support the suggestions of Cundiff and Harris (1995) that higher yields will increase harvest costs per ton. One of the reasons for this discrepancy is that the study of Cundiff and Harris (1995) focussed mainly on the baling operation, while our study included mowing, raking and baling. Furthermore, our study showed that mowing and raking together, took more time than baling with the large baler, but were influenced less by yield.

CONCLUSIONS

This study showed that total time required to mow, rake and bale high-yield fields of switchgrass was considerably lower than for low-yield fields when expressed on a per Mg basis. Since labor and machinery costs would be strongly related to the time required for these operations, high yields would be expected to reduce harvest costs/Mg. This strongly justifies further research to increase switchgrass yields, especially if this can be done with no cost to producers, such as by developing new varieties. However, additional research is also needed on harvesting, especially to develop strategies to better handle baling of high-yield fields.

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