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Corn Stover Availability and Collection Efficiency Using Typical Hay Equipment

Robert M. Prewitt
University of Kentucky

Michael D. Montross
University of Kentucky, michael.montross@uky.edu

Scott A. Shearer
University of Kentucky

Timothy S. Stombaugh
University of Kentucky, tim.stombaugh@uky.edu

Stephen F. Higgins
University of Kentucky, shiggins@bae.uky.edu

See next page for additional authors

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R. M. Prewitt, M. D. Montross, S. A. Shearer, T. S. Stombaugh,
S. F. Higgins, S. G. McNeill, S. Sokhansanj

Abstract. *Corn stover has been identified as a potential feedstock for the production of fermentable sugars and thermochemical processes. The availability and efficiency of typical hay equipment for collecting corn stover has not been well quantified. Corn stover was collected for two years on a central Kentucky farm near Louisville. Six different harvesting treatments, using traditional hay equipment, were used to harvest corn stover. A rotary mower, rotary scythe (flail-type mower with windrow-forming shields), parallel bar rake, and a round baler were utilized. The average stover moisture content prior to grain harvest was above 40%, and field drying was required before baling. All treatments were analyzed for collection efficiency and corn stover yield. The stover collection yields varied from 1.93 to 5.34 dry t/ha, with collection efficiencies (ratio of stover collected to the total above-ground stover excluding grain) between 32.1% and 94.5%. The most promising collection strategy was disengaging the straw chopper and spreader to produce a windrow behind the combine. This windrow could then be baled in a separate operation that resulted in a collection efficiency of 74.1%.*

Keywords. *Bale, Baling, Bioenergy, Biomass, Harvest, Maize, Residue, Yield.*

The above-ground residue left behind after harvesting corn for grain is referred to as corn stover. Corn stover includes stalks, leaves, cobs, and husks that are either partially tilled into the soil or left undisturbed on the field surface depending on tillage practices. The dry weight of stover is approximately equal to the dry weight of the harvested grain (Tyner and Buttum, 1978). More recent work (Pordesimo et al., 2004; Shinners et al., 2005) found similar stover to grain ratios when the grain moisture content was between 18% and 30%. The annual U.S. corn harvest between 1998 and 2002 averaged 242 Mt of corn from 28.6 million ha (USDA, 2006); therefore, the total amount of dry corn stover annually available would be approximately 7.19 dry t/ha, assuming corn grain at 15% moisture content (all weights and yields are reported at 0% moisture content, and all moisture contents are in percent wet basis).

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The authors are **Robert M. Prewitt,** Graduate Research Assistant, **Michael D. Montross, ASABE Member Engineer,** Associate Professor, **Scott A. Shearer, ASABE Member Engineer,** Professor, **Timothy S. Stombaugh, ASABE Member Engineer,** Associate Extension Professor, **Stephen F. Higgins,** Research Specialist, and **Samuel G. McNeill, ASABE Member Engineer,** Associate Extension Professor, Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, Kentucky; and **Shahab Sokhansanj, ASABE Member Engineer,** Professor, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, Tennessee. **Corresponding author:** Michael D. Montross, 128 Barnhart Bldg., University of Kentucky, Lexington, KY 40546-0276; phone: 859-257-3000, ext. 106; fax: 859-257-5671; e-mail: montross@bae.uky.edu.

Sokhansanj et al. (2002) reviewed numerous aspects of corn stover collection with respect to utilizing the material for bioenergy applications. They found that the overall collection efficiency (ratio of stover collected to the total above-ground stover excluding grain) for corn stover using flail choppers, rakes, and balers was less than 30%. In addition, the timeliness for collection and moisture content issues are major problems associated with corn stover harvest. Most research has been based on a multiple-pass system for collecting corn stover in which the grain is harvested using a combine and the stover is then mowed and/or raked and baled (Sokhansanj et al., 2002; Shinners et al., 2003), although single-pass systems are being developed (Quick, 2003; Shinners et al., 2005).

Richey et al. (1982) investigated round baling of corn stover with moisture contents in the range of 14% to 33%. They estimated that 25% of the total available stover and 50% of the windrowed material was harvested. Shinners et al. (2003) determined that approximately 53%, 56%, and 33% of the total available stover was collected using a forage harvester, wet baling, and dry baling, respectively. Quick (2003) reported collection efficiencies of approximately 70% with a prototype single-pass collection system, while Shinners et al. (2005) reported efficiencies as high as 92%.

The objectives of this research were to: (1) determine the availability of corn stover, (2) determine the collection efficiency of corn stover with typical hay equipment, and (3) measure the density of the bales.

Materials and Methods

2001 Field Trials

During 2001, a 12 ha field of corn located in Shelby County, Kentucky (east of Louisville, Ky.) was investigated. The field had been in a no-till corn, soybean, and wheat rota–

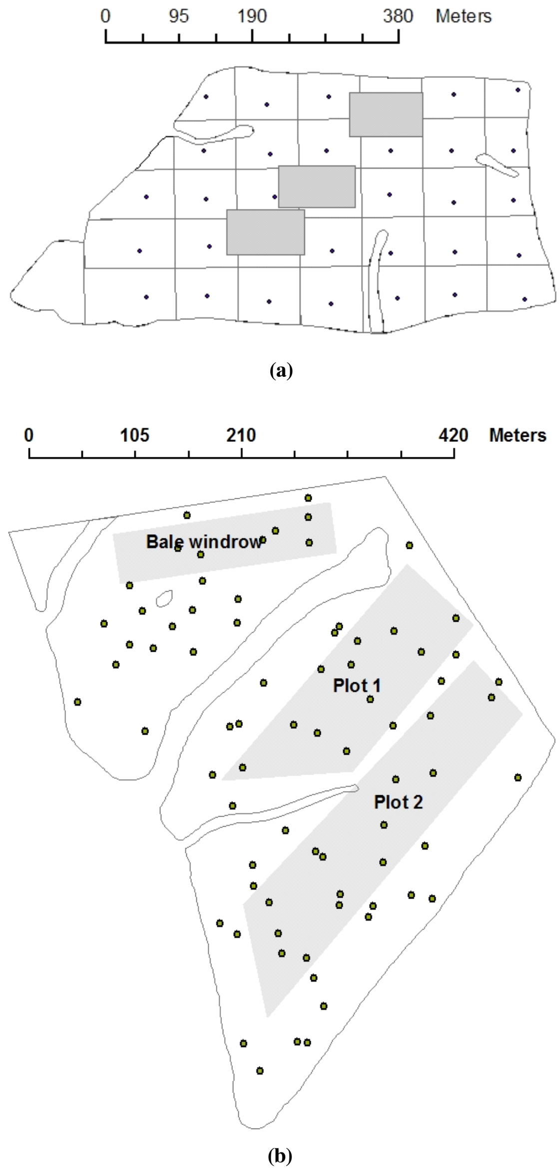

Figure 1. Sample locations and field layout for the (a) 2001 and (b) 2002 corn crops (shaded areas represent the approximate locations within the field where corn stover was collected).

tion for the past 21 years. The field was planted to DeKalb 626 hybrid corn (Monsanto, St. Louis, Mo.) in 0.76 m rows.

Stover Availability

On 17 October 2001, prior to grain harvest, the field was divided into 0.4 ha grids, and whole-plant samples were taken at the locations shown in figure 1a. The available stover in each cell was estimated by measuring the plant population (two rows 33 m long) and the weight of ten corn plants at the center of the two rows where the plant population was determined. Three corn plants representing the mean, lightest, and heaviest plants of the ten were put into bags and removed from the field. These plants were analyzed for moisture content and dry matter yield by components (corn, cob, and all other stover). The moisture content and dry matter distribution of the three plants analyzed in the lab were assumed to be representative of the ten plants weighed in the field, and an average plant weight was estimated. The average grain and stover dry weight per plant was multiplied by the plant population and divided by the area (two rows 33 m long, for a total area of 50.3 m^2).

Individual stalks (a total of 30) were randomly selected, and the average moisture content and weight distribution of cobs, leaves, stalks, husks, and corn were determined. The stover was placed in plastic bags, stored in a 4°C cooler, and separated by hand and weighed within three days. The moisture content was determined by drying at 103°C for 24 h (*ASAE Standards*, 2003) to determine the average moisture content and for calculation of stover yield.

Treatments

Grain was harvested on 19 October 2001 using a Gleaner R70 grain combine with a 12-row head, an Ag Leader PF3000, and a Trimble AgGPS 132. Plots twelve rows wide were selected with a nominal distance of 150 m and were replicated in three areas of the field. Three collection treatments were randomized within each area, and triplicate collections were performed (shaded blocks in fig. 1a). This resulted in a total of nine bales from each treatment, for a total of 27 bales produced.

Each treatment required between zero and two field operations prior to baling. The pickup on the baler for all treatments was adjusted to 3.8 cm above the ground. For the first treatment (BO), only a baler was used with no additional field operations. Uncut stover was baled, and six passes were required per block to collect the stover due to the baler pickup width of two rows. The second treatment (RB) consisted of raking uncut stover (four passes) into two windrows and baling the resulting windrows. The final treatment (RC) consisted of utilizing a rotary mower (four passes per block), raking the cut stover into two windrows, and baling the resulting windrows. Mowing and/or raking occurred on 13 November 2001, 25 days after grain harvest. Baling was performed between 14 and 15 November 2001. Typical low-yielding areas in the field, such as headlands and grass waterways, were avoided to help lessen the variation of grain and stover yields.

2002 Field Trials

During 2002, a 17 ha field of corn located in Shelby County, Kentucky (20 km from the previous field) was harvested (fig. 1b). The field was in the first year of a no-till corn, soybean, and wheat rotation and was planted to Pioneer 31R88 hybrid corn (DuPont, Des Moines, Iowa) in 0.76 m rows, which was preceded by a fescue hay field. Grain harvest occurred between 4 and 6 October 2002 using a John Deere 9500 combine with an 8-row head, a GreenStar yield monitor, and a StarFire GPS receiver.

Stover Availability

On 2 October 2002, an estimate of the stover available prior to grain harvest was determined by measuring all of the material above the roots in two rows 1.65 m long (fig. 1b). The plant population was estimated at each sampling site by counting plants in two rows 12.8 m long. In addition, random samples from the locations shown in figure 1b were sorted to determine the quantity and moisture content of individual plant components, i.e., cobs, grain, husks, leaves, and stalks. Due to the quantity of material, not all of the samples were analyzed for moisture content. The GPS location of each sample site was recorded, and the material was placed in bags and taken to the University of Kentucky for moisture content and calculation of stover yield. This procedure resulted in an estimate of stover yield as a function of grain yield, since all of the material was collected from a constant area.

Collection efficiency was calculated by extracting the grain yield from yield maps in each area that a bale was produced. Stover availability was estimated using regression equations developed from the hand-harvested samples as a function of grain yield. In addition, collection efficiency was estimated using the 1:1 grain-to-stover ratio used by previous researchers.

Treatments

During 2002, five collection treatments were investigated in plots eight rows wide. The BO, RB, and RC treatments from 2001 were repeated, and two additional treatments were included. This resulted in four passes being required for the BO treatment (two rows baled per pass). Treatment RB required two passes with the rake to form one windrow that was then baled. Treatment RC required four passes with the mower and two passes with the rake to produce a single windrow that was baled in one pass per block. A flail-type mower with windrow-forming shields (rotary scythe) was operated to form two windrows in two passes per block. The two windrows were then baled in two passes with the baler (treatment RS). In addition, the straw chopper and spreader were disengaged on the combine, and the resulting windrow was then baled (treatment BW). Therefore, treatment BW required one pass, with the baler gathering the windrow left behind the combine. Because of the time required to disengage the straw chopper and spreader on the combine, treatment BW was performed in a separate area of the field. A total of 67 bales were produced from all treatments in 2002.

Equipment Utilized

All stover was harvested using a John Deere 457 Cover-Edge, MegaWide belt-type round baler (Moline, Ill.) using plastic net wrap. The JD 457 has the capability of producing 1.5 m diameter by 1.2 m wide bales. A New Holland 256 side-delivery ground-driven rake (New Holland, Pa.) capable of raking a 2.6 m swath was used. A Matthew's Company 2109 2.75 m flail type mower (Crystal Lake, Ill.) with windrow-forming shields (rotary scythe) was also used in a separate treatment during 2002. All field activities were monitored using an Ag Leader PF 3000 yield monitor (Ames, Iowa) and Trimble Ag GPS 132 receiver (Sunnyvale, Cal.). The data was imported into ArcMap Version 8.1 (ESRI, Redlands, Cal.), where the area and time required to harvest was determined. ArcMap was also used to determine grain yield from areas where bales were produced and estimate available stover.

Bales were weighed using a Digistar 3300 Stockweigh scale (Fort Atkinson, Wisc.) with a capacity of 1500 kg, a resolution of 0.45 kg, and an accuracy of 1%. The moisture content was determined by collecting three cores at unique locations from each bale immediately after baling. Two were from the side (center of the curved portion of the bale) about 30 cm deep, and the third was slightly above the center (flat portion of the bale) about 30 cm deep. All material collected was dried at 50°C for four days for further chemical analyses and to allow for safe storage. Subsamples were taken and dried according to ASAE Standard S358.2. The PROC GLM procedure in SAS software (SAS Institute, Inc., Cary, N.C.) was used to evaluate the significance of measured values within each year for this study.

Results and Discussion

Moisture Content and Distribution of Material Prior to Grain Harvest

A total of 30 locations (fig. 1a) were sampled (300 plants), and three plants were removed from each location during 2001 (total of 90 plants). The average moisture content during 2001 of the corn harvested by hand was 21.0% and varied between 17.2% and 27.2% with a standard error of 0.3%. The average moisture content of the cob fraction was found to be 41% with a variation between 32% and 49% and a standard error of 0.8%. Stalks ranged in moisture between 47% and 69% with an average of 61% and a standard error of 1.0%.

In 2001, thirty stalks were randomly selected and separated by hand into cobs, grain, husks, leaves, and stalks. There was a wide range in moisture content between individual fractions and between plants. The moisture content of the plant components varied between 14% and 76%. Overall, the average moisture contents (and standard errors) of the cobs, grain, husks, leaves, stalks, and whole stover were 32% (6.2%), 18% (4.5%), 37% (3.3%), 19% (0.5%), 51% (5.6%), and 43% (6.7%), respectively.

These moisture trends continued in 2002. Stalks had the highest moisture content, while cobs, husks, and leaves were slightly lower. Thus, baling immediately after harvest and storing dry bales inside a barn was not possible due to the high stover moisture content.

Table 1 summarizes the distribution of material that was measured prior to grain harvest in both years. There was some variation in the distribution of corn stover components between years, which was expected considering that two different hybrids were used and the growing seasons were significantly different. Grain represented between 48% and 50% of the total dry weight of the material, a range similar to that of previous research (Pordesimo et al., 2004; Shinners et al., 2005). Stalks were the largest non-grain source of material and represented between 21% and 23% of the total dry weight of the plant. The cobs, leaves, and husks represented approximately 28% of the remaining non-grain material. There were statistical differences between every plant component except husks and leaves during 2001.

Stover Availability

During 2001, the stover availability was estimated using the plant population and weight of the material collected at

Table 1. Average dry weight distribution (standard errors in parentheses) of cobs, husks, leaves, stalks, and grain of all sample locations for the 2001 and 2002 corn crops.[a]

Component	2001[b] (%)	2002[c] (%)	2001-2002 Average (%)
Cobs	7.9 a (1.2)	7.9 a (0.5)	7.9
Husks	10.1 b (0.9)	6.6 b (0.3)	8.4
Leaves	11.1 b (0.9)	13.2 c (0.6)	12.2
Stalks	22.6 c (1.3)	21.6 d (1.0)	22.1
Grain	48.3 d (1.9)	50.8 e (2.5)	49.5

[a] Different letters (a, b, c, d, and e) indicate different column means for each year (α = 0.05).
[b] Data from a total of 30 plants.
[c] Data from a total of 672 plants.

Table 2. Stover yield relationships as a function of grain yield (g, t/ha) for determining the quantity (t/ha) of total stover during 2001 and 2002 and the quantity of stalks, leaves, cobs, and husks for the 2002 field trials.

Component	Component Yield (t/ha)	r^2	Standard Error of Regression Coefficients	
			Slope	Intercept
2001 total stover[a]	$0.847g + 2.15$	0.78	0.0139	0.0873
2002 total stover[b]	$0.763g + 1.26$	0.92	0.00444	0.0295
2002 stalk yield	$0.351g + 0.492$	0.78	0.00343	0.01701
2002 leaf yield	$0.1306g + 0.769$	0.63	0.0164	0.0109
2002 cob yield	$0.0947g + 0.373$	0.76	0.00694	0.00479
2002 husk yield	$0.0908g + 0.236$	0.81	0.00635	0.00434

[a] Total of 320 plants from 32 locations within the field.
[b] Total of 672 plants from 72 locations within the field.

the points shown in figure 1a. The grain yield estimated from the hand-harvested samples was compared to the yield map data. Yield data using ArcMap was extracted to estimate the yield from the combine pass closest to the hand sample location. Yield map and hand sample data were linearly correlated with an r^2 of 0.82 (not shown), a slope of 1.06 with a standard error of 0.03, and with the intercept forced through zero. It was assumed that hand-harvested samples were representative of field conditions, so the relationship of stover availability as a function of grain yield was developed (fig. 2). An equation summarizing stover availability as a function of grain yield is presented in table 2 and was used to calculate the available stover for each bale based on the yield map.

During 2002, all of the above-ground corn plant material was taken from a fixed area (two rows 1.65 m long), from a total of 56 locations (fig. 1b) and totaled 672 plants. The yield of individual components and total stover could be estimated, since the amount of material and area were known. A plot of the grain yield measured at the 56 locations and the quantity of cobs, husks, leaves, and stalks are shown in figure 3. The data indicated that maps of the available stover and estimates of the quantity of specific corn stover fractions could be developed as a function of grain yield. Regression equations and statistical descriptors for the curves shown in figure 3 are summarized in table 2. High correlations ($r^2 > 0.76$) were observed for all components except leaves. The leaves were difficult to handle in the field during sampling, since they tended to break off when placed into bags. During hand sorting, small, low-moisture content leaves broke into small pieces that were not quantified.

Grain yields averaged 7.61 and 6.46 dry t/ha during 2001 and 2002, respectively. During 2001, the standard deviation of the dry grain yield was 1.27 t/ha. Grain yield was slightly more variable during 2002, with a standard deviation of 2.60 t/ha. The regression equations derived from the hand-harvested areas were used to estimate the stover availability as a function of grain yield. The average stover availability was calculated as 9.60 t/ha with a standard deviation of 0.97 t/ha during 2001 (fig. 4a) and 6.19 t/ha with a standard deviation of 1.98 t/ha during 2002 (fig. 4b). Lower-than-average rainfall in 2002 reduced grain yields and limited the effectiveness of herbicide control.

Available stover calculated using the equations in table 2 indicated that the 1:1 grain-to-stover ratio reported by Tyner and Buttum, (1978) is not a constant. Available stover estimated at a grain yield of 2.00 and 8.00 t/ha would be 3.84 and 8.93 t/ha during 2001. In 2002, the total available stover at a grain yield of 2.00 and 8.00 t/ha would be 2.78 and 7.36 t/ha, respectively.

The relationships developed in table 2 would be expected to be dependent on hybrid, fertilization, and rainfall. However, when combined with the yield map data, they were assumed to accurately quantify the available corn stover for each field and were used to calculate collection efficiency. The data also indicated that accurate relationships of the available stover as a function of grain yield could be developed that would be useful for spatially variable collection of stover based on soil fertility, field slope, soil type, erosion potential, and other variables as a function of grain yield. Existing simulation models of crop growth and grain-to-stover ratios could be used for estimating the quantity of available stover (Hodges et al., 1987).

Collection Efficiency

After grain harvest in 2001, stover was left to dry in the field for three weeks until the moisture content was less than 20%. Harvesting stover after three weeks would be typical of operators who would harvest stover after most or all of their grain had been harvested. In 2002, stover was collected four days after grain harvest, when the moisture content ranged between 25% and 35%, although no bales showed signs of

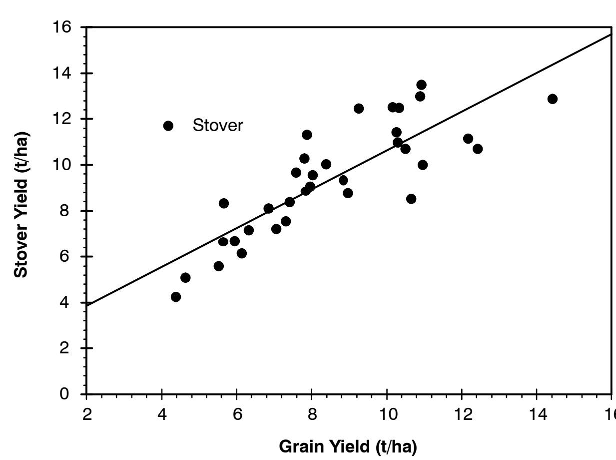

Figure 2. Estimated total dry stover yield as a function of dry grain yield for the 2001 crop from 30 locations and a total of 300 plants.

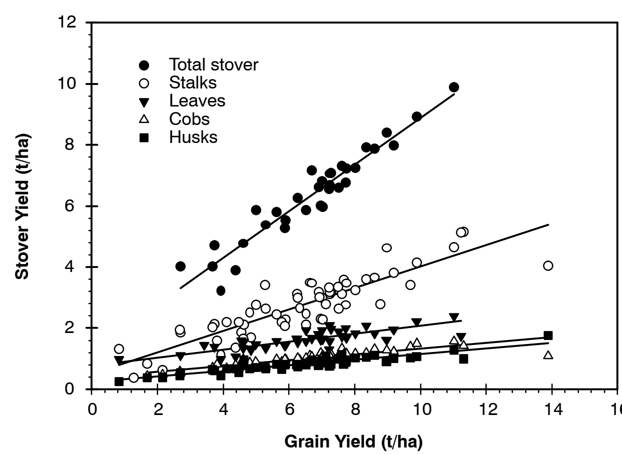

Figure 3. Observed yield (t/ha) of total stover, stalks, leaves, cobs and husks from 56 locations (total of 672 plants) as a function of dry grain yield (t/ha) during 2002.

Figure 4. Grain yield map (dry t/ha) for the (a) 2001 and (b) 2002 corn crop.

molding or heating during storage. During both years, high-moisture corn stover would likely have created excessive respiration heat during storage if baling was performed immediately after grain harvest. Thus, collection and storage of corn stover as silage may be more appropriate than attempting to bale dry stover. In addition, weather conditions in Kentucky are often not favorable during the fall for baling dry corn stover.

When the 1:1 grain-to-stover ratio was used, the available stover was between 7.82 and 8.15 t/ha during 2001 prior to grain harvest (table 3). However, when the relationships in table 2 were used, the estimated available stover was between 8.77 and 9.05 t/ha, an increase of approximately 12% relative to the 1:1 grain-to-stover ratio. There was no statistical difference in the available stover using either method during 2001. The collection efficiencies during 2001 using the 1:1 grain-to-stover ratio were 41.1%, 57.2%, and 65.7% for BO, RB, and RC, respectively, with standard errors between 2% and 4% (table 3), and all values were statistically different. When the relationships in table 2 were used, the collection efficiencies were 36.4%, 51.2%, and 59.7% for BO, RB, and RC, respectively, with standard errors between 2.58% and 5.32%. The collection efficiencies using the relationships in table 2 were approximately 10% lower. However, both methods resulted in collection efficiencies of similar magnitude and did not change the overall trend in the data. The disc cutter bar mower conditioner (discbine) was not effective in mowing and windrowing dry corn stover, so no data were collected.

In 2002, the available stover using the 1:1 grain-to-stover ratio varied between 4.77 and 6.72 t/ha, while the relationships in table 2 resulted in an available stover estimate of 4.90 to 6.39 t/ha (table 3). There were significant differences in the available stover between treatments, although the locations of stover collection were randomized within the field. The estimated available stover was on the same order of magnitude with both estimation methods and had a lower variation than the 2001 data, which reflected the improved sampling methodology. The collection efficiencies using treatments BO and RB during 2001 and 2002 were similar, although the material was collected after different post-harvest intervals. Treatment RC had significantly lower collection efficiency, approximately 50% lower, during 2002. This was probably due to the higher moisture that year. The rotary scythe (treatment RS) provided the highest collection efficiency (between 91.3% and 94.5%) for corn stover due to the low cutting height of the blades and the vacuum effect created by the rotating blades. The rotary scythe also cut any grass and weeds that were present in the field, which added to its apparent har–

Table 3. Average and standard error (in parentheses) of the stover collected (t/ha), available stover (t/ha) and collection efficiency (%) based on the 1:1 grain-to-stover ratio and the relationships in table 2, and bale density (kg/m^3) for the treatments investigated during 2001 and 2002.[a]

			Using 1:1 Grain-to-Stover Ratio		Stover Estimated from Table 2		
Year	Treatment[b]	Stover Collected (t/ha)	Available Stover (t/ha)	Collection Effic. (%)	Available Stover (t/ha)	Collection Effic. (%)	Bale Density (kg/m^3)
2001[c]	BO	3.19 a (0.16)	7.82 a (0.12)	41.1 a (2.24)	8.77 a (0.16)	36.4 a (2.58)	176 a (5.29)
	RB	4.59 b (0.16)	8.15 a (0.10)	57.2 b (2.95)	9.05 a (0.11)	51.2 b (3.52)	155 b (4.85)
	RC	5.34 c (0.31)	7.98 a (0.15)	65.7 c (4.39)	8.91 a (0.16)	59.7 c (5.32)	153 b (4.45)
2002[d]	BO	3.04 c (0.19)	6.72 d (0.05)	44.5 b (2.18)	6.39 c (0.06)	46.7 b (2.93)	124 b (3.31)
	RB	2.84 b (0.12)	5.77 b (0.05)	48.7 b (2.49)	5.66 b (0.06)	50.4 b (2.89)	110 a (2.56)
	RC	1.93 a (0.24)	5.97 b (0.06)	32.1 a (3.32)	5.81 b (0.06)	33.3 a (4.56)	112 a (3.81)
	RS	4.48 d (0.14)	4.77 a (0.05)	94.5 c (4.73)	4.90 a (0.07)	91.3 c (4.79)	112 a (2.34)
	BW	4.58 (NA)	6.18 c (0.09)	74.1 (NA)	5.97 b (0.09)	77.4 (NA)	118 a (3.74)

[a] Different letters (a, b, c, and d) indicate different column means for each year ($\alpha = 0.05$); NA = not available.
[b] BO = bale-only across entire width of plot, RB = rake uncut stover into a windrow and bale, RC = rotary cutter, rake into a windrow and bale, RS = rotary scythe and windrow, and BW = bale behind combine with straw chopper disengaged.
[c] Stover moisture at harvest less than 20%.
[d] Stover moisture at harvest between 25% and 35%.

vest efficiency, although this was not quantified. However, the rotary scythe also pulled some stalks completely out of the ground when it encountered wet field conditions. This is considered a disadvantage because inorganic compounds and soil particles are known to create problems for downstream processing and are undesirable in a feedstock for fermentable sugars or other chemical/thermochemical conversions.

A collection method that had a high level of efficiency and required a minimal amount of field operations was baling the windrow created by the combine (treatment BW). The 74.1% to 77.4% collection efficiency (table 3) was due to the fact that the combine placed material on corn stubble above the ground and thus created a windrow suitable for baling. The standard error of treatment BW could not be calculated because the bales were not tracked individually. From preharvest field data, the stover was composed of approximately 16% cobs, 12% husks, 28% leaves, and 50% stalks. If the stover passing through the combine was composed of the leaves, cobs, and husks with portions of the stalk, then 50% of the stover was potentially available in the windrow. By windrowing behind the combine, half of the stover was readily available for harvest. The windrow was placed over two rows of corn and with the 8-row head resulted in potentially 25% of the stalks being collected.

Treatment BW would be an easy-to-implement collection strategy for most producers while a biomass economy and single-pass equipment are being developed. The only additional equipment required for most producers would be a baler. Some potential problems are adequate weather conditions to allow drying to a safe moisture content and machinery traffic during grain harvest contaminating the stover with soil and decreasing the collection efficiency. High moisture content bales could be collected and potentially stored as ensiled material if they were wrapped in plastic. Additional research needs to be conducted to determine the collection costs with each treatment and to investigate differences in processed value.

Recent research has indicated that cobs, leaves, and husks will produce a higher level of fermentable sugars than stalks pretreated under equivalent conditions (Montross and Crofcheck, 2004). This indicates that there could be advantages to selectively harvesting the cobs, leaves, and husks. In addition, research has indicated that only 20% to 30% of the crop residue can be removed without deleterious effects on soil carbon levels and increased risk of soil erosion (Wilhelm et al., 2004). Therefore, high collection efficiencies of the whole-plant stover observed with treatment RS may not be desirable from a sustainability or processing standpoint. The most practical solution for farmers initially interested in supplying corn stover to biorefineries in the near future is treatment BW. This treatment required minimal equipment changes, and a high collection efficiency was observed by disengaging the straw chopper and spreader to produce a windrow during grain harvest and baling the windrow in a separate operation.

Table 3 also presents the dry bale densities for both years and all treatments. Treatment BO resulted in the highest bulk density during both years. This was due to the longer time required to form the bale, which resulted in a higher density. The lower bulk densities that were measured during 2002 were due to the higher moisture content of the stover. The bulk density of the bales collected in this study followed a different trend than reported previously. Richey et al. (1982) found that collection at a material moisture content of 14.3% and 33% produced bales that had a dry bulk density of 103 and 130 kg/m^3, respectively. Some of the differences could be explained by the baler used and the particle size of the material. Richey et al. (1982) did not list the type of baler, while the baler used in this study produced a dense core. Richey et al. (1982) also investigated the shredding of corn stover, which would have created a particle size consistent with treatment RS in this study. Shinners et al. (2005) found a similar range of 109 to 118 kg/m^3 for round baled stover at a moisture content of 36.8%.

Conclusions

A wide range of moisture content exists within the stover components prior to harvest. At grain harvest, grain and leaves are at approximately the same moisture content. However, the remaining stover components have an average moisture content greater than 40%, and baling immediately after grain harvest would be problematic. Linear relationships existed between grain yield and stover yield. Further relationships could be developed for other hybrids and agronomic factors to be used to predict available corn stover from yield maps and would allow for collection based on field slope, soil type, or other variables. The collection efficiency of the various treatments ranged between 32.1% and 94.5%, and stover collected varied between 1.93 and 5.34 t/ha. The bale-only (BO) and rake and bale (RB) treatments resulted in collection efficiencies between 36.4% and 57.2%. The rotary mow, rake, and bale treatment (RC) had collection efficiencies of 65.7% and 32.1% during 2001 and 2002, respectively. The rotary scythe (RS) had the highest collection efficiency (91.3%), although removing that much stover may not be sustainable. The best near-term solution for farmers collecting corn stover was baling the windrow produced when the straw chopper and spreader were disengaged (BW), which resulted in a collection efficiency of 74.1%.

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