RYE COVER CROP AS A SOURCE OF BIOMASS FEEDSTOCK: AN ECONOMIC PERSPECTIVE

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ABSTRACT

As more emphasis is placed on biopower and biofuels, the availability of biomass feedstock is taking center stage. The growth of the biomass feedstock market is further strengthened by the implementation of new regulations and federal programs. One option for biomass feedstock is the removal of cover crops, such as cereal rye. An experiment was initiated to compare three rye residue management techniques (residue retained, residue harvested or removed, and no rye cover control) and four nitrogen fertilizer treatments (0, 45, 90, 125 lb ac^{-1}). Initial findings from this study show that the removal of rye cover crops for biomass feedstock is a viable option for producers, given the assumptions in the study. Further investigation is needed to determine the complete economic impact of removing rye cover crop for biomass feedstock.

INTRODUCTION

Biopower and biofuels are two areas where biomass feedstocks have the potential to provide renewable energy (English, et al, 2006). Recently, two regulations were published that established federal programs that may drive the expansion of the use of biomass feedstock in energy production: the Renewable Fuel Standard Program (RFS2) Final Rule and the Biomass Crop Assistance Program (BCAP).

The United States Environmental Protection Agency (EPA) published the RFS2 Final Rule on March 16, 2010. The final rule set the annual volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel as part of the National Renewable Fuel Standard (RFS) program. The RFS program was required as part of the Energy Independence and Security Act of 2007 (EISA). For 2010, the RFS volume standard is set at 12.95 billion gallons (bg). Each of the specific renewable fuel categories also has volume standards. The required renewable fuel volume increases each year between 2008 and 2022, reaching 36 bg in 2022 (EPA, 2010). Currently, cellulosic ethanol is being produced at facilities focusing on research and development. According to the RFS2 Final Rule, there are over 35 small pilot- and demonstration-level plants in North America (EPA, 2010). This revision to the RFS program strengthens the need for additional sources of biomass feedstock to meet the volume standards.

As part of the Food, Conservation, and Energy Act of 2008, the BCAP provides agricultural and forest land owners and operators with matching payments for collection, harvest, storage and transportation of biomass materials. The biomass materials must be sold to a qualified Biomass Conversion Facility (BCF), which is defined as a certified facility that produces head, power, biobased products, or advanced biofuels. The matching payment is limited to a maximum of $45 dry ton (dt)$^{-1}$ and a two-year payment duration (FSA, 2009). Nationwide, there are over 450 facilities certified as BCFs; however, the type of biomass utilized at each facility is not clearly identified. The BCAP provides a market for a variety of biomass feedstock and a guaranteed price for the short-run.

While there is significant research being conducted on corn stover, switchgrass and, more recently, miscanthus, as biomass feedstock (English et al., 2006; Brechbill and Tyner, 2008; James et al., 2010; Turhollow, 1994), there is limited research on the use of cover crops as biomass feedstock. In the Southeast, cereal rye is a popular winter cover crop and could be harvested for biomass. Therefore, the objective of this study was to estimate the net returns associated with the removal of rye cover crop for biomass in a continuous cotton operation.

MATERIALS AND METHODS

A field experiment was established in November 2005 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center – Field Crops Unit (32^{o} 25' 19" N, 85^{o} 53' 7" W), near Shorter, in central Alabama. The soil was a Marvyn loamy sand (fine-loamy, kaolinitic, thermic Typic Kanhapludult). This area is characterized by a humid subtropical climate, with an average annual precipitation of about 1100 mm (Schomberg et al., 2006).

Three rye residue management treatments were evaluated, which included residue retained, residue harvested or removed, and no rye cover control. The experiment also included four nitrogen fertilizer rates (0, 45, 90, and 125 lb ac^{-1}). Rye (cultivar "Elbon") was drilled at 90 lb ac^{-1} in early November each year using a no-till drill. In the retained treatment, rye was rolled down at the early milk (73) development stage (Zadoks et al., 1974) in late April each year, then sprayed with glyphosate (N-phosphonomethyl glycine) at a rate of 0.8 lb a.i. ac^{-1}. At the same time, rye biomass in the removed treatment was mechanically harvested to a height of 4 inches over the soil surface and removed from the plots. The no cover plots were kept weed free by using herbicide.

In early May each year, the experimental area was tilled in-row with a narrow-shank subsoiler to a depth of 14 inches. The in-row tillage was conducted using a tractor with a Trimble AgGPS Autopilot automatic steering system (Trimble, Sunnyvale, CA 94088), with sub-inch level precision, to avoid compaction of the cotton rows. Cotton was planted during the third week of May each year with a John Deere 1700 MaxEmerge Plus™ (Deere & Co., Moline, IL) air planter with a 40 inch spacing between rows. Cotton was harvested with a spindle-type picker. Other management operations were the same for all treatments.

Net return is driven by two main components: yield and production costs. A partial budgeting approach was used to estimate the change that occurred in farm profit or loss with the addition of a cover crop to the current rotation and varying rates of nitrogen application (Boehlje and Eidman, 1983). This approach allowed for the comparison of costs incurred with either retaining or removing the cover crop. Aside from ginning and hauling costs and nitrogen (N) fertilizer costs, all other cotton production costs were excluded from this study. Fixed costs were not considered and production costs and market prices were held constant at 2009 values (Table 1). Holding prices and costs constant removes variability due to changes in the market. Machinery costs, excluding fuel costs, were based on machinery cost data included in the Mississippi State Budget Generator Version 6.0 (Laughlin and Spurlock, 2008). Fuel and fertilizer costs were from USDA-NASS prices for 2009 (NASS, 2009b). Costs for planting the rye cover crop included the cost of fertilizer and fall application, no-till grain drill, and rye seed.

Herbicide costs, as part of termination, were not included in the study because all treatments, including the no cover crop treatment, received the same application of herbicide. Cover crops were terminated using a roller or a mower/conditioner. Custom application rates were used for fertilizer application, mowing and baling the cover crop, and moving, loading and hauling the biomass (NASS, 2009a; Halich, 2009). It was assumed that the biomass bales were 5 ft x 5 ft and weighed 1200 lbs. The cost of net wrapping was included in the custom rate for the baler. Due to varying production needs throughout the year by potential end users, the bales were assumed to be stored on farm until needed (6 months). The cost to move the bales to the field edge was \$2 ton^{-1}. The bales were loaded on trailers and hauled to the final location. Assuming a 40 mile trip, the cost for loading was \$1.15 ton^{-1} and the cost for hauling was \$6.80 $bale^{-1}$. The market value of cotton lint and cottonseed produced was included in net return as part of the revenue calculation. The price for cotton lint and cottonseed (\$0.64 lb^{-1} and \$129 ton^{-1}, respectively) were the Alabama marketing year average prices received by farmers in 2009 (NASS, 2009b). The biomass price assumed in this study was \$50 ton^{-1}. Reductions in fertilizer needs due to the cover crop or soil erosion resulting from the removal of the cover crop were not accounted for in this study.

The experiment was a randomized split-plot design with four replications. Cotton lint yields and net returns were analyzed using SAS PROC MIXED (SAS Institute, 2008). Replications were treated as a random effect, and cover crop management (RM) and nitrogen fertilizer rate (N) as fixed effects. There was a significant interaction between year and treatments; therefore, cotton lint yield and net returns were analyzed within each year. Significant differences and mean comparisons were based on Fisher's protected LSD at a 5% probability level (α=0.05).

RESULTS AND DISCUSSION

Table 1 lists the treatment effects of cover crop management and N fertilizer rates on cotton lint yields and net returns. For the purposes of this study, cotton lint yields are discussed only as they relate to potential changes (positive and negative) in net returns. Across all four years, cotton lint yields were numerically highest where the rye cover crop was retained in the field and where fertilizer rates were 90 lb ac^{-1} or above. In 2006, the cotton lint yields for all cover crop management treatments were not significant (P-value = 0.0768). For 2007, 2008, and 2009, the cotton lint yields for all cover crop management treatments were significant, with the retention of the rye cover crop being significantly higher than the removal of the rye cover crop in 2008 and 2009. With regard to N fertilizer rates, cotton lint yields at 90 lb ac^{-1} and 125 lb ac^{-1} were the highest, with 125 lb ac^{-1} being significantly higher in 2006 and 2009. Figure 1 displays the average biomass removed per year. There is variability in the biomass yield each year due to weather conditions in the fall and winter.

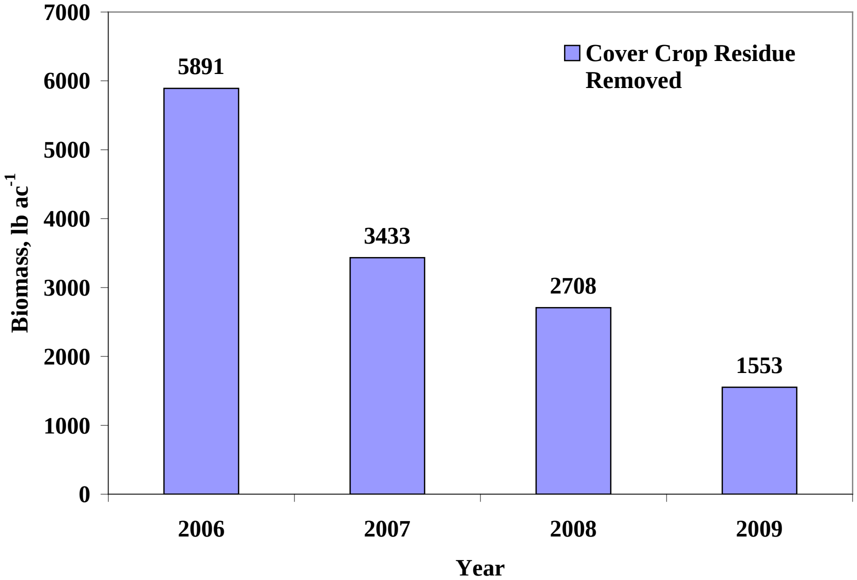

Figure 1. Rye biomass removed during the 2006, 2007, 2008, and 2009 growing seasons at the E.V. Smith Research Center in Shorter, Alabama.

For 2006, 2008, and 2009, net returns for cover crop management treatments were not significant (P-value = 0.1762, 0.0883, and 0.0647, respectively). In 2007, the net return for the removal of the rye cover crop was the highest ($420.58 ac^{-1}), but was not significantly different from the net return for the retention of the rye cover crop ($411.51 ac^{-1}). For N fertilizer rate treatments, net returns were significant for all years. In all four years, there was no significant difference between the net returns from 90 lb ac^{-1} and 125 lb ac^{-1}. In 2007 and 2008, there was no significant difference between the net returns from 45 lb ac^{-1}, 90 lb ac^{-1}, and 125 lb ac^{-1}.

As cotton yields increase, net returns increase, assuming constant production costs; however, increases and decreases in net returns were driven by changes in yields, both for cotton and biomass, and production costs associated with the cover crop and cotton. For cover crop management treatments, cover crop production costs were the highest for the removal of the rye cover crop and the lowest for no cover crop. The amount of biomass removed directly impacts the cover crop production costs. Cotton yields also influence production costs through the increase or decrease in ginning and hauling costs, which were calculated by the pound of cotton lint. Increasing N fertilizer rates also change the production costs and any additional revenue is dependent on the potential increase in revenue from yield being greater then the increase in fertilizer costs. Other cotton production costs may change with increases or decreases in yield, such as machinery efficiency; however, these costs were not included in this preliminary study.

In 2006, cotton lint yields and net returns responded significantly to cover crop management and N fertilizer rate treatments (Table 2). The removal of rye residue with zero lb ac^{-1} and 125 lb ac^{-1} of N fertilizer produced the lowest yield (576 lb ac^{-1}) and the highest yield (1345 lb ac^{-1}), respectively (Figure 2). When the rye cover crop was retained, the cotton lint yield differed by 20.9 lb ac^{-1} from the yield associated with the removal of the rye cover crop, and was not statistically different. Yields observed at the 90 lb ac^{-1} N fertilizer rate were not statically different across all cover crop management treatments. As expected, when no N fertilizer was applied, cotton lint yields were the lowest across all cover crop management treatments.

Even with higher cover crop production costs, the removal of the cover crop had the highest net return at 45, 90, and 125 lb ac^{-1} of N fertilizer (Figure 3). The net return associated with the removal of cover crop residue is dependent on the ability to sell the biomass at a price that covers increased production costs or to have a contract with an end user that covers production costs, including transportation costs. Production costs for the removal of the cover crop exceeds the cost of retaining the residue by \$24.89 ac^{-1}, excluding moving, loading and hauling biomass.

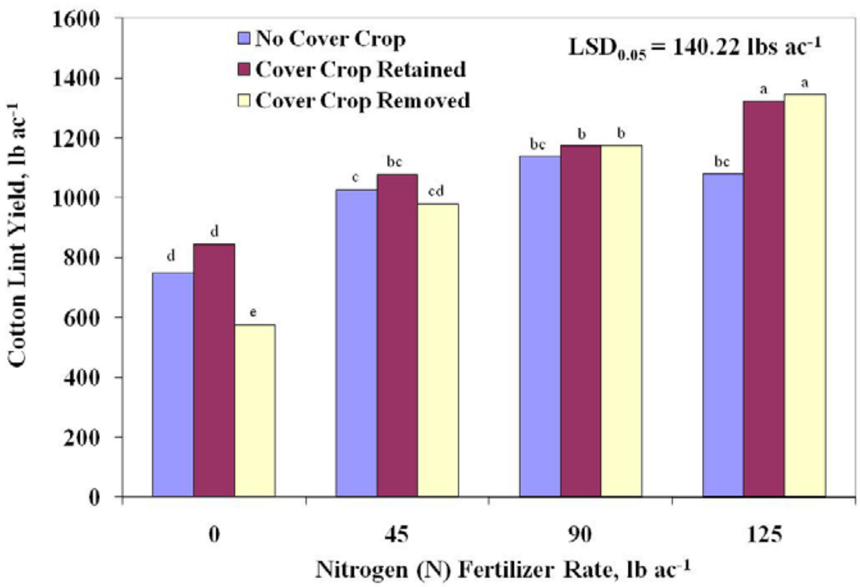

Figure 2. Cotton lint yields following a combination of cover crop management and nitrogen fertilizer rate treatments during the 2006 growing seasons at the E.V. Smith Research Center in Shorter, Alabama. Different letters denote statistical significance between treatments.

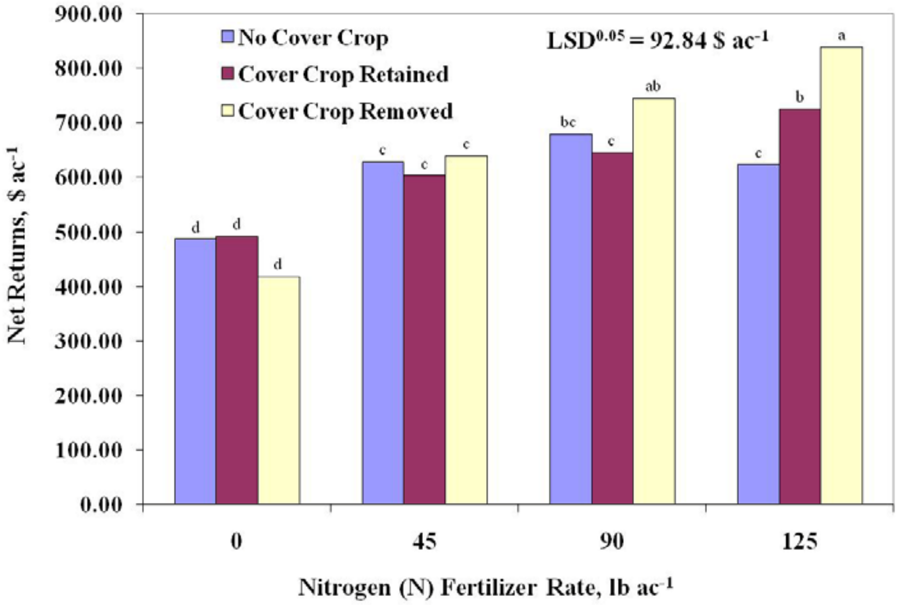

Figure 3. Net returns following a combination of cover crop management and nitrogen fertilizer rate treatments during the 2006 growing seasons at the E.V. Smith Research Center in Shorter, Alabama.

CONCLUSION

Cotton lint yields and net returns responded to cover crop management and N fertilizer rates. Depending on year, net returns were largest for the retention of rye cover crop or the removal of rye cover crop for biomass feedstock. Based on the assumptions in this study, harvesting rye cover crop for biomass feedstock is a viable option. Additional analysis will be performed to determine the magnitude of change in the results due to changes in the basic assumptions.

Disclaimer

Mention of a company name or trademark does not constitute endorsement by the United States Department of Agriculture or the Agricultural Research Service to the exclusion of others.

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TABLES

Table 1. Cost of cover crop management and fertilizer nitrogen (N) rate treatments.†

Production Item	Cover Crop Retained	Cover Crop Removed	
	-----------------------$\$\ \text{ac}^{-1}$-----------------------		
Application of fertilizer for cover crop, including fertilizer	20.00	20.00	
Cover crop establishment, including seed and no-till grain drill	34.72	34.72	
Roller	2.91	NA‡	
Custom mowing/conditioning	NA	12.10	
Custom raking	NA	5.70	
Custom baling large round bales with net wrap	NA	10.00	
Custom moving and loading round bales, $\$\ \text{Ton}^{-1}$	NA	3.15	
Custom hauling round bales, $\$\ \text{Bale}^{-1}$	NA	6.80	
	Nitrogen (N) Fertilizer Rate		
	-----------------------lb ac^{-1}-----------------------		
	45	**90**	**125**
	-----------------------$\$\ \text{ac}^{-1}$-----------------------		
Application of N fertilizer for cotton, including fertilizer	40.15	62.20	79.35

† Costs include material costs and variable costs of application. Fixed costs of application are not included in the costs.
‡ Not applicable to the treatment option.

Table 2. Cotton Lint Yields and Net Returns for cover crop management and nitrogen (N) fertilizer rates for the 2006, 2007, 2008 and 2009 growing seasons at the E.V. Smith Research Station in Shorter, Alabama.† ‡

	Cotton Lint Yields				Net Returns			
	2006	2007	2008	2009	2006	2007	2008	2009
Cover Crop Management	--------------------------lb ac^{-1}	--------------------------			--------------------------$ ac^{-1}	--------------------------		
No Cover Crop	998.4	616.8	914.5	854.4	604.44	356.06	549.79	500.62
Rye Cover Crop Retained	1104.9	790.6	1115.7	1005.6	616.08	411.51	623.10	541.40
Rye Cover Crop Removed	1019.0	722.7	999.1	867.1	659.94	420.58	586.75	468.96
$LSD_{0.05}$	NS‡	74.5	106.1	85.8	NS	54.10	NS	NS
Fertilizer Nitrogen (N) Rate								
0 lb ac^{-1} N	723.1	521.9	741.4	848.6	465.48	318.99	457.31	479.63
45 lb ac^{-1} N	1027.2	715.7	1038.5	810.7	623.24	405.01	610.53	454.97
90 lb ac^{-1} N	1163.1	784.1	1155.7	957.1	689.65	427.48	664.76	528.18
125 lb ac^{-1} N	1249.8	818.5	1103.4	1019.8	728.92	432.73	613.58	551.86
$LSD_{0.05}$	76.3	61.0	93.3	58.1	49.67	39.68	60.74	37.84
Analysis of Variance (P>F)								
Cover Crop Management	0.0768	0.0036	0.0101	0.0089	0.1762	0.0439	0.0883	0.0647
Nitrogen Rate	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cover Crop Management X Nitrogen Rate	0.0018	0.8364	0.0708	0.3653	0.0018	0.8364	0.0708	0.3653

† Net Returns are calculated as total revenue from cotton lint, cottonseed, and biomass minus cover crop establishment and harvest costs, N fertilizer costs associated with cotton, and ginning and hauling costs.

‡ Not significant at the 0.05 level of probability.