Sustainable Feedstock Supplies for Bioenergy Production

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Introduction

To support emerging cellulosic bioenergy operations such as the POET-DSM Project Liberty™ near Emmetsburg, Iowa, and the DuPont Cellulosic Ethanol operation near Nevada, Iowa, field research coordinated by ARS-NLAE scientists has been conducted at the Agricultural Engineering/Agronomy Research Farm (AEA) since 2008. The initial research focused on continuous corn production with no, moderate, and high rates of corn stover harvest. All stover removal has been done using single-pass technology developed by Stuart Birrell, Agricultural and BioSystems Engineering Department. The initial study included 1) comparisons of chisel-plow and no-tillage management for each of the stover harvest treatments using standard nutrient management and plant populations; 2) an intensive corn management system using a twin-row planting configuration to increase plant population and higher nutrient inputs to support those plants; 3) two rates of biochar applied to offset carbon removal associated with stover harvest; 4) corn with an annual cover crop; and 5) corn with a perennial cover crop [white clover (*Trifolium repens*)]. Corn grain and stover yields, nutrient removal, changes in soil organic carbon content, and effects of the management practices on several soil health indicators were measured on an annual basis. The objective was to provide the emerging cellulosic bioenergy industry guidelines for sustainable harvest of corn stover.

Methods and Materials

The study is being carried out within Field 70/71 at the ISU AEA Farm. The five management systems were imposed using a randomized complete block design with each treatment replicated four times. Tillage, planting, fertilization, and weed control were carried out using standard ISU recommendations.

Commercial corn hybrids (Pioneer Brand 36V75 in 2008, 2009, and 2010; Pioneer Brand P0461xr in 2011, 2012, and 2013; and Pioneer Brand P0407 AMXT in 2014, 2015, and 2016) have been planted in three-year cycles in late April or early May each year. Grain and stover harvest have occurred between September and November, depending on crop maturity and weather patterns.

Lime, phosphorus, potassium, and micro-nutrients were applied based on ISU soil-test recommendations. Nutrient removal was determined by collecting whole-plant corn samples between physiologic maturity and combine harvest from 1.5 m^2 areas within each plot. Plant samples were separated into four components: 1) vegetative material from the ear shank upward (top), 2) vegetative material from approximately 10 cm above the soil surface to just below the ear (bottom), 3) cobs, and 4) grain. Weights for the non-grain components were summed to estimate the above-ground biomass associated with each plant fraction. Oven dry grain weights were divided by the sum of grain plus dry non-grain plant fractions to estimate the harvest index (HI). Plant tissue samples were dried, ground, and analyzed for P, K, Ca, Mg, Na, S, Al, B, Cu, Fe, Mn, and Zn concentrations using an ICP (inductively-coupled plasma) and for C and N using dry combustion. SAS Version 9.3 was used to compute mean yields.

Results and Discussion

Corn grain and stover yields of select rotations for the past eight years are presented in Table 1. The perennial cover crop rotation was dropped, because with current corn production practices, the clover was shaded out/died and had to be replanted annually, which made the rotation non-economical. Severe drought significantly reduced 2012 yields, but with improved nutrient management, hybrids, and other cultural practices, overall yields have been increasing even without surface tillage. Non-traditional crop rotations and cover crop mixtures are being evaluated to improve soil physical health. Stover harvest increased fertilizer replacement cost by \$27.60, \$22.10, and \$18.30 for top, bottom, and cob fractions, respectively (data not presented). Detailed assessments of soil fertility and soil health changes associated with stover harvest, tillage, and crop rotation treatments are being carried out and will be summarized in future reports. With good soil and crop management, corn stover harvest is a viable operation for Iowa and investments in bioenergy and other bio-products should be pursued.

Table 1. Tillage and stover harvest effects on crop yield for 2008–2013 and 2014–2015.

2008-2013 corn	**No stover removal**		**Moderate harvest**		**Low-cut (high rate)**	
Treatment	**Chisel**	**No-till**	**Chisel**	**No-till**	**Chisel**	**No-till**
			Grain (bu/acre)			
Standard (Control)	151	153	172	164	171	172
Twin-row	157	155	174	172	174	168
BioChar 1	151	—	174	—	173	
BioChar 2	163	—	169	—	177	—
Annual cover crop	—	—	165	—	173	—
			Stover (tons/acre)			
Standard	—	—	1.67	1.69	2.57	2.65
Twin-row	—	—	1.94	1.99	2.78	2.70
BioChar 1	—	—	1.77	—	2.55	—
BioChar 2	—	—	1.86	—	2.66	—
Annual cover crop	—	—	1.62	—	2.65	—
			2014 and 2015 grain (bu/acre)			
Standard (Control)	179	—	198	188	198	189
1st yr corn	—	—	—	—	—	198
2nd yr corn	—	—	—	—	—	187
Soybean (2015)	—	—	—	65	—	64