cenusa bioenergy

Quarterly Progress Report

Agro-ecosystem Approach
to Sustainable Biofuels Production via
the Pyrolysis-Biochar Platform

April 2015

Agriculture and Food Research Initiative Competitive Grant
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LEGAL NOTICE

Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform (AFRI-CAP 2010-05073)

Quarterly Report: November 1, 2014 – January 31, 2015

Project Administration

- **Project Organization and Governance**

Ken Moore (Professor, Iowa State University) continues as the CenUSA Bioenergy Project Director with Anne Kinzel as the Chief Operating Officer. Jill Cornelis (ISU Bioeconomy Institute) provides assistance with project financial matters.

- **Commercialization Objective**

The work on the new Commercialization Objective continues to progress as anticipated and is on track. Additional details are available in the Commercialization Objective update.

- **CenUSA Bioenergy Advisory Board**

Our Advisory Board continues to be a real force for CenUSA. We have featured several members of the Advisory Board in our BLADES newsletter and expect to continue to do so throughout Year 4. We anticipate a strong turnout from the Advisory Board for our 2015 annual meeting based on preliminary information from board members.

- **Executive Team Meetings and CenUSA Research Seminar**

The Co-Project directors representing each of the ten project objectives continue to meet monthly with Ken Moore and Anne Kinzel via online meetings held in CenUSA's dedicated Adobe Connect meeting room. The virtual meeting room allows for documents to be viewed by all participants, enhancing communications and dialogue between participants. Tom Binder, the Advisory Board chair also attends these meetings, to ensure there is an Advisory Board presence during these important project gatherings.

Beginning in February 2015 we will host a monthly Graduate Seminar immediately following the Executive Team meetings. The Seminars will feature a panel of CenUSA personnel discussing "mildly" controversial topics geared towards spurring interaction between students, CenUSA faculty personnel and Advisory Board members.

- **2015 CenUSA Annual Meeting**

We have started the planning process for the 2015 CenUSA 2014 annual meeting. The meeting will be held at the University of Wisconsin, Madison July 28 – 29. Our host will be Dr. Michael Casler (ARS Madison/University of Wisconsin). The focus will be on CenUSA graduate and undergraduate students. The agenda provides significant opportunities for interaction between CenUSA Advisory Board members, CenUSA personnel and our graduate and undergraduate students. Student participation has been favorably received at previous annual meetings and we will build on those past interactions.

- **Communications**

Our Communications Team continues to focus on the strategy we devised in early 2014 to make the project more visible among the biofuels/bio-products research community, commercial firms and the interested public. The key elements of the plan include: a bimonthly newsletter, BLADES; social media: Twitter (@CenUSABioenergy) and Facebook (https://www.facebook.com/CenusaBioenergy), a project website (www.cenusa.iastate.edu); and the video sites Vimeo (https://vimeo.com/cenusabioenergy) and YouTube (https://www.youtube.com/user/CenusaBioenergy).

- **BLADES.** We continue to publish our virtual bimonthly newsletter BLADES (see http://cenusa.iastate.edu/news-and-events). Our goal is to provide information to members of the interested public in articles with a length of 400-600 words. In the second quarter we published a November 2014. BLADES circulation has increased to 750 subscribers (up from 650 in the last quarter). Our "click-through rate averages 26% which exceeds the educational industry average (9.2%)

  ✓ **November 2014 Articles**

  - CenUSA looks for a new batch of summer interns.
  - A producer's viewpoint – John Weis
  - 2015 - A turning point in the bioeconomy
  - CenUSA website 101

- **Twitter and Facebook**

  We continue to experience steady growth on both sites. We have started using a new hashtag "#GrassAcademy" on our Twitter site. We are exploring the use of additional hashtags to feature perennial grass commercialization activities.

  Our Twitter account is approaching 500 followers whom we have segmented it into lists to better manage the account.

- **CenUSA Website**

The redesign of the website is proceeding on target. We anticipate launching our new website in early February 2015. With the addition of a revamped website we anticipate that we will be able to drive additional traffic to our Vimeo and YouTube pages.

- **Financial Matters**

  The Administrative Team continues to monitor all project budgets and subcontracts to ensure adherence to all sponsor budgeting rules and requirements. We will also be working to implement the new Commercialization Objective budget.

Germplasm to Harvest

Objective 1. Feedstock Development

Feedstock Development focuses on developing perennial grass cultivars and hybrids that can be used on marginal cropland in the Central United States for the production of biomass for energy. In 2014, the focus is on the establishment of new breeding and evaluation trials.

1. **Accomplishments Summary**

   - In evaluations of current varieties and experimental populations of switchgrass in five CenUSA varietal trial locations, resistance to rust in certain varieties/populations was found to vary markedly among locations suggesting strong environmental influences on expression of rust resistance.

   - *Uromyces graminicola* was found to cause rust in switchgrass only in certain CenUSA varietal trial locations (Nebraska and Wisconsin), whereas *Puccinia emaculata* was found in all of the 5 locations examined, indicating a more restricted geographic distribution for the former species. Switchgrass varieties and populations planted in Nebraska varied in relative levels of infection by the two rust species.

2. **Planned Activities**

   - **Breeding and Genetics – ARS-Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**

     ✓ Begin grinding and scanning 2014 biomass samples.

     ✓ Oversee data organization and sample processing from 24 field trials planted at remote locations.

     ✓ Thresh and clean seed of all new switchgrass and big bluestem populations.

- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria and Akwasi Boateng – ARS Wyndmoor)**

  ✓ Measure behavior of ground and pelletized samples for grinding to finer particle sizes using a hammer mill.

  ✓ Analyze additional switchgrass sample set supplied by Mike Casler for ester and ether linked ferulates.

  ✓ Evaluate pelletized samples for enzymatic sugar conversion using low moisture ammonium pretreatment.

  ✓ Continue preparing and analyzing data for new publications

  ✓ Analyze new grass samples on the py-GC/MS.

- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**

  ✓ Complete assessment of rust severity in switchgrass samples submitted by collaborators in the CenUSA varietal trial.

  ✓ Determine the relative frequency at which the two rust pathogens of *Puccinia emaculata* and *Uromyces graminicola* infect switchgrass planted in different locations across the north central states.

  ✓ Begin choice studies in the greenhouse to determine if greenbugs show a feeding or ovipositional preference among switchgrass, big bluestem and Indiangrass.

  ✓ Being electronic feeding monitoring studies to characterize yellow sugarcane aphid feeding on big bluestem and Indiangrass.

3. **Actual Accomplishments**

- **Breeding and Genetics – Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**

  ✓ We are halfway finished with grinding 2014 biomass samples.

  ✓ We have compiled about half of the 2014 biomass data from the field trials.

  ✓ All switchgrass seed has been threshed, cleaned, weighed, and germinated for 2015 trials.

  ✓ We have just started processing big bluestem seed lots.

- **Feedback Quality Analysis (Bruce Dien and Akwasi Boateng)**
  - ✓ Pelletized material was ground with a hammer mill, the energy for grinding measured, and distribution measured. This was done for pelletized samples on small and pilot scale. Ground unpelleted samples will be completed in the next report period.
  - ✓ The sample set supplied by Mike Casler has been analyzed for ester and ether linked ferulates and the data has been shared and is in the process of being analyzed.
  - ✓ Pelletized and unpelletized samples have been compared for enzymatic sugar conversion using low moisture ammonium pretreatment.
  - ✓ Provided data to Mike Casler of pyrolysis product results determined by py-GC/MS and mineral content determined by ICP for calibration of NIR.
  - ✓ Prepared new grass samples for analysis on py-GC/MS.
  - ✓ Prepared bulk ground pelletized switchgrass for pilot scale pyrolysis.
- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Preliminary choice studies are underway to determine if greenbugs show a feeding or ovipositional preference among switchgrass, big bluestem and indiangrass.
  - ✓ Electronic feeding monitoring studies are complete for yellow sugarcane aphid and greenbugs on switchgrass. The two aphids showed different feeding behaviors between when feeding upon resistant and susceptible switchgrasses. Electronic feeding monitoring studies are underway to characterize yellow sugarcane aphid feeding on big bluestem and indiangrass.
  - ✓ All samples for characterizing the arthropods associated with switchgrass have been processed.
  - ✓ Rust disease severity was rated on a 1 (lowest) to 10 (highest) scale in switchgrass leaf samples collected from 20-22 varieties planted at five locations of the CENUSA varietal trials (Urbana, IL; West Lafayette, Indiana; Columbia, Missouri; Mead, Nebraska; Arlington, Wisconsin). Rust levels varied among the locations with the highest levels (ratings >7) found in Columbia, MO and Urbana, IL. The response of varieties to rust differed between the two locations, with several varieties exhibiting a ‘susceptible’ response in Columbia, MO while exhibiting ‘resistant’ to ‘highly

resistant' responses in Urbana, IL. All varieties appeared moderately to highly resistant in the other 3 locations.

- ✓ The species of fungi were identified from leaf sample collected from the four of the five varietal trial locations. *Puccinia emaculata* was detected in samples from all four sites. *Uromyces graminicola* was found only in samples from Mead, Nebraska and Arlington, Wisconsin. Leaf samples from Mead, Nebraska for used in determining the relative frequency of infection by each fungus, based on numbers of its telia (teliospore-producing pustules). In 11 out 22 varieties, 100% of the telia were those of P. emaculata. The remaining 11 varieties were infected by both rust species, with the percentage of telia belonging to *U. graminicola* varied from 1 to 62%.

4. Explanation of Variances

None to report.

5. Plans for Next Quarter

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**
  - ✓ Finish grinding and scanning 2014 biomass samples.
  - ✓ Finish collection of 2014 biomass data from 13 locations.
  - ✓ Thresh and clean seed of all new big bluestem populations.
  - ✓ Make final preparations for 2015 field season.
- **Feedstock Quality Analysis (Bruce Dien and Akwasi Boateng)**
  - ✓ NCAUR has received 88 new biomass samples from Mike Casler and Rob Mitchell. These samples will be analyzed for soluble sugars, starch, and moisture contents.
  - ✓ The pelletized and unpelletized switchgrass sample set will be analyzed for enzymatic sugar release following liquid hot-water pretreatment.
  - ✓ Titer new commercial cellulases and hemicellulases preparations on hot-water pretreated switchgrass for preparation to screen next group of biomass samples.
  - ✓ Analyze new grass samples on the py-GC/MS and perform ICP analysis for mineral content
  - ✓ Perform pilot scale pyrolysis on pelletized switchgrass
  - ✓ Continue to analyze data for publications

- **Pathology and Entomology (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Complete choice studies to determine if greenbugs show a feeding or ovipositional preference among switchgrass, big bluestem and indiangrass.
  - ✓ Complete electronic feeding monitoring studies are underway to characterize yellow sugarcane aphid feeding on big bluestem and indiangrass.
  - ✓ Complete statistical analysis of switchgrass rust severity data collected from five CenUSA varietal trial locations.
  - ✓ Complete identification of rust species in switchgrass leaf samples from five CenUSA varietal trial locations.
  - ✓ Derive ITS DNA sequences from Nebraska and Wisconsin strains of *Uromyces graminicola*. This information, which is critical for the genetic identification of this rust species, currently is absent from all genetic databases.

6. Publications / Presentations/Proposals Submitted

- Submitted
  - ✓ Koch, K., T. Heng-Moss, & J. Bradshaw. 2014. Comparative feeding behavior of cereal aphids on switchgrass, Panicum virgatum L. Entomological Society of America, Nov. 19, 2014, Portland, OR. https://esa.confex.com/esa/2014/webprogram/Paper86938.html
  - ✓ Stewart C.L., J.D. Pyle, K.P. Vogel, G.Y. Yuen, & K.G. Scholthof. Multi-year pathogen survey of biofuel switchgrass breeding plots reveals high prevalence of infections by Panicum mosaic virus and its satellite virus. Phytopathology. Submitted Dec. 1, 2014.
- **Published**
  - ✓ Casler, M.D. and K.P. Vogel. 2014. Selection for biomass yield in upland, lowland, and hybrid switchgrass. Crop Sci. 54:626-636.
  - ✓ Vogel, K.P., R.B. Mitchell, M.D. Casler, & G. Sarath. (2014). Registration of 'Liberty' switchgrass. J. Plant Registr. 8:242-247.
  - ✓ Stewart, C.L. 2014. Panicum Mosaic Virus Complex and Biofuels Switchgrass. M.S. Thesis, University of Nebraska-Lincoln.

Objective 2. Sustainable Feedstock Production Systems

The Sustainable Feedstock Production Systems objective focuses on conducting comparative analyses of the productivity potential and the environmental impacts of the most promising perennial grass bioenergy crops and management systems using a network of 14 fields strategically located across the Central United States. The overarching goal is to produce a quantitative assessment of the net energy balance of candidate systems and to optimize perennial feedstock production and ecosystem services on marginally productive cropland while maintaining food production on prime land.

- **Iowa State University**

  Following are updates of on-going field and laboratory research at the Ames location, also included is a summary of results (2008-2012) for long-term field trials receiving biochar and residue harvesting treatments.

  - **2014 Biomass Yields on CenUSA System Plots, Armstrong Research and Demonstration Farm.** End-of-season biomass was collected from the switchgrass and low diversity grass plots on November 11, 2014. No biomass was collected from the high diversity plots, which were mowed in late August to control for weeds. There were no significant differences in sown species yield between the two plant treatments, with or without biochar application. On average, plots yielded 7.3 Mg ha^{-1} sown biomass. There was a slight tendency for switchgrass plots to contain fewer weeds ($P = 0.10$), but on average each plot contained 2.7 Mg ha^{-1} weedy biomass. These data suggest that by the end of the third growing season, switchgrass and low diversity grass plots yield similar amounts of sown and weedy biomass and that biochar has no effects on yield or weed biomass.

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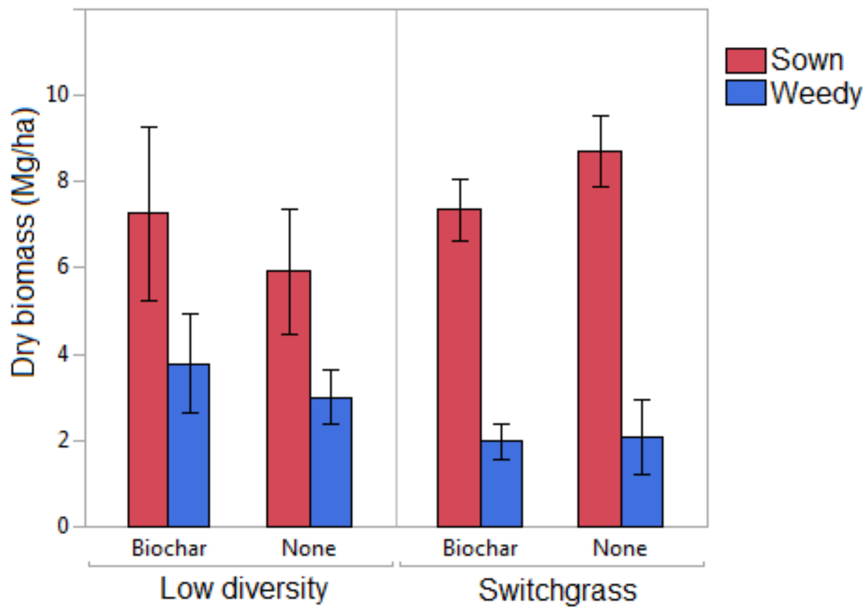

Fig. 1. Impact of biomass system and biochar on yield of biomass (sown) and weeds.

- **Greenhouse Gas Emissions from biochar amended soils (a laboratory incubation study).** We completed a 140-day laboratory incubation study. The study investigated whether or not carbonate minerals that are typically mixed with biochar and/or labile organic compounds that are commonly adsorbed on biochar surfaces contribute to greenhouse gas (CO_2) emissions from biochar-amended soils. For the study, soil from the Armstrong Research and Demonstration Farm (Exira silty clay loam) was mixed with, and incubated with, corn stover and mixed wood biochars (CS5f and MW6g, respectively), which had been subjected to various treatments (Table 1). These treatments were designed to remove carbonates (*acid-insoluble*) and labile organic compounds (*bicarbonate-insoluble*) from the biochars before they were incubated with the soil, and to add any organic compounds that were extracted from the biochars back into the soil (*acid-soluble* and *bicarbonate-soluble*). The results demonstrate that organic compounds extracted from biochar using a bicarbonate solution are readily mineralized and turned into CO_2 by soil microbes when they are added back to the soil. But the results also suggest that as long as those labile compounds remain adsorbed on the biochar that their availability to soil microbes is limited. Removing carbonate minerals from the biochar before incubation had little effect on CO_2 emissions, suggesting little contribution of the carbonate minerals to CO_2 emissions. The results are important for understanding how and why biochar amendments influence greenhouse gas emissions from soils, and suggest that increases in CO_2 emissions following biochar amendments due to labile compounds adsorbed on biochar surfaces may not persist over long periods of time.

Table 1. Soil treatments used in incubation experiment

Treatment	Description
C0	Control (no amendment)
C1	Carbonate added in amount equivalent to CS5f
C2	Carbonate added in amount equivalent to MW6g
EaCS5f	Acid extract of CS5f
EbCS5f	Bicarbonate extract of CS5f
CS5fWu	Untreated CS5f
CS5fWa	Acid washed CS5f
CS5fWb	Acid and bicarbonate washed CS5f
EaMW6g	Acid extract of MW6g
EbMW6g	Bicarbonate extract of MW6g
MW6gWu	Untreated MW6g
MW6gWa	Acid washed MW6g
MW6gWb	Acid and bicarbonate washed MW6g

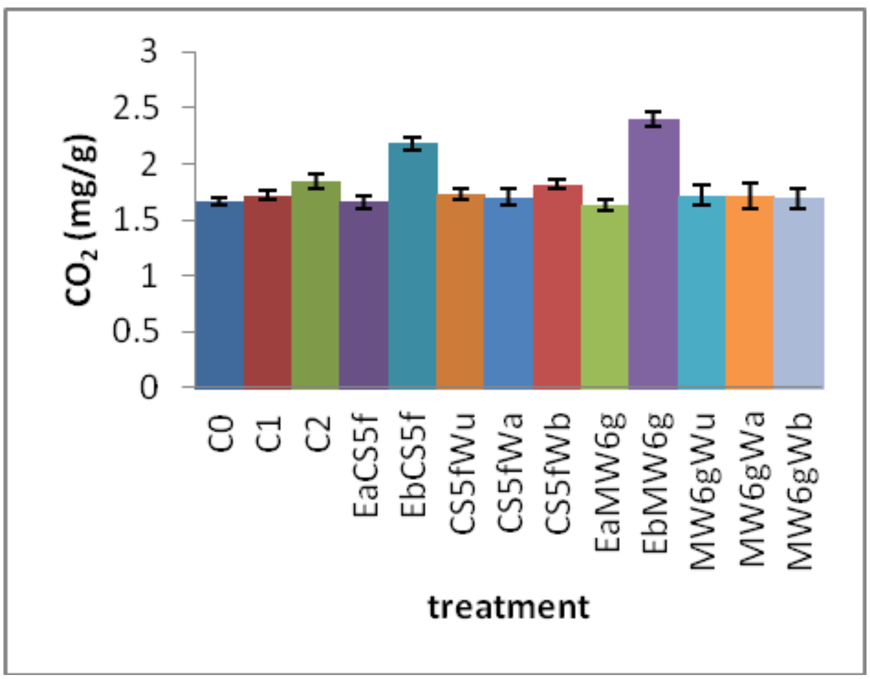

Fig. 2. Cumulative CO_2 emissions during 60-day equilibration period.

- **Biochar Impacts on Potential Mineralizable Nitrogen.** Much of the N fertility that supports plant growth comes from mineralization of soil organic matter. Several studies suggest that biochar may influence N dynamics in soils. In a new study we are testing whether biochar amendments influence Potential Mineralizable Nitrogen (PMN). Soil samples collected from multiple biochar field trials are being analyzed for PMN in laboratory incubations. The impacts of cropping systems, residue removal and rate and depth of biochar incorporation are factors being considered in this study. The research is ongoing at this time.

- **Update of Activities on the Long Term Rotation Plots (Sorenson Farm).** Physical property analyses were recently completed on 208 intact soil cores collected from the long-term rotation plots in Spring 2014. The data includes solute transport (chemical breakthrough curves), saturated hydraulic conductivity (Ksat), bulk density, porosity, and gravity drained water content. Data are still being organized and statistical analyses are pending. Analysis of the chemical properties of soil from cores is ongoing. Analyses include pH (leachate), electrical conductivity of leachate, total carbon, total nitrogen and C/N ratio of the soil, cation exchange capacity (CEC) and anion exchange capacity (AEC). Preliminary Results averaged across treatments for the first 168 out of 208 total cores are shown below. Statistical analysis of the complete data set is on-going.

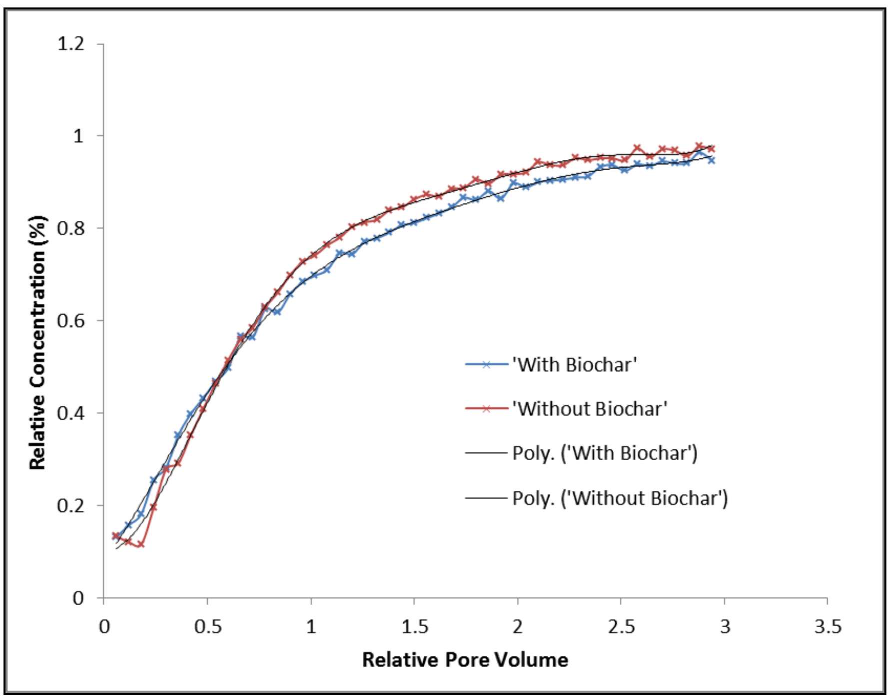

Fig. 3. Averaged chemical breakthrough curves show effects of biochar amendments on ion transport. Statistical analysis is pending.

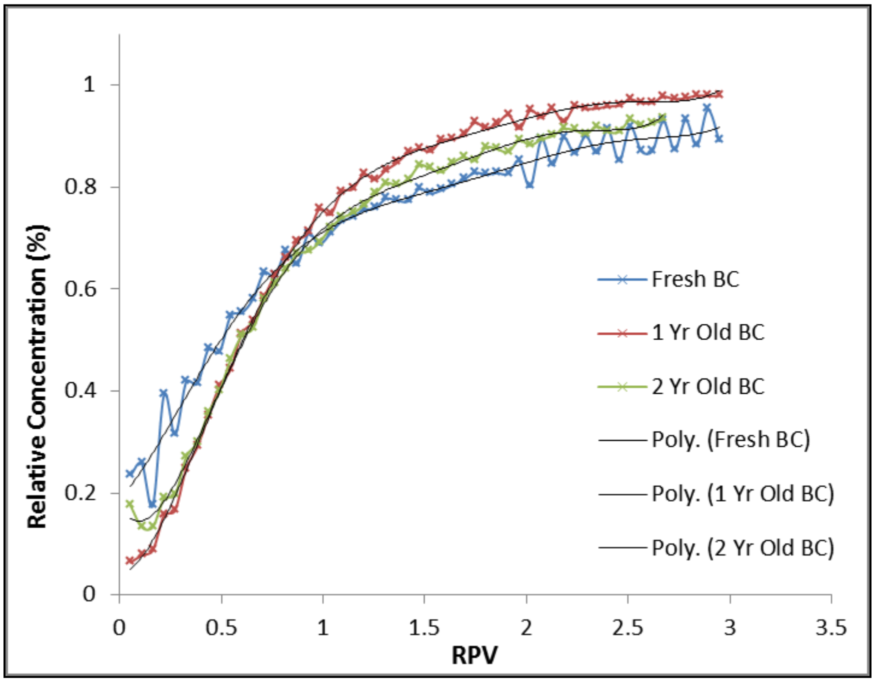

Fig. 4. Averaged chemical breakthrough curves show effects of biochar aging (time since incorporation into soil) on ion transport. Statistical analysis is pending.

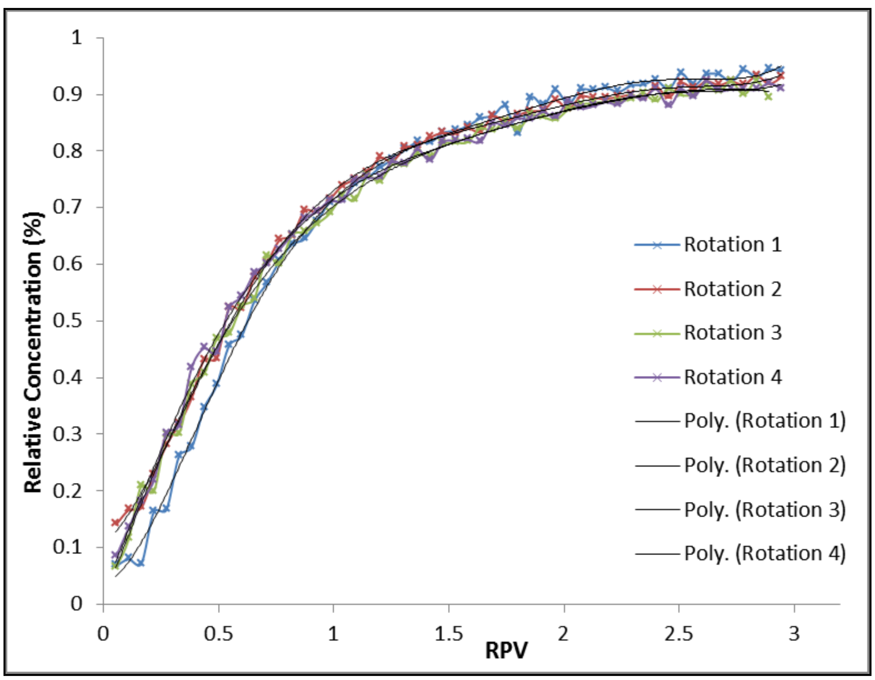

Fig. 5. Averaged chemical breakthrough curves show effects of crop rotations on ion transport. (Rotation 1 = CCCCCC, Rotation 2 =CSCSCS, Rotation 3 = CST/SCST/S, rotation 4 = CCCSgSgSg; where C=corn, S=soybeans, T=triticale, and Sg=switchgrass). Statistical analysis is pending.

- **Summary of findings (2008-2012) for long-term biochar and residue removal field trials.** A long-term field plot experiment partially supported by CenUSA is assessing the impact of residue removal and a onetime biochar application on soil quality parameters and yield of continuous corn. The hypothesis being tested is that biochar amendments will increase the sustainability of long-term biomass harvesting.

  Slow pyrolysis hardwood biochar was surface applied in the rates of 0 (Control), 9.9 (C1), and 18.4 T/Ha (C2) in the fall of 2007 on large field plots (0.11 ha each) at the Iowa State University Agriculture and the Agriculture Engineering Research Farm in Boone County, Iowa. The biochar was incorporated to the depth of about 20 cm by chisel plow tillage. Starting in the spring of 2008 plots were planted to continuous corn and conventionally managed. Starting in the fall of 2008, various corn stover removal treatments (nominally referred to as 0, 50, and 100%) were imposed on the plots which resulted in nine biochar rate- by - residue removal treatment-combinations, each replicated four times, for a total of 36 plots. The "0% residue removal" indicates that all biomass, with the exception of the grain was left on the soil surface. The "50% residue removal" indicates that upper half of the plant just below the corn ear was removed together with grain using a single-pass harvesting technique. The "90% residue removal" identifies management practice where corn plant was cut 15 cm above the soil surface and harvested along with grain.

  Fertilization practices were based on the results of annual surface soil testing (P and K) and interpretation using Iowa State University Extension and Outreach recommendations (ISU, 2013). Base fertilization rates were adjusted for the amount of nutrients removed with residue harvest. In the 2010 growing season a set of soil measurements was performed to evaluate the impact of biochar additions and residue removal on soil physical properties three years after the biochar application. Measurements included bulk density estimations and aggregate size distribution from compacted and uncompacted rows, Mehlick III nutrients, soil pH, and ECEC.

  Corn grain and biomass was harvested with a John Deere 9750 STS dual-stream single-pass harvesting system, where a modified combine collects grain and stover and separates them into two different harvest streams. Yield of grain was adjusted to 13% moisture content, where biomass yields are presented on the dry-matter basis.

  ✓ **Mehlich III.** Soil testing performed three years post biochar application showed no significant difference in Ca, Cu, Fe, K, Mg, Mn, P, S, and Zn content (data not shown). Biochar itself has very limited amounts of available nutrients and thus was not effective in increasing nutrient content of soil. Two-year residue removal had a significant impact only on soil Zn and S content (Figure 6). Averaged across biochar treatments, 90% residue removal treatment resulted in significantly greater S content

(6.62 mg kg^{-1}) than 50% residue removal (4.6 mg kg^{-1}). Similarly for Zn, 90% residue removal resulted in significantly greater Zn content (2.06 mg kg^{-1}) than 50% residue removal (1.57 mg kg^{-1}). The increased S content may reflect greater application rates of S for 90% residue removal treatment (16 vs 27 kg ha^{-1}) compared to 0% residue removed. It is not clear why residue removal Mehlich III extractable Zn in the soil.

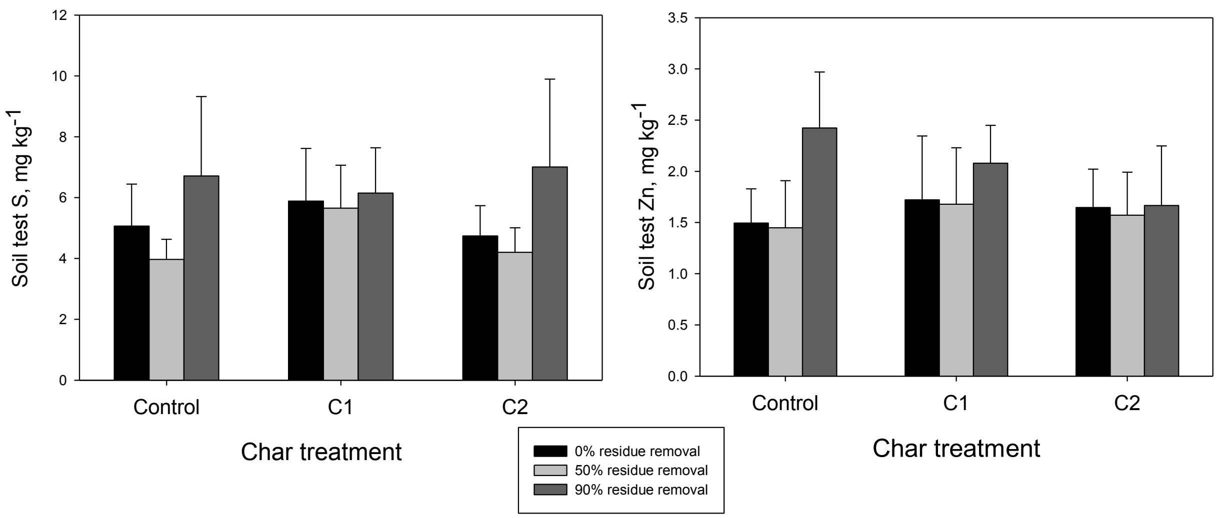

Fig. 6. Effect of biochar application and continues residue removal (0, 50, and 90% residues removed continuously for three years) on soil test S and Zn three years after biochar application. Residue removal had significant effect on soil test S and Zn.

- ✓ **Soil pH.** Significant soil pH variability was observed between plots before initiation of the experiment and those differences remained after biochar and residue removal treatments were imposed (Figure 7). The pH values for all but absolute control (No biochar, 0% residue removed) increased about 0.5 pH units from 2007 to 2008, after which soil pH gradually declined until 2011 when lime was applied in the rate of 2.2 ton ha^{-1} to all plots. The general decline in soil pH with time reflects the effects of acidifying effect of N-fertilizer and biomass removal. The slight increase in pH observed in 2008 might reflect seasonal pH variation due to different sampling times; in 2008 plots were sampled on Aug 1st, whereas in 2007 and other years sampling was mid to late November. It is not uncommon to observe seasonal variation of pH to up to 2 units.

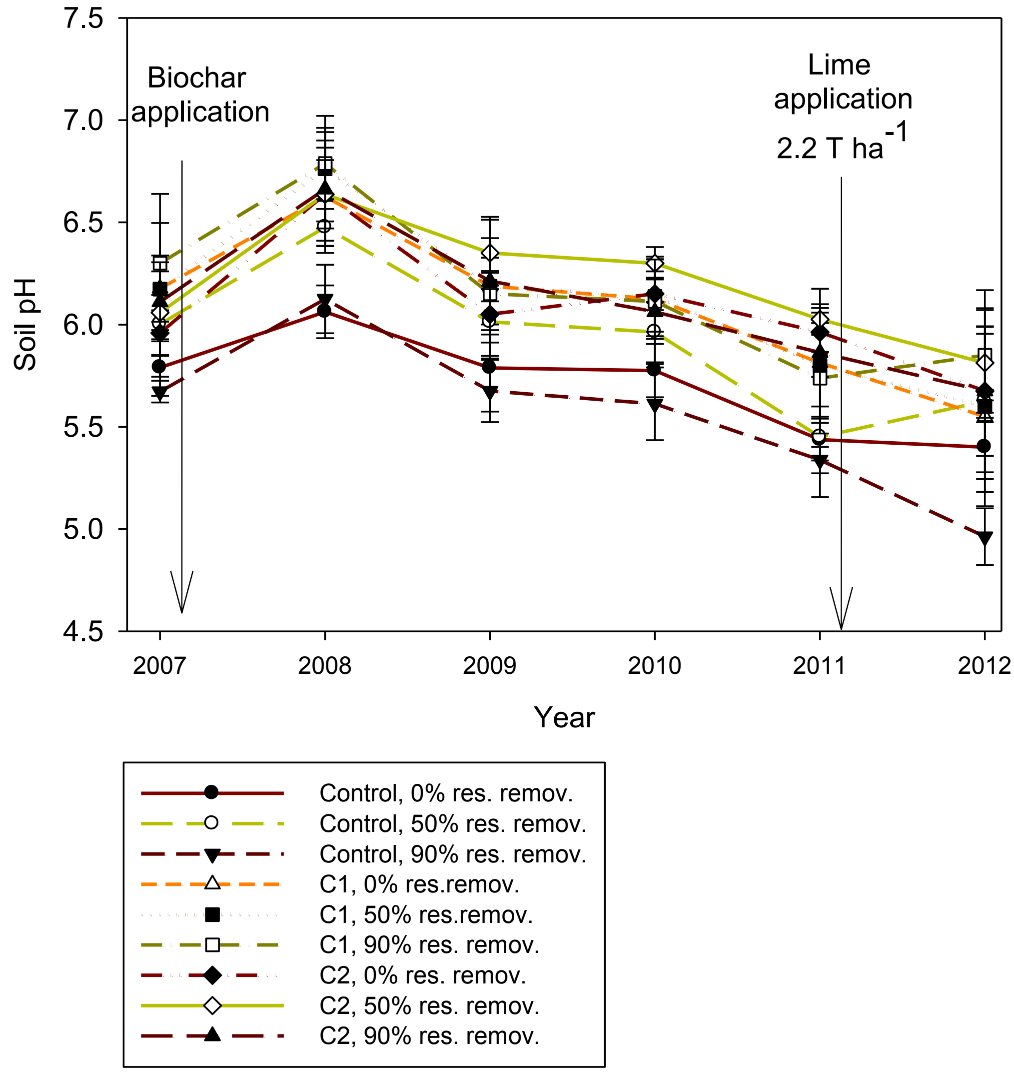

Fig. 7. Temporal change in soil pH as related to biochar amendment and residue removal. Significant variability in pH was observed before the biochar application in 2007.

- ✓ **Soil Bulk Density.** Soil bulk density was measured in the summer of 2010 from two rows per plot; one row was subjected to repeated machinery traffic (traffic), whereas other was not (no traffic). Neither residue removal nor biochar application had an effect on bulk density (Figure 8). Significant differences in bulk density were observed only between trafficked and untrafficked rows.

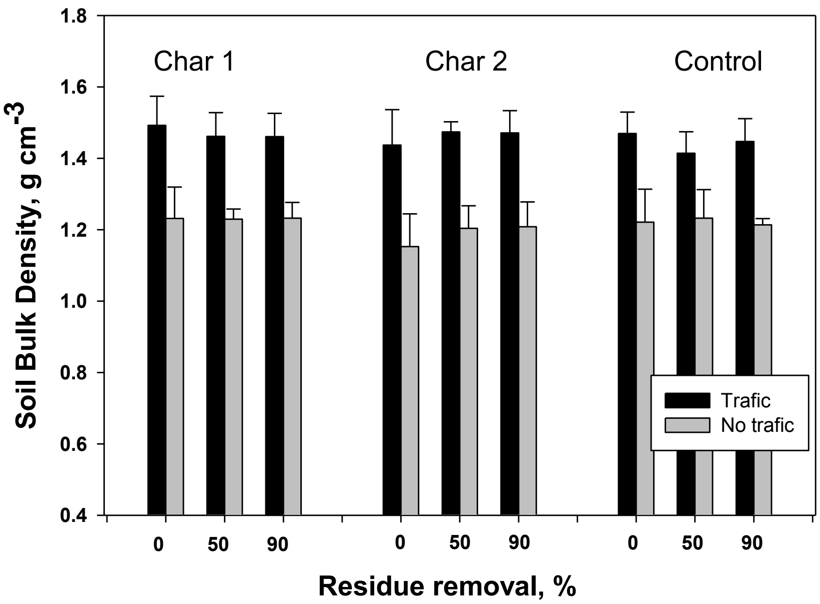

Fig. 8. Effect of biochar application (Char 1, Char 2, and Control), residue removal (0, 50, and 90%) and repeated traffic on soil bulk density measured three years after biochar application. Compaction imposed by repeated traffic was the only factor significantly impacted bulk density.

- ✓ **Aggregate Size.** One time biochar application did not affect aggregate size distribution. Above ground residue removal (90%) in 2008 and 2009 resulted in significantly smaller aggregates measured during the growing season of 2010. This difference was observed only in rows that had repeated traffic (Figure 9). In those rows, 90% residue removal resulted in decrease of median aggregate diameter from 0.32 to 0.28mm (0% residue removed).

- ✓ **Biomass Removed.** The amount of residues harvested during the 2009-2012 years reflects the amount of rainfall during growing season (Table 2). The average rainfall amounts during growing season (April-August) for the study site ranged from 37 cm in 2012 to 92.7 cm in 2010. The 25-year average for this location is 59.3 cm (s = 18.7). In 2010, plots had excessive rainfall amounts, which increased the risk of nutrient leaching and runoff, whereas 2012 was characterized by widespread drought.

  Averaged across biochar treatments, amount of residue removed from 50% and 90% treatments were significantly greater in 2009 and 2011 then in 2010 and 2012. On average, 4.1 and 7.2 Mg ha^{-1} residues were harvested in 2009 from 50% and 90% treatments, respectively, which is 20 and 44% greater residue harvested from those treatments than in 2010, and 21 and 34% greater than in 2012. Biomass harvest was not recorded in 2008 – the first year of study.

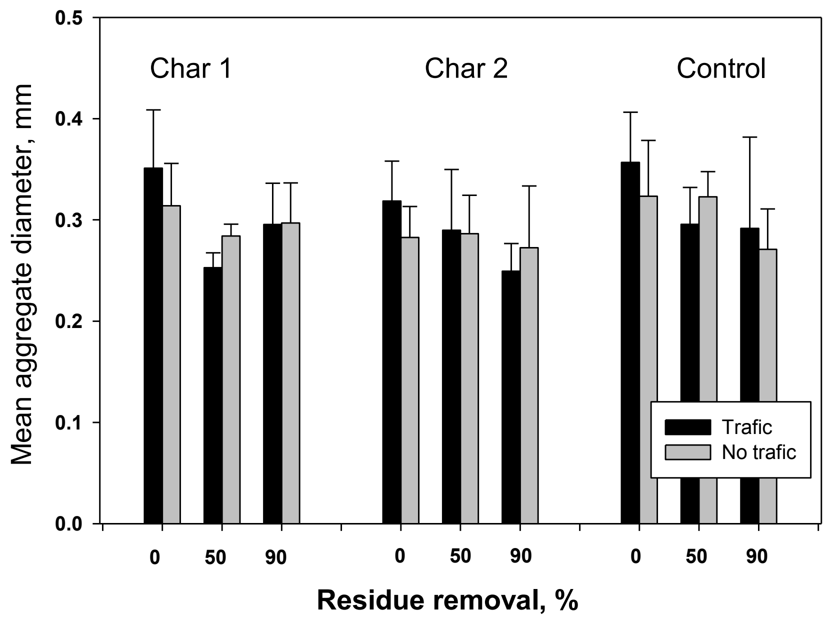

Fig. 9. Effect of biochar application, residue removal, and repeated traffic on mean aggregate diameter measured three years after biochar application and two years of residue removal. Residue removal significantly impacted mean diameter only in areas with repeated traffic.

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Table 2. Amount of residue removed each year (Mg ha^{-1}) averaged across 4 replications. Numbers in parenthesis denote standard deviation. Biomass harvested was not recorded in 2008. Averaged across biochar treatments, residue removed from 50% and 90% treatments were significantly greater in 2009 and 2011 than in other two years.

Year/*Apr-Aug rainfall, cm**		**Residue removed, Mg ha^{-1}**	
	Biochar trt	50%	90%
2009	Control	3.9 (0.4)**	7.7 (1.3)
51.5	C1	4.3 (1.1)	6.8 (0.5)
	C2	4.1 (1.2)	7.1 (0.2)
2010	Control	2.9 (1.0)	3.7 (0.7)
92.7	C1	3.1 (0.3)	4.6 (0.4)
	C2	3.9 (1.2)	7.0 (1.1)
2011	Control	3.9 (0.5)	6.3 (0.9)
55.4	C1	4.0 (0.4)	6.2 (1.0)
	C2	3.8 (0.31)	6.4 (0.6)
2012	Control	3.4 (0.7)	4.0 (0.5)
37.1	C1	3.0 (0.5)	4.3 (0.75)
	C2	3.3 (0.4)	5.7 (1.0)

*25-year average for this location is 59.3 cm, st. dev. 18.7cm
**Means followed by standard deviation in parenthesis.

- ✓ **Grain Yield.** There was no yield difference between biochar treatments in 2008 – the first year after biochar application. Biochar has limited fertilization effect therefore significant yield increases were not expected in the Midwestern Mollisols. Residue removal treatment was implemented during the harvest of 2008 and the significant yield differences were observed the next growing season; 50 and 90% residue removal resulted in 2 to 3.7 Mg ha-1 yield increase over no residue removal treatment (Figure 10). In 2010 the yield difference decreased to 0.15 – 1.7 Mg ha-1 and in 2011 and 2012 there was no significant difference between residue removal treatments for plots that received biochar (C1 and C2). Low grain yields in 2012 partly reflected unfavorable drought conditions during growing season.

Considerable yield gain in the plots that had partial or full residue removal rates reflects a short term SOM mineralization trend that supplied additional N and other nutrients to the maize plants. Another explanation of yield increase in plots with residue removal is absence of negative effects of allelopathy. Decomposing residue releases phytotoxic compounds capable of reducing yields of the next year crop, thus, removing residues can significantly improve maize yield in monoculture. The presence of biochar particles in soil seem to mitigate the negative effects of allelopathy as evidenced by smaller or no difference in grain yield observed between residue removals treatments for the plots amended with biochar.

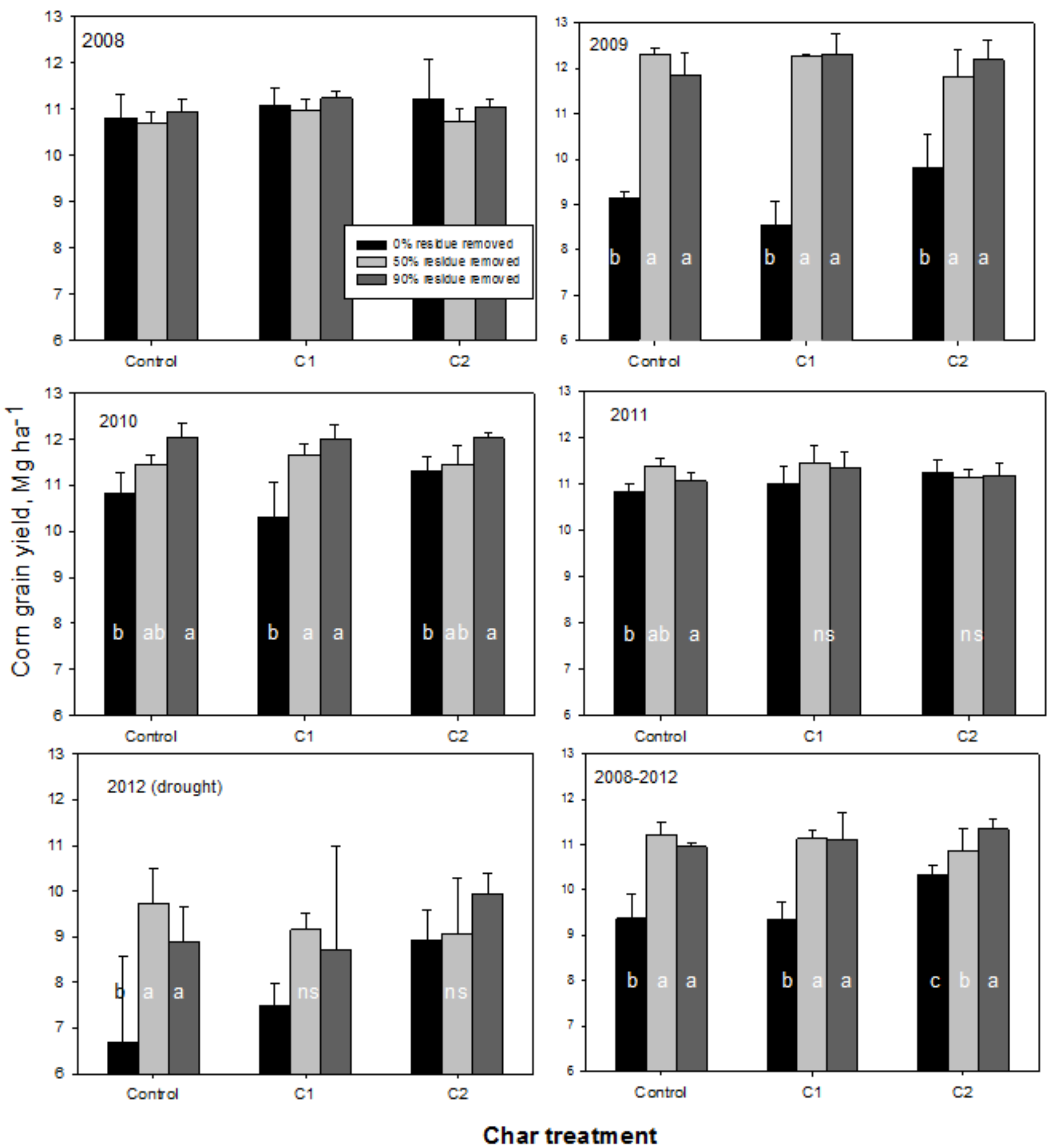

Fig. 10. Maize grain yield (Mg ha^{-1}) differences among treatments. Different letters define significant differences in yield within biochar treatments.

- **Purdue University**

Biomass harvesting, drying, and sample processing have been the primary focus of the work this quarter. A summary of biomass yield from our network of trials is provided below. Sample processing continues and analysis is commencing.

Table 3. Impact of long-term phosphorus (P) and potassium (K) fertilization on biomass yield of Shawnee switchgrass in 2014 at Throckmorton Purdue Agricultural Center. Yields are expressed in kg dry matter/ha ± standard error of the mean. There was no effect of P (P=0.54) or K (P=0.55) on switchgrass yield, and the P x K interaction on yield also was not significant (P=0.68). As in previous years, switchgrass yields are high irrespective of soil P and K levels. Soil test P and K analyses are underway as are tissue test P and K concentrations.

	Historic K Fertilizer Rate, kg K/ha/yr				
Historic P Fert. Rate, kg P/ha/yr	0	100	200	300	400
0	9673 ± 879	9386 ± 785	10427 ± 896	11256 ± 626	9833 ± 827
25	10331 ± 825	10151 ± 486	10351 ± 451	9256 ± 410	9752 ± 824
50	9724 ± 1087	9403 ± 765	10075 ± 510	10244 ± 710	9856 ± 253
75	10212 ± 788	8979 ± 662	9300 ± 462	9937 ± 1044	9816 ± 977

Table 4. Biomass yield (kg/ha) of Liberty switchgrass, Miscanthus x giganteus, and a big bluestem-indiangrass prairie grown on three marginal soils on Purdue Agricultural Centers (PACs) in Indiana. All three species had the highest biomass yield at Throckmorton PAC; the least marginal of these sites. The Southeast PAC site is a landfill overburden and all species, but especially Liberty switchgrass had large yield reductions relative to Throckmorton. Average over all sites, Miscanthus has double the yield of switchgrass, and four-fold greater biomass than the big bluestem-Indiangrass prairie.

Species	Throckmorton PAC	Northeast PAC	Southeast PAC	Mean
Liberty Switchgrass	13517	11799	3047	9454
Miscanthus	26868	15503	12908	18426
Big bluestem-Indiangrass	7744	3755	2170	4556
Species x Location LSD (0.05)=4841				

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Table 5. Biomass yield (kg/ha) of Liberty switchgrass, Miscanthus x giganteus, dual-purpose biomass sorghum, and maize (control) on an eroded, marginal hillside at Throckmorton Purdue Agricultural Center in 2013 and 2014. Liberty switchgrass yields were consistent both years averaging 13,515 kg/ha, and were over twice that of Miscanthus, the other perennial grass in this study. Sorghum was the highest yielding species in the study averaging nearly 19,000 kg/ha, over three time the yield of maize, the other annual species in the experiment.

Species	2013	2014	Mean
Liberty Switchgrass	13983	13047	13515
Sorghum	5566	7611	6589
Miscanthus	15860	21832	18846
Maize	2079	7437	4758
	Year x Species LSD (0.05)=2451		

Table 6. Biomass yield (kg/ha) and biomass moisture concentration at the Systems Analysis plots located at the Water Quality Field Station in 2014. The unmanaged native prairie had the lowest biomass production that was approximately half that of Shawnee switchgrass. Miscanthus has the highest biomass production. Maize biomass production was approximately 50% greater than that of dual-purpose sorghum. Moisture concentration was lowest in maize (218 or 21.8%), highest in sorghum, with the other systems intermediate (around 300 g/kg or 30%). The high water content of the sorghum is probably due to it being adapted to the longer growing season found in TX where it was developed. A regionally adapted (e.g., for the corn belt) biomass sorghum would likely have matured and dried down in a fashion resembling maize.

Species	**Biomass Yield, kg DM/ha**	**Biomass Moisture, g H_2O/kg**
Shawnee Switchgrass	5810	273
Miscanthus x g	22015	343
Native prairie	2316	308
Dual-purpose sorghum	10334	584
Maize	17507	218
LSD (0.05)	2558	27

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Table 7. Sorghum biomass production on marginal soils generally exceeded that of maize. At TPAC the N x Biomass System interaction was not significant indicating a consistent response of all systems to added N fertilizer. The N rate and System main effects were significant. The photoperiod-sensitive sorghum produced approximately twice the biomass of maize irrespective on N rate. Sweet sorghum also was productive at this location, especially under 0 and 50 kg N/ha N rates. At NEPAC, all systems had statistically similar yields at 0 kg N/ha, whereas yields of the photoperiod-sensitive sorghum generally surpassed that of the other systems at 100 kg N/ha and higher N rates. The N rate x Biomass System interaction also was significant at SEPAC. Maize yield did not increase with N fertilizer application whereas biomass of all three sorghums increased significantly with N fertilization. The least significant difference (LSD) is provided for significant interaction effects.

		Yield (kg/ha) of Biomass Production System			
Location	**N Fertilizer Applied, kg N/ha**	**Maize**	**Dual-purpose Sorghum**	**Photoperiod-sensitive Sorghum**	**Sweet Sorghum**
Throckmorton Purdue Agricultural Center (TPAC)	0	4337±1190	6661 ± 785	12111 ± 1377	12074 ± 735
	50	4942 ± 1117	7539 ± 819	12688 ± 3461	10723 ± 2232
	100	8519 ± 1506	11007 ± 756	17220 ± 2243	14665 ± 1961
	150	7621 ± 2689	10186 ± 1605	17063 ± 665	12674 ± 2278
	200	9794 ± 1682	10211 ± 1259	17353 ± 1185	13553 ± 1048
		System x N Rate Interaction at TPAC was Not Significant (Standard Errors provided as an Estimate of Variation; 2x Std Error=95% CI)			
Northeast Purdue Agricultural Center (NEPAC)	0	2544	1311	1221	487
	50	4437	5927	7595	2265
	100	4469	7666	11567	7032
	150	12569	7908	12712	9441
	200	9434	7308	14424	8370
		System x N Rate Interaction at NEPAC LSD (0.10)=3258			
Southeast Purdue Agricultural Center (SEPAC)	0	2027	4889	6415	7440
	50	2776	6910	11241	12443
	100	3317	8698	11602	11187
	150	3120	9719	14647	13956
	200	4079	8295	16416	13237
		System x N Rate Interaction at SEPAC LSD (0.05)=2769			

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Table 8. Application of N fertilizer to Shawnee switchgrass to soils that had received long-term differential application of P and K fertilizer tended to increase biomass (means and std. errors) at Throckmorton Purdue Agricultural Center. The N rate x PK fertility interaction was not significant; however, the N rate main effect was nearly significant (P=0.12); likewise, the P rate main effect is approaching statistical significance (P=0.17).

N Applied, kg N/ha	Historic P and K Applications (1997-2004)			
	0 kg P/ha 0 kg K/ha	0 kg P/ha 400 kg K/ha	75 kg P/ha 0 kg K/ha	75 kg P/ha 400 kg K/ha
0	9845 ± 1059	10091 ± 426	9541 ± 482	9984 ± 339
50	10935 ± 390	11338 ± 397	10713 ± 559	10047 ± 375
100	10474 ± 437	10953 ± 194	10521 ± 265	10084 ± 198
150	10725 ± 511	9863 ± 745	10861 ± 463	9506 ± 698

Table 9. Application of N and P/K significantly influenced yield of Miscanthus at Throckmorton Purdue Agricultural Center. The N rate main effect was highly significant (P=0.001) as was the N rate x PK application interaction. This interaction resulted from greater yield responses to N in soils fertilized with P and K.

	Application Rates of P and K Fertilizer	
N Fertilizer Application, kg N/ha	0 kg P/ha-0 kg K/ha	75 kg P/ha-300 kg K/ha
0	25808	22999
50	28445	29150
100	27611	30345
150	29147	31534
	N rate x PK Application Interaction LSD (0.05)=2952	

We have been developing methods to improve identification of marginal lands suitable for bioenergy crop production. We have evaluated the method of an 8-digit HUC watershed in Indiana. Currently we are using the method to delineate suitable marginal lands in the Upper Mississippi River basin. We have also developed a baseline SWAT model for the Upper Mississippi River basin. We plan to use the model to evaluate hydrologic and water quality impacts of growing bioenergy crops in the marginal areas identified above in the next quarter.

- **University of Illinois Urbana-Champaign**
  - **Factor Analysis Plots**
    - ✓ Biomass was harvested on August 28, 2014 for the H1 (post anthesis stage) harvest treatment and on December 1, 2014 for the H2 (after killing frost) and H3 (alternate

H1 and H2) treatments. Dry matter was determined for all samples and biomass yield was determined for all treatments (Figure 11 and 12).

- ✓ Currently, we are grinding all subsamples for chemical composition and fiber analysis.

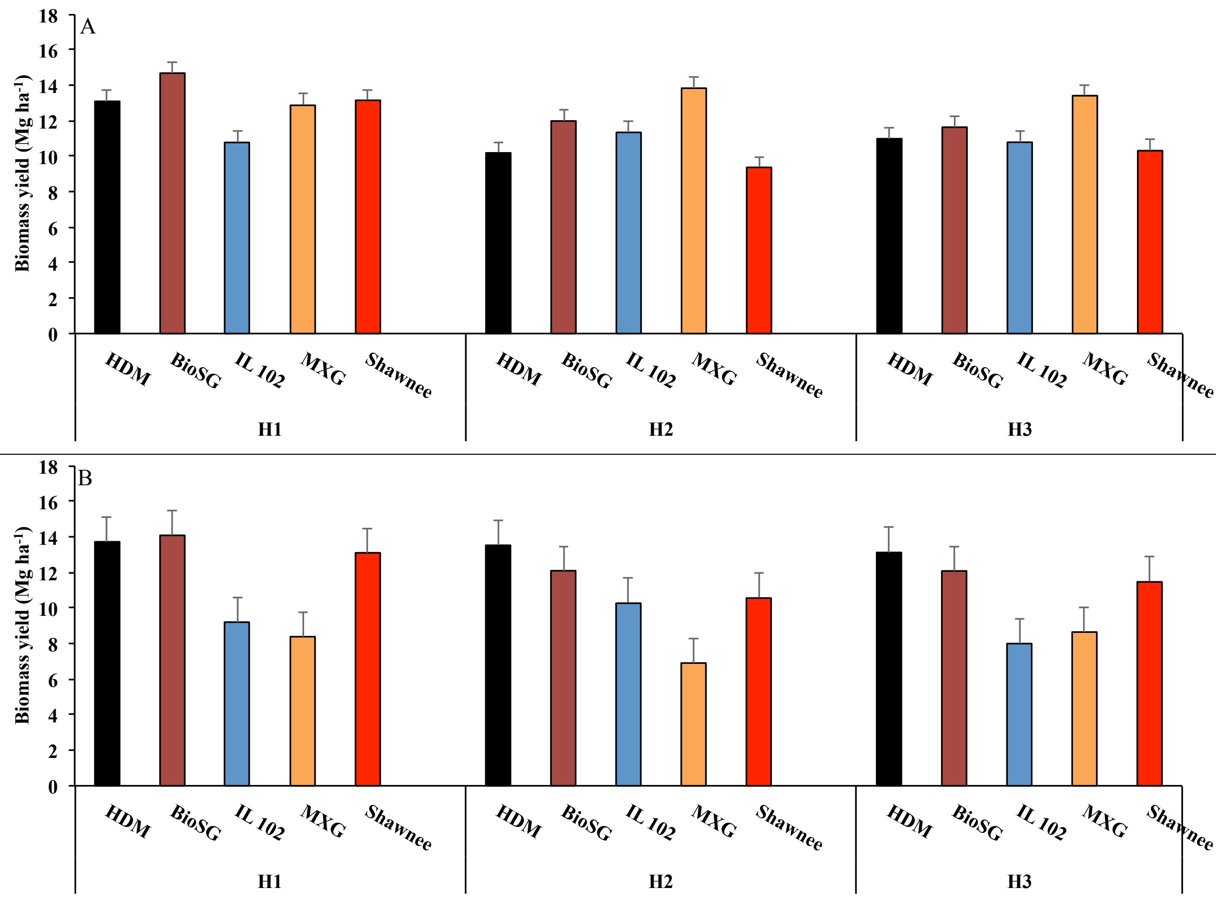

Fig. 11. Effects of harvest timing (H1: post anthesis stage, H2: after killing frost, H3: alternate H1 and H2) on biomass yield of High diversity mixture (HDM), Bioenergy switchgrass (BioSG), 'Savoy' Prairie cordgrass (Savoy), Miscanthus x giganteus (MXG), and 'Shawnee' switchgrass (Shawnee) grown on wet marginal land in Urbana, IL. Biomass yield was averaged across N rates. Two field plots were planted on May 2012 (A) and May 2013 (B), respectively. The first biomass was harvested in 2014.

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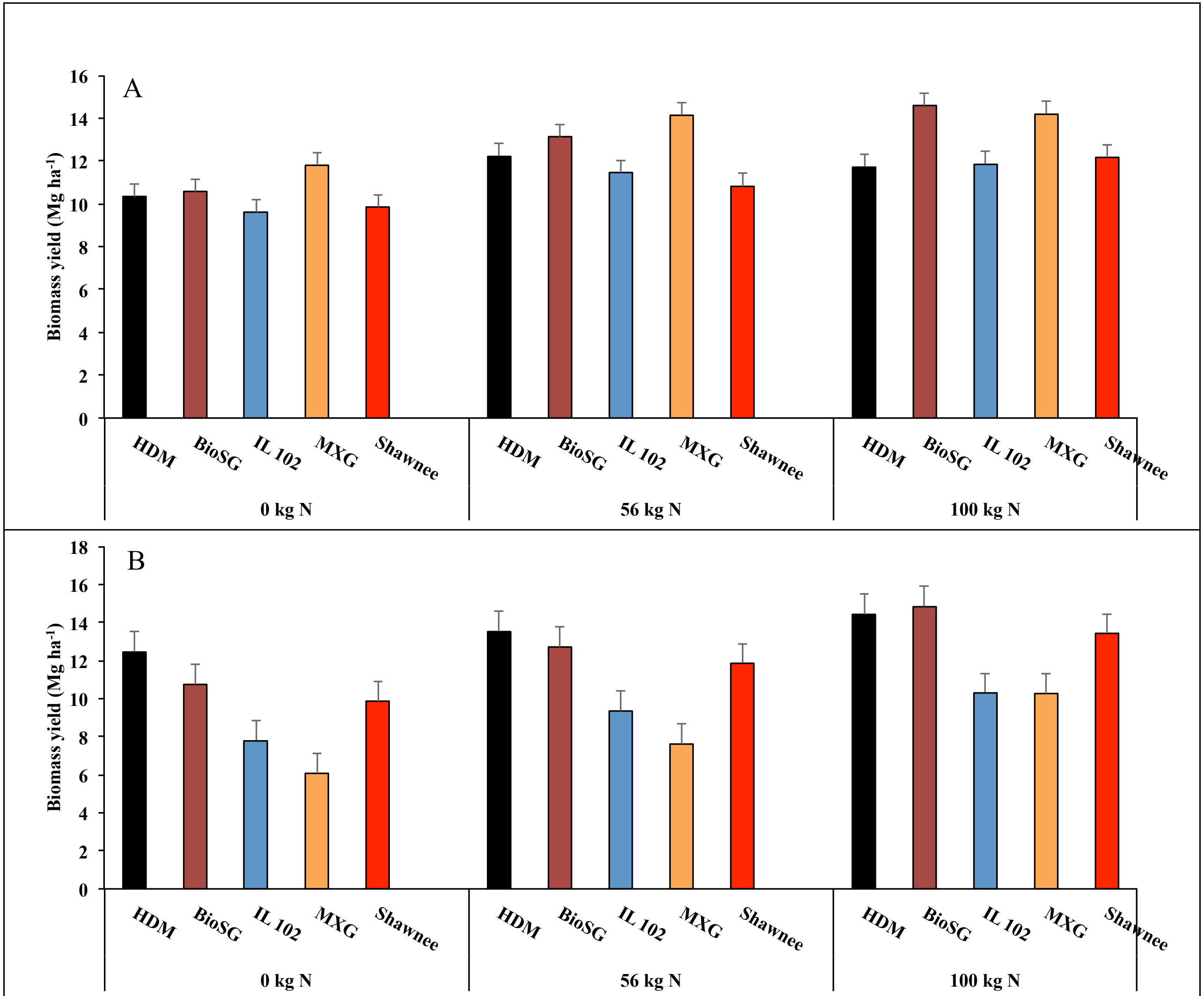

Fig. 12. Effects of N rate on biomass yield of High diversity mixture (HDM), Bioenergy switchgrass (BioSG), 'Savoy' Prairie cordgrass (Savoy), Miscanthus x giganteus (MXG), and 'Shawnee' switchgrass (Shawnee), grown on wet marginal land. Two field plots were planted on May 2012 (A) and May 2013 (B), respectively. The first biomass was harvested in 2014.

- **Comparison Field Trial**

  ✓ Plant height and light interception data were measured until the end of August 2014 in the comparison field trial of Kanlow switchgrass (SW), IL ecotype big bluestem (BB), four populations of prairie cordgrass (20-107, 46-102, 17-109, 17-104), and Miscanthus x giganteus (Mxg).

  ✓ The plots were harvested on November 13, 2014 and biomass samples were collected.

- ✓ The 4-year (2011-2014) field data collection has been completed. Currently, we are compiling all field and laboratory data to compare yield potential and feedstock quality of four species grown on wet marginal land.

- **Abiotic Stress Trial**

  - ✓ Biomass was harvested on for prairie cordgrass (17-109 and PCG-109) and switchgrass (Kanlow) grown on salt-affected soil (EC>20 dS m-1) in Salem, Illinois and on two poorly drained soils in Pana, Illinois and Urbana, Illinois on November 24, 2014.
  - ✓ Samples were collected at harvest and dry matter yield was determined (Figure 13).
  - ✓ Currently, we are grinding tissue samples for chemical composition and fiber content analysis.

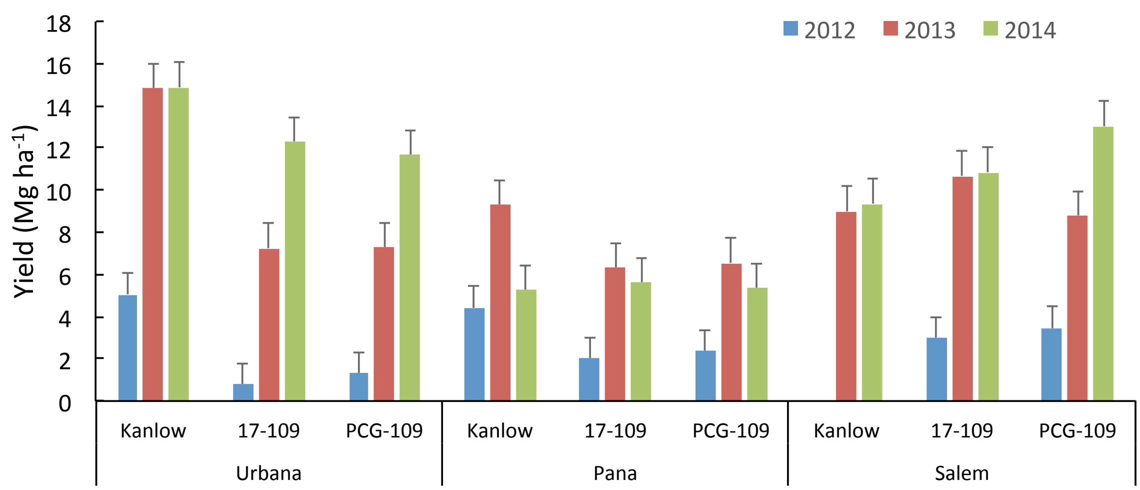

Fig. 13. Biomass yields of prairie cordgrass and switchgrass grown on salt affected soil (EC>20 dS m-1) in Salem, IL and on two poorly drained soils in Pana, IL and Urbana, IL.

- **University of Minnesota**

  The late biomass harvests at Becker and Lamberton were completed on October 29, 2015 and November 13, 2915, respectively.

  - **Factor plots at Lamberton, Minnesota**

Post-frost harvest (H2) biomass yields are depicted in Figure 14. 'Liberty' experienced some winterkill stand loss during the harsh 2013-2014 winter, and gaps in the stand were filled with weeds (see weedy biomass comparison in Figure 14).

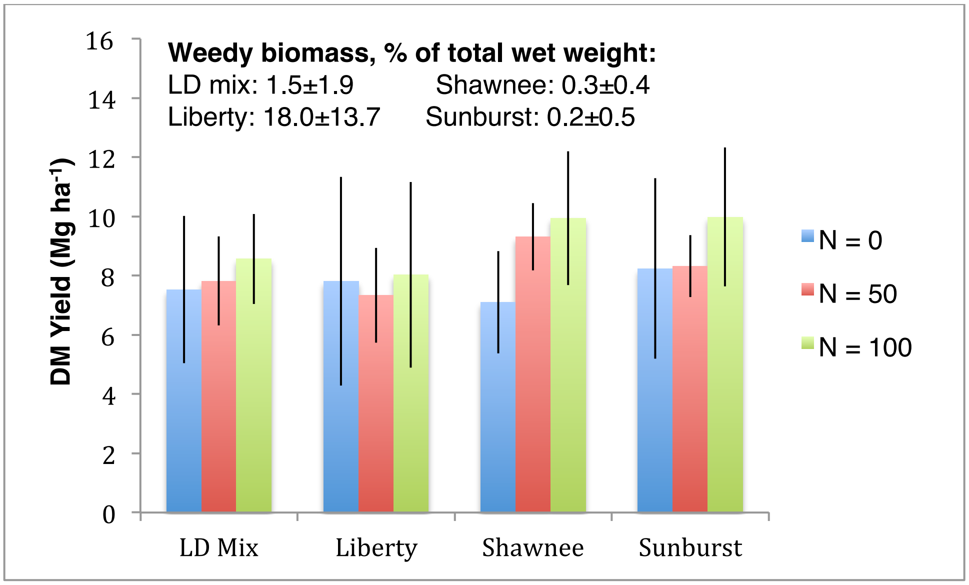

Fig. 14. November 13, 2014, dry matter yield on H2 grass plots at Lamberton, MN. Error bars denote one standard deviation.

- **Factor plots at Becker, Minnesota**

Weed pressure was high, and all plots had to be hand-weeded in July, despite attempts at control using 2,4-D. Stand loss in Liberty resulted in weedy biomass infill, similar to Lamberton. Dry matter yield on post-frost harvest (H2) plots is shown in Figure 15 and yield on alternating-harvest plots (H3) is shown in Figure 16.

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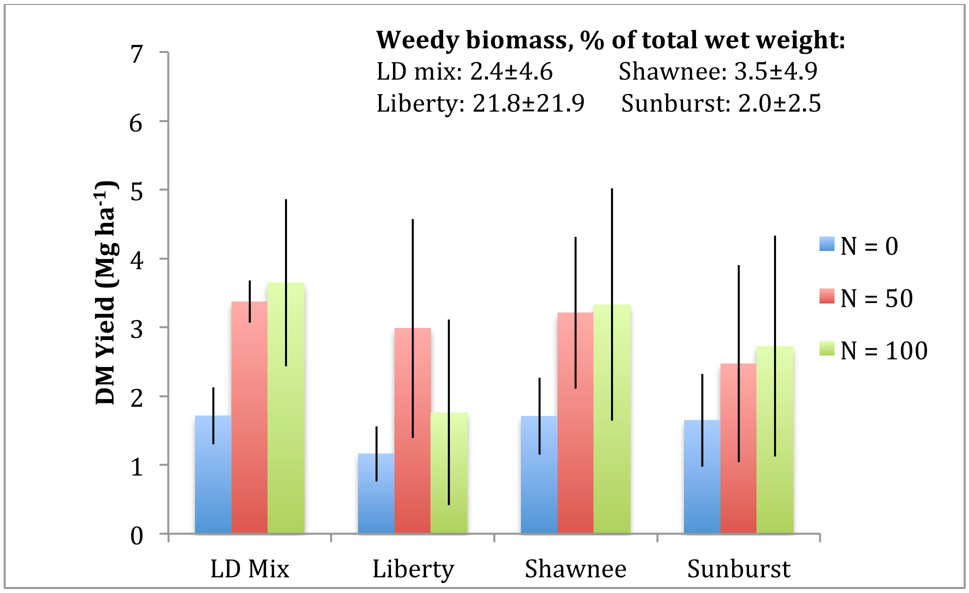

Fig. 15. October 29, 2014, dry matter yield on post-frost harvest (H2) grass plots at Becker, MN. Error bars denote one standard deviation.

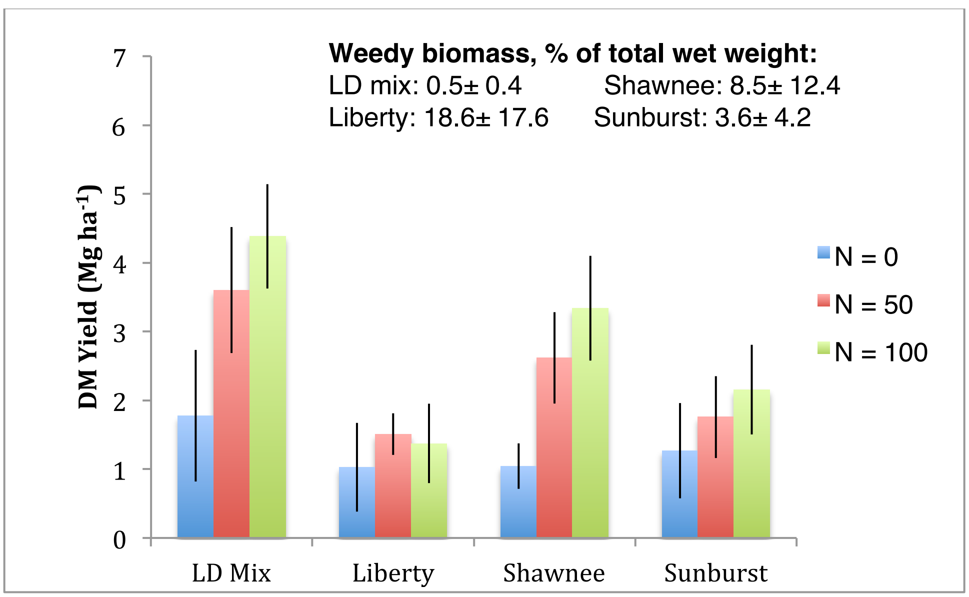

Fig. 16. October 29, 2014, dry matter yield on alternate-harvest (H3) grass plots at Becker, MN. Error bars denote one standard deviation.

- **USDA-ARS, Lincoln**
  - **Factor Analysis Plots**
    - ✓ Anthesis harvest treatments and sample collection were completed as scheduled.

- ✓ A late killing frost delayed post-frost harvests until mid-November 2014. The 2014 samples are being processed.
- ✓ Yield data for 2012-2014 is being evaluated.
- ✓ Feedstock samples collected in 2012 and 2013 from Nebraska have been processed, scanned, and are being predicted.

- **System Analysis Plots**
  - ✓ The feedstock samples collected in 2012, 2013, and 2014 from Nebraska have been processed and are being scanned and predicted.
  - ✓ Greenhouse gas (GHG) sampling occurred 28 times from March - December 2014. Samples from 2013 and 2014 are being summarized. GHG sampling for 2015 has been initiated.
  - ✓ Visual obstruction measurements (VOM) were collected until harvest in November 2014. VOM and elongated leaf height data are being summarized.
  - ✓ Baled yields were lower than expected. The limited precipitation in 2012 and 2013 is still impacting biomass yield.

Table 10. Baled dry matter yields for switchgrass, big bluestem, and low diversity mixture fields fertilized with 50 or 100 lb N/acre. Feedstocks were harvested and baled in November 2014 from fields near Mead, NE.

Feedstock	50 lb N/acre	100 lb N/acre
	----- Dry Matter Yield (tons/acre) -----	
Switchgrass	3.6	3.9
Big bluestem	4.2	4.2
Low diversity mix	5.3	5.0

  - ✓ Continued to manage a field-scale herbaceous perennial feedstock research and demonstration site in cooperation with Vermeer Manufacturing near Pella, IA. These feedstocks were harvested and baled on 12 and 13 November. Baled yield on a dry matter basis was 1.8 tons/acre for Liberty, 1.1 tons/acre for big bluestem, and 1.2 tons/acre for the LDM. Bales were sampled for future analysis.
  - ✓ Continued managing a small-plot herbaceous perennial feedstock research and demonstration site on a floodplain in cooperation with Vermeer Manufacturing near Pella, Iowa. The site was not harvested in 2014 due to flooding. However, this site provided the first confirmation of seedling flood tolerance in Liberty switchgrass.

- ✓ Continued managing the annual & perennial feedstocks to supply CHP to an advanced ethanol fermentation plant. Winter wheat has been planted and oats will be planted near 15 March.
- ✓ Completed Year 3 of the warm-season (WS) grass grazing trial:
  - ➢ Compared switchgrass (PV), indiangrass (SN), big bluestem (AG), and 2 WS grass mixtures.
  - ➢ Grazing is a very profitable option and can mitigate the risk for growing perennial grasses for bioenergy.
  - ➢ 3-year average gains of 144–225 lbs BW/acre.
  - ➢ Warm-season grasses may provide dual use for grazing and biomass production with appropriate management (See Exhibit 1).

Table 11. Average daily gain (ADG) and body weight (BW) gain for switchgrass, big bluestem, indiangrass, Mix 1 (big bluestem, indiangrass, and sideoats grama) and Mix 2 (big bluestem, indiangrass, switchgrass, little bluestem, and sideoats grama) pastures grazed for three years near Mead, NE.

Feedstock	ADG (lb/hd/day)	BW Gain (lb beef/acre)
Switchgrass	1.0	144
Big bluestem	1.5	221
Indiangrass	1.5	218
Mix 1	1.5	212
Mix 2	1.6	225

- ✓ A draft decision support tool that compares the returns from row crop production to the returns for perennial grasses for bioenergy is being developed with Dr. Keri Jacobs (Objective 6 Team Leader). This tool will allow producers to enter their field- and production-specific costs and returns to make site-specific management decisions for marginally productive cropland. We will be meeting in late February to finalize the tool.
- ✓ Completed processing and shipping biomass feedstock samples to Renmatix.
- ✓ Completed a 5-year study on the effects of row spacing on biomass yield and legume establishment into upland and lowland switchgrass ecotypes. Row spacings were 6, 12, 18, 24, 30, and 36 inches. Yield data has been summarized. Averaged across all

legumes, preliminary results indicate 12" rows had the greatest yields for upland switchgrass, whereas there was no difference for 12-30" rows for lowland switchgrass. Legume data is being analyzed and samples are being processed.

- ✓ Completed Year 5 of a multi-location study comparing the biomass yield and composition of 28 warm-season grass monocultures and mixtures. Preliminary results indicate the five highest yielding entries were: 1) Miscanthus x giganteus (10.5 tons/acre), 2) Kanlow N1 switchgrass (7.1 tons/acre), 3) a mixture of Goldmine big bluestem, Warrior indiangrass, & Shawnee switchgrass (6.2 tons/acre), 4) Scout indiangrass (6.0 tons/acre), and 5) Shawnee switchgrass (5.7 tons/acre). All yields are reported on a dry matter basis. Mxg had the greatest yield in all but one year and produced 18 tons/acre DM in 2011, more than twice as much biomass as any other entry. Samples are being processed for compositional evaluation.

- **Plans for Next Quarter**

  - ✓ Continue grinding, scanning, and predicting 2012, 2013, and 2014 biomass samples.
  - ✓ Prepare fields for 2015 field season. Burn, spray as needed and apply fertilizer treatments.
  - ✓ Ship 'Shawnee' switchgrass bales to IA for feedlot feeding trial.

- **Publications, Presentations and Proposals Submitted**

  - **Presentations**

    - ✓ Bakshi, S., Aller, D. & D.A. Laird. (2014). Comparison of the Physical and Chemical Properties of Laboratory- and Field-Aged Biochars. Abstract 99-13 in ASA, CSSA, and SSSA International Annual Meetings. Nov. 2-5, 2014. Long Beach, CA.
    - ✓ Dierking, R.M, Allen, D.J., Volenec, J.J. & S.M. Brouder. (2015). Yield, biomass composition, and N use efficiency of four *Miscanthus* × *giganteus* genotypes as influenced by various rates of N management. (draft).
    - ✓ Dierking, R., Volenec, J.J., Brouder, S.M. & D. Allen. (2014). 140-3 *Miscanthus* yields and tissue N concentrations during establishment with various N-rates grown on marginal soils. Poster 140-3. Inter. Meeting of the Amer. Soc. Agron.-Crop Sci. Soc. of Amer.-Soil Sci. Soc. of Amer. Nov. 2-5, 2014. Long Beach CA. https://scisoc.confex.com/scisoc/2014am/webprogram/Paper86714.html.

- ✓ Fidel, R., Laird, D.A. & T.B Parkin. (2014). Influence of Biochar Organic and Inorganic Carbon on Soil Greenhouse Gas Emissions. Abstract 96-4 in ASA, CSSA, and SSSA International Annual Meetings. Nov. 2-5, 2014. Long Beach, CA.
- ✓ Laird, D.A. & Huang, S. (2014). Fresh and Field Aged Biochar Have Different Impacts on Soil Bulk Density, Saturated Hydraulic Conductivity and Nitrate Leaching. Abstract 99-16 in ASA, CSSA, and SSSA International Annual Meetings. Nov. 2-5, 2014. Long Beach, CA.
- ✓ Long, M.K., Volenec, J.J. & S.M. Brouder. (2014). Lignocellulosic theoretical ethanol production of potential bioenergy sorghum genotypes. Poster 284-9. Inter. Meeting of the Amer. Soc. Agron.-Crop Sci. Soc. of Amer.-Soil Sci. Soc. of Amer. Nov. 2-5, 2014. Long Beach CA. https://scisoc.confex.com/scisoc/2014am/webprogram/Paper87703.html.
- ✓ Orr, M.-J., Bischoff-Gray, M., Cunningham, S.M., De Armond, N., Volenec, J.J., Brouder, S.M. & R.F. Turco. (2014). Comparative analysis of soil properties and greenhouse gas flux responses to nitrogen fertilization in bioenergy production systems. Poster 100-12. Inter. Meeting of the Amer. Soc. Agron.-Crop Sci. Soc. of Amer.-Soil Sci. Soc. of Amer. Nov. 2-5, Long Beach CA. https://scisoc.confex.com/scisoc/2014am/webprogram/Paper88067.html.
- ✓ Rogovska, N., Laird, D.A., Leandro, L. & D. Aller. (2014). Biochar Effects on Severity Soybean Root Disease Caused By Fusarium virguliforme. Abstract 99-2 in ASA, CSSA, and SSSA International Annual Meetings. Nov. 2-5, 2014. Long Beach, CA.
- ✓ Laird D.A. (2014). Biochar's contribution to sustainable bioenergy production. Iowa Learning Farms. Webinar: https://iowalearningfarms.wordpress.com/2014/12/15/top-10-webinars-6-biochars-contribution-to-sustainable-bioenergy-production/
- ✓ Laird D.A. (2014). Biochar: Pathways to Commercialization. Northeast Bioenergy Webinars: Biochar at Small and Large Scales. Webinar: https://www.youtube.com/watch?v=zWpuG1VObwY
- ✓ Raj, C., Chaubey, I., Brouder, S.M., Bowling, L.C., Cherkauer, K., Frankenberger, J., Goforth, R.R., Gramig, B.M. & J.J. Volenec. (2014). Sustainability analysis of bioenergy driven land use change under climate change and variability. Poster H53E-0909. American Geophysical Union Fall Meeting. Dec. 15-19, 2014. San Francisco, CA.

- **Proposals Submitted**

- ✓ U. S. Department of Energy, Office of Science, Office of Biological and Environmental Research-Systems Biology Research to Advance Sustainable Bioenergy Crop Development. Bioenergy from genes to landscapes: developing strategies to maximize feedstock productivity while minimizing environmental impacts. Dukes, J.S. (PD), Co-PIs: Brouder, S.M., Carpita, N., Chaubey, I., Filley, T., McCann, M., Meilan, R., Turco, R., Volenec, J.J. (Purdue); Dou, F., Mullet, J. (Texas A&M); DeAngelis, K. (Univ. Massachusetts-Amherst); Dweikat, I. (Univ. Nebraska-Lincoln).
- ✓ U.S. Department of Energy, Golden Field Office, Development of Methodologies for Determining Preferred Landscape Designs for Sustainable Bioenergy Feedstock Production Systems at a Watershed Scale. Bio3BL-Bioenergy Landscape Design for the Triple Bottom Line. Chaubey, I. (PD). Co-PIs: Buckmaster, D., Brouder, S.M., Turco, R., Volenec, J.J., Allen, D., Gramig, B., Goforth, R., Flaherty, E., Engel, B., Mosier, N., Tyner, W., McMillian, S., Prokopy, L., Gkritza, N. & C. Martin.

Objective 3. Feedstock Logistics

The Feedstock Logistics objective focuses on developing systems and strategies to enable sustainable and economic harvest, transportation and storage of feedstocks that meet agribusiness needs. The team also investigates novel harvest and transport systems and evaluates harvest and supply chain costs as well as technologies for efficient deconstruction and drying of feedstocks.

Iowa State University

1. **Planned Activities**

   Planned activities in this quarter included:

   Continued evaluation and refinement of the dry matter loss models for field conditions, and how the models can be used to improve management of field harvest operations under different projected weather conditions.

2. **Actual Accomplishments**

   - **Impact of rainfall level and crop density on compositional and dry matter loses from switchgrass and corn stover.** We conducted an experimental study to estimate the impact of rainfall level and crop density on compositional and dry matter loses from switchgrass and corn stover. Three levels of densities were studied for both switchgrass (0.97 kg/m^2 to 3.23 kg/m^2) and corn stover (0.78 kg/m^2 to 2.61 kg/m^2). Switchgrass and corn stover samples were subjected to four rainfall levels (7.5 mm to 75 mm) under a rainfall simulator, with a moderate rainfall intensity of 7.5 mm/hr. After the rainfall treatment, both switchgrass and corn stover samples were incubated for 48 hours at room condition to simulate the field-drying period after a rainfall event.

Losses from both corn stover and switchgrass were measured by following methods: 1) total solids in the runoff water after a rainfall event (leaching loss), 2) extractive loss by measuring the water soluble portion of biomass before and after rainfall events (extraction losses), and 3) total dry matter in the biomass sample before and after the rainfall treatment using the oven drying method (dry matter loss). Initial and final compositional analysis (mineral, ash, and fiber content) was measured for all treatments.

Both rainfall level and swath density significantly affect the leaching losses. In switchgrass, leaching losses varied from 0.19% to 2.83% at 7.5 mm and 75 mm of rainfall, respectively. On average, the low-density swath had a leaching loss of 1.64% compared to 0.85% in the high-density swath. Similarly, corn stover had a leaching loss of 0.45% compared to 3.26% at 7.5 mm and 75 mm of rainfall, respectively. A similar effect of swath density was observed in which the leaching losses for LD swaths was 2.98% compared to 1.68% in HD swaths.

Rainfall level significantly affected extraction losses of switchgrass and corn stover. Switchgrass extraction losses were 2.34% at the 7.5 mm rainfall level compared to 4.74% at 75 mm rainfall level. Corn stover extraction losses were 1.15% at the 7.5 mm rainfall level compared to 4.31% at 75 mm rainfall level. No significant influence of swath density was observed on switchgrass and corn stover extraction losses.

Rainfall level also had a significant effect on dry matter loss from switchgrass. On average, switchgrass dry matter loss was 2.58% at a rainfall level of 7.5 mm compared to 3.07%, 4.47%, and 6.1% at 25 mm, 50 mm and 75 mm, respectively. However, corn stover showed higher dry matter losses of 8.6%, 9.13%, 8.5% and 7.5% after rainfall events of 7.5 mm, 25 mm, 50 mm, and 75 mm, respectively. This could be due to the microbial growth on highly conditioned corn stover samples during the incubation period. Therefore, a single rainfall event between swathing and baling can result in dry matter losses of up to 6.1% and 7.5%, for switchgrass and corn respectively. This loss would have a significant effect on biomass feedstock yield and cost.

In terms of mineral analysis, rainfall level and swath density had a significant effect on K content for corn stover and switchgrass. In corn stover, there was a significant decrease of 0.39 % K units from LD compared to a 0.2% decrease in MD and HD swaths. Also, 0.10% and 0.22% units were lost at a rainfall level of 7.5 mm and 25 mm, respectively, and were significantly less than 0.34% and 0.40% lost at 50 mm and 75 mm of rainfall. In switchgrass, a decrease of 0.01% units was recorded in HD swaths compared to a decrease of 0.05% units in LD and MD switchgrass. Therefore, the HD swath provided a barrier to resist K loss. A slight effect of rainfall was also observed in which 0.07% units of K were lost at 50 mm of rainfall compared to 0.03% at 25 mm rainfall.

In corn stover, swath density had a significant effect on ash content. Ash content was decreased by 4.9% units in LD and MD swaths compared to 0.84% unit decrease in HD swaths. In switchgrass, no significant change was observed at different swath densities or rainfall level. At LD, switchgrass lost 0.55% units of ash compared to a gain of 0.2 and 0.3% units at MD and HD, respectively. More losses were expected in corn stover due to extensive conditioning of corn stover stems compared to switchgrass.

A slight increase in NDF, ADF, cellulose and hemicellulose content was observed in corn stover samples after the rainfall treatment. Similarly, a slight increase in NDF, ADF and cellulose content was also observed for switchgrass samples after the rainfall treatment. However, a decrease in hemicellulose content was observed for samples stored in MD and HD swaths. In addition, hemicellulose content significantly decreased with rainfall level from 0.06% at 7.5 mm to 0.57% at 75 mm. A decrease in hemicellulose content is consistent with other studies done on switchgrass storage and is shown to be more affected than the cellulose content.

3. Explanation of Variance

Only minor variances in planned activities have been experienced.

4. Plans for Next Quarter

Continued evaluation and refinement of the dry matter loss models for field conditions, and how the models can be used to improve management of field harvest operations under different projected weather conditions.

5. Publications, Presentations, and Proposals Submitted

None submitted.

University of Wisconsin

1. Planned Activities

- Preparation of samples taken during fall harvest for lab analysis.
- Lab experiment of the compaction and re-shaping system for round bales.
- For comparison purposes, addition of corn stover treatments to the study on means to enhance ruminant feed value of very mature grasses.

- Quantification of yield losses that occur from mowing lodged grasses.
- Beginning of techno-economic modeling of various bale transport and processing scenarios based on the previously collected research results.

2. Actual Accomplishments

- Initial samples collected during the fall work on bale storage characteristics and feed value enhancement are being ground and prepared for NIR analysis. To ensure consistency of results, the prepared samples will be stored until these two studies are complete so that initial and final samples can be analyzed at the same time.
- We have developed a process that reshapes and compacts round bales into a parallelepiped or cuboid shape. Improvements to the compression process made in the last quarter were successful, specifically to reduce parasitic friction losses and develop improved methods of restraining the compacted bale. Bale compaction experiments to quantify compression forces; bale density; and bale expansion rate were conducted using both perennial grasses and corn stover (for comparison purposes). Initial bale density is greater for perennial grasses than corn stover, so less compression energy was required and the density improvement was greater with stover bales. Also, results have shown that less energy is required when the bale is compacted bi-axially rather than uni-axially (i.e. compacted in both the vertical and horizontal directions as compared to simply vertically). We have been able to increase switchgrass bale density by 44% to 13.8 lbs DM/ft^3 and corn stover density by 109% to 15.5 lbs DM/ft^3.
- Experiments to improve mature grass ruminant digestion by mechanical and chemical means were started in the last quarter using switchgrass. The following treatments were created and stored in 2-gal. anaerobic containers: (a) control; (b) treated with calcium hydroxide @ 5% by weight; and (c) treated with ammonium hydroxide @ 4 % by weight. Two DM contents were used - 45% and 82% DM. All treatments were also split into two physical treatments – chopped or shredded by hammer milling. In this quarter we created the same treatments using corn stover for comparison purposes.
- Perennial grasses are typically harvested in the latefall after senescence so that yield is maximized and nutrient translocation has occurred. However, the crop is typically very tall by that time and heavy winds and rain prior to cutting can cause considerable crop lodging. If the lodging is in an unfavorable direction compared to the optimum mowing direction, then the mower may leave very long stubble resulting in yield loss. We quantified these lodging related losses in fields of switchgrass and native grasses. Measured losses were 0.47 and 0.79 tons DM/ac for these two grasses, respectively. These losses would have substantial negative impact on the profitability of grass stands,

so design changes to mowing equipment to reduce losses in lodged crops should be considered.

- We have investigated numerous ways to reduce harvest, handling, storage and transport costs, including:
  - Pre-cutting at baling.
  - Mega-sized round bales.
  - Film wrapping bales for storage; and re-shaping and re-compacting round bales.

We have begun to analyze the economic impact – either positive or negative – of these approaches. Current efforts are focused on transport options for various bale configurations.

3. Explanation of Variance

We are still behind in completing manuscripts for publication. The manuscript drafts are written but additional data collected needs to be added to complete the conclusions.

4. Plans for Next Quarter

- Continue efforts to submit manuscripts concerning results of grass drying systems and bale aggregation/logistics.
- Continue to collect post-storage size-reduction energy requirements of bales focusing on precision-cut chopping.
- Continue work on the system to compact and re-shape round bales.
- Remove the first batch of bales used in the storage study.
- Remove and analyze treatments to enhance the feed value very mature switchgrass.
- Continue to assess the economic viability of the various bale harvest and configuration options previously investigated.

5. Publications, Presentations, and Proposals Submitted

None

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Objective 4. System Performance Metrics, Data Collection, Modeling, Analysis and Tools

This objective provides detailed analyses of feedstock production options and an accompanying set of spatial models to enhance the ability of policymakers, farmers, and the bioenergy industry to make informed decisions about which bioenergy feedstocks to grow, where to produce them, what environmental impacts they will have, and how biomass production systems are likely to respond to and contribute to climate change or other environmental shifts.

We focus on four overarching tasks:

- Task 1. Adapt existing biophysical models to best represent data generated from field trials and other data sources.
- Task 2. Adapt existing economic land-use models to best represent cropping system production costs and returns.
- Task 3. Integrate physical and economic models to create spatially explicit simulation models representing a wide variety of biomass production options.
- Task 4. Evaluate the life cycle environmental consequences of various bioenergy landscapes.

Iowa State University

1. Planned Activities

The first two broad tasks under this objective are to adapt existing biophysical models to best represent field trials and other data and to adapt existing economic land-use models to best represent cropping system production costs and returns.

2. Actual Accomplishments

We have completed our first large scale scenarios using the detailed SWAT model for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds. We published a paper in the journal of the European Agricultural Economics Association this summer (*European Review of Agricultural Economics*). In addition, the paper formed the basis for the plenary session of the world congress of the European Agricultural Economics Association held in Ljubljana, Slovenia in August 2014. That paper describes the results of baseline and a conservation practice placement to evaluate the water quality effects at the landscape level. A second set of scenarios using the extended 12-digit scenario models have been initiated using switchgrass and corn/soybean rotations as possible land use options. We are working with a survey of corn belt farmers to use as a basis for developing a set of scenarios to represent how farmers indicate that they plan to respond to climate change over the next few decades. Given the potential importance of adaptation in the response to climate change, we plan to integrate these farmer indicated responses with bioenergy scenarios.

3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Quarter**

We will continue to adapt existing biophysical models to best represent field trials and other data and to adapt existing economic land-use models to best represent cropping system production costs and returns. We are also developing scenarios of specific interest to the goals of CenUSA including the optimal placement of switchgrass to achieve a range of environmental improvements while producing energy. To do so, we have initiated work with colleagues from Purdue and plan model comparisons between watersheds at multiple locations. We have two selected small watersheds selected (one in Iowa and one in Indiana). Appropriate SWAT versions and code have now been agreed upon as have a set of scenarios.

5. **Publications, Presentations, and Proposals Submitted**

- Kling, C.L. Principal Investigator. Climate and Human Dynamics as Amplifiers of Natural Change: A Framework for Vulnerability Assessment and Mitigation Planning National Science Foundation (2012-2016, 480,000).
- Kling, C. L., "Linking Externalities from the Land to their Consequences in the Sea: A Model of Land Use, Costs, Hydrology and the Gulf of Mexico Hypoxic Zone," Presented at the *Water Resources Conference, Saint Paul, Minnesota*
- Panagopoulos, Y., Gassman, P., Arritt, R., Herzmann, D., Campbell, T., Jha, M., Kling, C.L., Srinivasan, R., WhiteM M. & J. Arnold. (2013). Surface Water Quality and Cropping Systems Sustainability under a Changing Climate in the Upper Mississippi River Basin. Journal of Soil and Water Conservation (2014): forthcoming.

University of Minnesota

1. **Planned Activities**

Planned activities for this quarter include continued work on:

- Task 1: Adapt existing biophysical models to best represent data generated from field trials and other data sources.
- Task 2: Adapt existing economic land-use models to best represent cropping system production costs and returns.

- Task 3: Integrate physical and economic models to create spatially explicit simulation models representing a wide variety of biomass production options.
- Task 4: Evaluate the life cycle environmental consequences of various bioenergy landscapes.
- Task 5: Employ the modeling systems to study the design of policies to cost effectively supply ecosystem services from biomass feedstock production.

2. Actual Accomplishments

Our main accomplishment this quarter was the publication of work on the air quality and climate change impacts of biofuels and other transportation energy options. This report received considerable media attention and interest from government and industry. Links to select coverage are provided below.

This quarter also saw the successful thesis defense of Ryan Noe, CenUSA-supported graduate master's student, who explored the potential for using the USDA Cropland Data Layer (CDL) for land-use/land-cover change modeling exercises.

- "Study: Your All-electric Car may not be so Green," *AP: The Big Story*, Dec. 15, 2014. http://bigstory.ap.org/article/e493f4621bf24bf9adc94ae1a95ac296/study-your-all-electric-car-may-not-be-so-green
- "Electric cars actually bad for the environment?" *The Willis Report*, Dec. 17, 2014. http://www.foxbusiness.com/on-air/willis-report/videos#p/157870/v/3949139294001

  "Switching to Vehicles Powered by Electricity from Renewables Could Save Lives" *University of Minnesota News Service* (Minneapolis, MN), Dec. 17, 2014. http://discover.umn.edu/news/environment/switching-vehicles-powered-electricity-renewables-could-save-lives
- "That Electric Car may not be as Green as you Think," *Twin Cities Pioneer Press* (St. Paul, MN), Dec. 15, 2014. http://www.twincities.com/technology/ci_27140844/u-study-finds-electric-cars-powered-by-renewables
- "Cleaner than what?" *The Economist* (London, UK), Dec. 20, 2014. http://www.economist.com/news/science-and-technology/21636715-why-electric-car-may-be-much-dirtier-petrol-one-cleaner-what
- Why Your Electric Vehicle Might Not Be as Green as You Think," *Popular Mechanics* Dec. 15, 2014. http://www.popularmechanics.com/cars/alternative-fuel/electric/electric-cars-pollute-more-than-gasoline-cars-17535339

3. **Explanation of Variance**

   No variance has been experienced.

4. **Plans for Next Quarter**

   Next quarter includes continued work on Tasks 1, 2, 3, 4, and 5.

5. **Publications, Presentations, and Proposals Submitted**

   - Tessum, C., Hill, J., & J. Marshall. (2014). Life cycle air quality impacts of conventional and alternative light-duty transportation in the United States. *Proc. Natl. Acad. Sci. U.S.A*. 111:18490–18495.
   - Noe R. (2015). Uncertainty in Cropland Data Layer Derived Land-Use Change Estimates: Putting Corn and Soy Expansion Estimates In Context. Thesis, University of Minnesota.

Post-Harvest

Objective 5. Feedstock Conversion and Refining: Thermo-chemical Conversion of Biomass to Biofuels

The Feedstock Conversion and Refining Objective will perform a detailed economic analysis of the performance of a refinery based on pyrolytic processing of biomass into liquid fuels and will provide biochar to other CenUSA researchers. The team concentrates on two primary goals:

- Estimating energy efficiency, GHG emissions, capital costs, and operating costs of the proposed biomass-to-biofuels conversion system using technoeconomic analysis;
- Preparing and characterizing biochar for agronomics evaluations.

Sub-objective 1. Perform Technoeconomic Analysis

1. **Planned Activities**.

   Understanding the mechanism by which lignin-derived compounds react in the presence of zeolites is important to enhancing aromatic yields and reducing coke generation. Hydroxyl and methoxy functionalities are most commonly produced from lignin and are thought to be important to lignin reactivity. In this study we analyzed catalytic pyrolysis of phenol and anisole using ZSM5 zeolites in the Frontier 3050 tandem micro reactor to understand the conversion steps with the aim of improving lignin conversion to hydrocarbons.

2. Actual Accomplishments

Anisole provided significantly higher carbon yield of aromatic hydrocarbons (59.6%) than phenol (29.5%), which gives evidence of the importance of functionality in conversion. Product selectivity was significantly different for these two monomers as illustrated in Table 12. Main products from anisole were benzene and toluene, while from phenol they were naphthalene, benzene and biphenyl. This shows that these two monomers have different mechanisms for conversion in ZSM5 catalyst. For these monomers radical-based mechanisms were proposed based on product distributions and selectivity. (Figures 17 and 18)

Table 12. Product distribution for catalytic conversion of anisole and phenol (ex situ catalysis, pyrolysis temperature = 600^{0}C, catalyst bed temperature = 600^{0}C, reactant loading = 0.25mg, catalyst CBV 2314 loading = 40mg)

Feedstock	Anisole	Phenol
Overall yield (%)		
CO	1.1 ± 0.1	1.0 ± 0.1
CO2	0.3 ± 0.1	0.2 ± 0.1
Catalytic coke	36.9 ± 0.9	56.4 ± 2.5
Pyrolytic char	0.0 ± 0.0	12.4 ± 0.1
Aromatics	59.6 ± 0.4	29.5 ± 1.4
Olefins	2.8 ± 0.2	2.8 ± 0.2
Total	101.0 ± 1.31	102.8 ± 4.9
Aromatics selectivity (%)		
Benzene	47.5 ± 0.7	33.4 ± 0.6
Toluene	21.8 ± 0.1	2.1 ± 0.1
Xylene	4.1 ± 0.0	0.3 ± 0.0
Naphthalene	9.4 ± 0.3	27.3 ± 0.7
Biphenyl	1.2 ± 0.1	12.0 ± 0.1
C9 aromatics [a]	3.2 ± 0.3	2.0 ± 0.1
C10$^+$ aromatics [b]	12.9 ± 0.7	22.8 ± 0.1
Olefin selectivity (%)		
Ethylene	55.1 ± 1.4	46.1 ± 1.8
Propylene	12.4 ± 2.4	23.0 ± 2.8

[a] C9 aromatics include indene and alkybenzenes.

[b] C10$^+$ aromatics include alkylated naphthalenes and higher polyaromatic hydrocarbons (PAH).

Anisole conversion starts by producing phenol, cresol and methylene radicals with the help of acid sites in zeolite catalyst. Benzene and toluene are produced from phenol and cresol, respectively, by reaction with methylene as shown in Figure 17. Finally methylene acts as an alkylating agent in the zeolite catalyst to produce benzene, toluene, xylenes and naphthalenes as final products (cresol and toluene pathways are not shown).

Phenol conversion is initiated by aryl, phenoxy, hydroxyl and hydrogen radical generation with the support of the zeolite catalyst. Some of these radicals recombine to produce products such as benzene, biphenyl and water. Hydroxyl radical produced in the first step can attack the phenoxy radical to defragment the aromatic ring and produce naphthalene and benzene, as shown in Figure 18.

The higher energy barrier associated with hydroxyl radical generation could be attributed to lower conversion with phenol, while methylene-donation by the methoxy group could explain the significantly higher conversion for anisole.

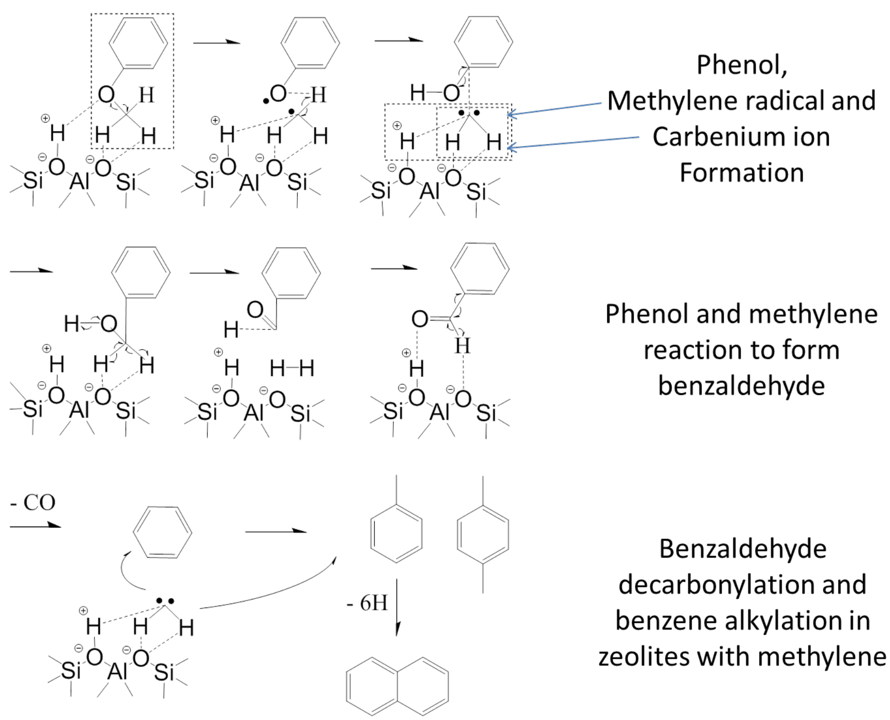

Fig. 17. Proposed mechanism for conversion of anisole over zeolites at 600^{0}C.

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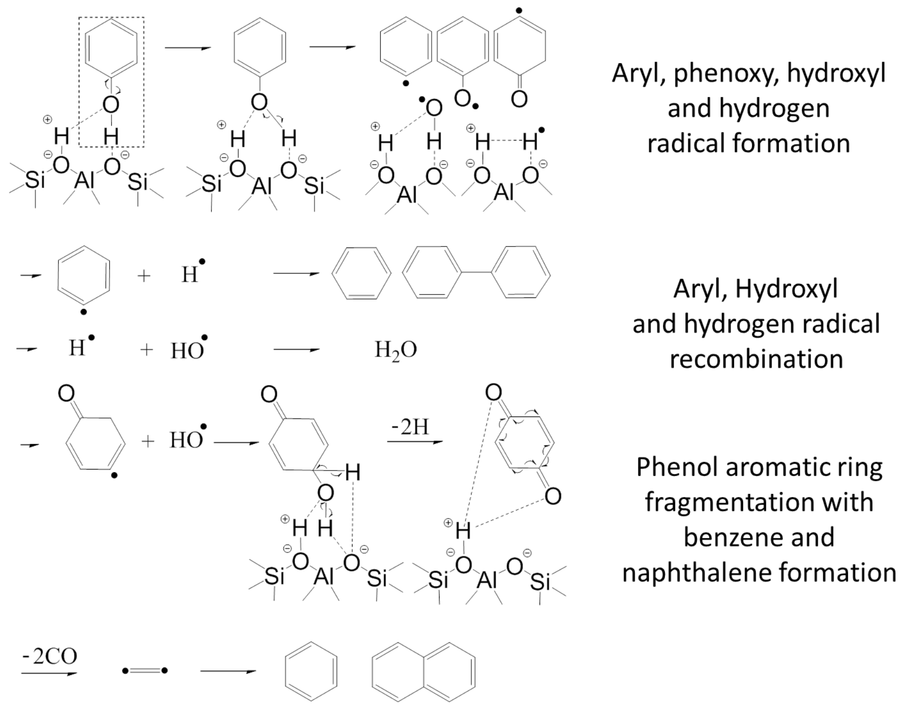

Fig. 18. Proposed mechanisms for conversion of phenol over zeolites at 6000C.

3. Explanation of Variance

None to report.

4. Plans for Next Quarter

Validating proposed mechanisms for anisole and phenol conversion and analyzing the influence of product intermediates in these conversions are planned as the next steps in this work.

5. Publications, Presentations, and Proposals Submitted

None.

Sub-objective 2. Prepare and Characterize Biochar

1. Planned Activities

The work documenting the effects Fe and Al pre-treatments of biomass on biochar AEC will be prepared as a manuscript for publication.

2. Actual Accomplishments

Preparation of a manuscript documenting the effects of Fe and Al pre-treatments of biomass on biochars AEC was initiated. Data for this manuscript has been compiled and preliminary figures and tables have been developed.

Analysis of albumin biochar has been completed to provide additional supporting data for the manuscript entitled "Anion Exchange Capacity of Biochar". The albumin biochar is a high N-biochar, which allows us to test the hypothesis that protonated N-heterocycles (pyridinium groups) contribute anion exchange capacity of biochars. In the following data sets the results for the albumin biochar produced at 500º and 700ºC are new; results for cellulose, corn stover, and alfalfa meal biochars produced at 500º and 700ºC have been previously reported.

Chemical analysis indicated that the 500º and 700ºC albumin biochars contained 10.8 and 8.39% N, respectively (Table 13). Oxygen content of the fresh albumin biochars could not be determined because these samples contained significant levels of ash, which interferes with O determination by difference. However, acid treatments (both HF+HCl) removed most of the ash allowing O contents of 8.41 % and 11.84 % to be determined for the 500 and 700°C acid treated-albumin biochars, respectively. FTIR analysis of the fresh albumin biochars (Figure 19) revealed little indication of oxygen containing functional groups (carbonyl, hydroxyl, and either groups), however a prominent either band (~1200 cm^{-1}) was evident in the FTIR spectra of the acid treated albumin biochar (Figure 20), suggesting that the sample had undergone significant oxidation during the acid treatments. The 1590 cm^{-1} band in the FTIR spectra has previously been attributed to O-heterocycles (oxonium groups), which may contribute pH-independent AEC to biochars. The intensity of the 1590 cm^{-1} band was weaker in the spectra of the albumin biochars than in the spectra of the cellulose, corn stover, and alfalfa biochars, however the presence of some oxonium groups in the albumin biochars cannot be ruled out. The FTIR analysis provided no evidence of pyridine groups, however, N1s X-ray Photoelectron Spectroscopy (XPS) of the 500°C and 700°C albumin biochars indicated that a significant fraction of the total N in the albumin biochars was present as pyridine N. Analysis of anion exchange capacity of the albumin biochars revealed substantial AEC under acidic conditions (pH=4) and non-zero levels of AEC under alkaline (pH=8) conditions (Table 14). The results thus indicate that both pH-dependent pyridinium groups and pH-independent oxionium groups may contribute AEC to biochars.

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Table 13. Properties of the untreated biochars, including mass yields, elemental composition, pH, ash content, specific surface area, and particle density.

Feedstock	HTT (°C)	Yield (%)	O	Element Content (%) C	N	H	S	pH	Ash %	BET -N_2 M^2/g	Particle Density g//cm^3
Albumin	500	24.2	60.81	10.8	2.91	0.34	a	12.5	19.49	0.9	*
Albumin	700	21.2	62.05	8.39	1.71	0.34	a	12.7	26.36	2.6	*
Alfalfa	500	29.8	66.03	3.4	2.43	0.18	a	10	28.84	39	1.61
Alfalfa	700	29.0	68.8	3.23	1.45	0.25	a	10	30.89	176	1.9
Cellulose	500	27.9	84.8	0	2.98	0.08	10.82	8.3	0.87	321	1.34
Cellulose	700	26.0	90.3	0.01	1.72	0.12	6.12	8.6	0.92	229	1.68
Corn Stover	500	31.5	75.45	1.48	2.67	0.08	a	10.1	20.03	150	1.56
Corn Stover	700	29.8	77.54	1.23	1.48	0.13	a	10.2	21.93	259	1.74

[a] cannot be determined from the methods used. [*] Not measured

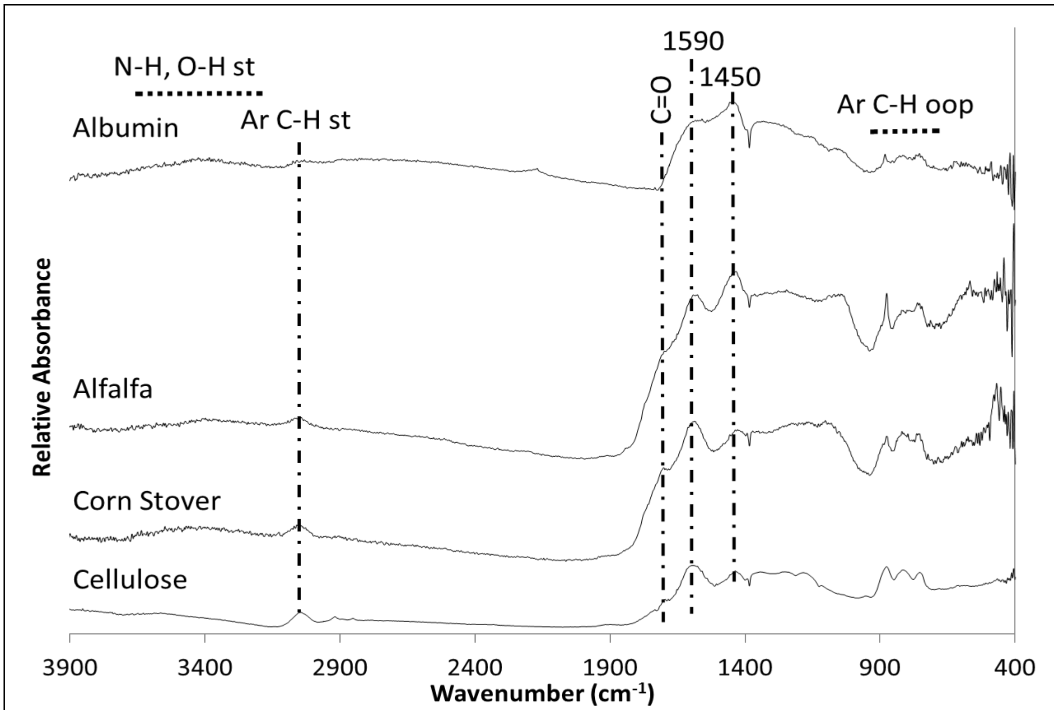

Figure 19. FTIR spectra of dialyzed biochars slow pyrolyzed at a HTT of 500 °C. N-H, O-H st indicate hydroxyl or amine/amide H-stretching bands; Ar C-H st is aromatic C-H stretching, C=O is carbonyl stretching, and Ar C-H oop indicates aromatic C-H out of plane vibrations.

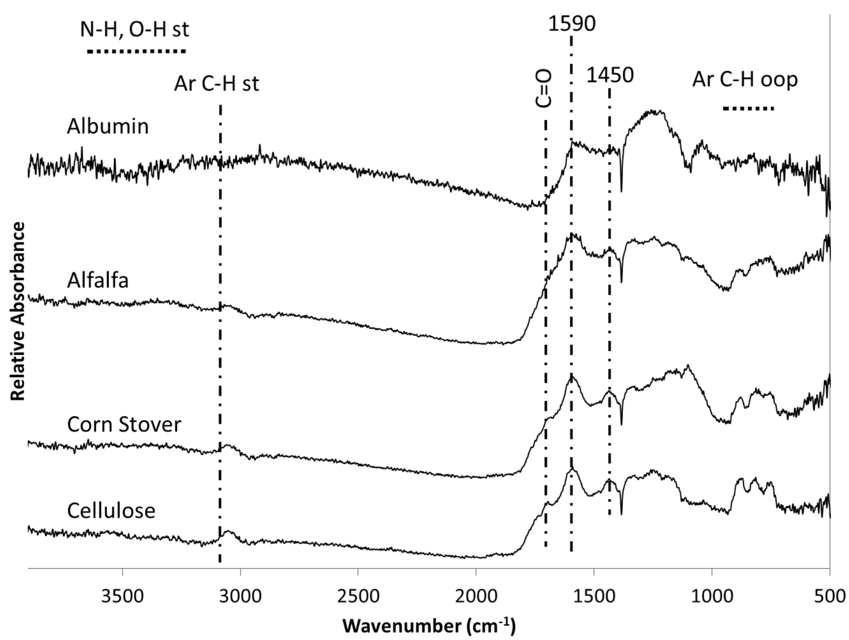

Fig. 20. FTIR spectra of HCl treated 500 °C HTT biochars. N-H, O-H st indicate hydroxyl or amine/amide H-stretching; Ar C-H st is aromatic C-H stretching, C=O is carbonyl stretching, and Ar C-H oop indicates aromatic C-H out of plane vibration.

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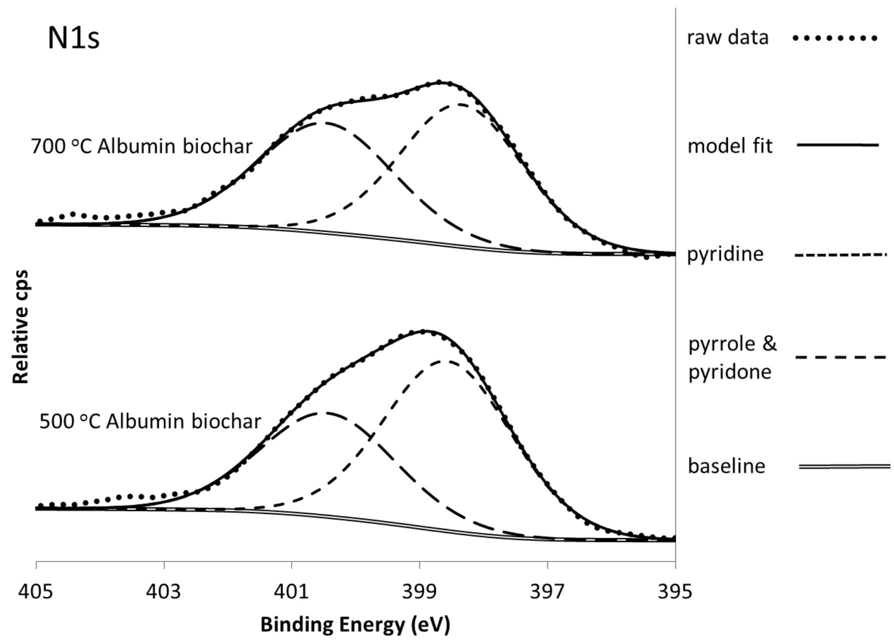

Figure 21. The N1s XPS spectra of the 500°C and 700°C albumin biochars.

Table 14. Anion exchange capacity of biochars produced from three feedstocks at 500 and 700 °C HTT. Analyses performed in triplicate and data is presented as average (standard deviation).

Feedstock	HTT (C)	pH4 (cmol kg $^{-1}$)	pH6 (cmol kg $^{-1}$)	pH8 (cmol kg $^{-1}$)
Albumin	500	14.7 (1.05)	2.45 (0.464)	1.65 (0.948)
Albumin	700	15.5 (1.71)	5.95 (1.10)	2.32 (0.881)
Alfalfa	500	10.9 (2.46)	3.1 (0.28)	0.94 (0.34)
Alfalfa	700	25.8 (4.08)	9.6 (1.07)	2.1 (0.87)
Cellulose	500	7.8 (1.94)	2.6 (0.21)	0.60 (0.37)
Cellulose	700	24.2 (5.94)	18.1 (8.66)	4.1 (0.18)
Corn Stover	500	17.5 (5.81)	3.8 (0.66)	1.0 (0.21)
Corn Stover	700	27.8 (9.10)	13.8 (4.22)	7.2 (1.39)

3. Explanation of Variance

Publishing the manuscript entitled *Anion Exchange Capacity of Biochar* is a high priority, therefore we focused on obtaining new data for the albumin biochars, which was needed to revise the manuscript in response to reviewer comments.

4. **Plans for Next Quarter**

The manuscript entitled "Anion Exchange Capacity of Biochar" will be re-submitted for publication. Changes in the physical and chemical properties of biochars on aging in soil environments will be quantified.

5. **Publications, Presentations, and Proposals Submitted**

None submitted.

Objective 6. Markets and Distribution

The Markets and Distribution objective recognizes that a comprehensive strategy that addresses the impacts to and requirements of markets and distribution systems will be critical to the successful implementation and commercialization of a regional biofuels system derived from perennial grasses grown on land unsuitable or marginal for the production of row crops. To create this comprehensive strategy the team focuses on two unifying approaches:

- The study and evaluation of farm level adoption decisions, exploring the effectiveness of policy, market and contract mechanisms that facilitate broad scale voluntary adoption by farmers; and
- Estimate threshold returns that make feasible biomass production for biofuels.

1. **Planned Activities**

Our team's anticipated activities were:

- **Activity A.** Prepare an outreach piece that compares the producer survey results over two years; this will summarize findings and identify implications for our project.
- **Activity B.** Continue to interact with industry on an Iowa State University Bioeconomy project to model the use of feedstocks as a fuel source for fast pyrolysis. The business model involves a distributed system of fast pyrolysis that provides as byproducts char and bio-oil. Char will be sold as a soil amendment, and bio-oil will be sold for use in furnaces for heat. The group includes soil scientists, chemical engineers and mechanical engineers (Hayes).
- **Activity C.** Continue modeling and analysis efforts of the regional supply curve for grasses and stover using a real options framework (Hayes). Present one of these at conference on this subject in 2013/2014. Publish two peer-reviewed papers in this area.

- **Activity D.** Continue a project to study the transportation economics of CRP when filter strips and grassy plantings are harvested for biomass. The expected outcome is a report describing the use of CRP for perennial grasses. The feature of this report will be an exploration of the trade-off between offering higher biomass prices to procure more product closer to the plant and lower biomass prices with increased transportation costs under various participation (harvest/yield) rates. The comparison is made to the case of stover and a dual crop model is considered to estimate biomass production from grasses and stover.

2. Actual Accomplishments

- **Planned Activity A.** Ongoing
- **Planned Activity B.** Ongoing.
- **Planned Activity C.** Ongoing.
- **Planned Activity D.** Nearing completion. The report is in draft form and is being prepared for submission to an academic journal and will be presented at an upcoming conference in Berkeley, CA. Results will be presented to the group when they are finalized.

3. Explanation of Variance

None. All activities are moving according to the project schedule.

4. Plans for Next Quarter

Our team will continue work as outlined in the planned activities. An additional piece is being added: Keri Jacobs and Rob Mitchell (Objective 2 Team Leader) are working on a producer decision tool based on the project's parameters for perennial grass production. The expected output here is a decision aid to be presented at the annual meeting and training provided to extension personnel.

5. Publications, Presentations, and Proposals Submitted

Dermot Hayes submitted a proposal to present a paper, "Sourcing Feedstock for Cellulosic Biofuels when Producer Participation in Low" at the 2015 Berkeley Bioeconomy Conference. Dermot Hayes will present the paper on April 2, 2015. Co-authors on the paper are Brittney Shaull and Keri Jacobs.

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Objective 7. Health and Safety

- The production of bioenergy feedstocks will have inherent differences from current agricultural processes. These differences could increase the potential for workforce injury or death if not properly understood and if effective protective counter measures are not in place.

  The Health and Safety team addresses two key elements in the biofuel feedstock supply chain:

- The risks associated with producing feedstocks; and
- The risks of air/dust exposure.

1. **Task 1. Managing Risks in Producing Biofeedstocks**

   - **Planned Activities**

     Additional data and details necessary for the new risk assessment model will be continued to be collected and filtered to match parameters of the new risk assessment model. Verification of the data sets and unique filters to construct related data from existing data will be accomplished. A technical paper proposal will be submitted to the 2015 *International Society of Agricultural Safety and Health* conference.

   - **Actual Accomplishments**

     - ✓ More injury and exposure data were collected to enhance the calculation of risk values. Actual injury data as well as data relating to specific machines were collected. A filter methodology was defined to calculate the necessary values from existing data sets that need adjustments to align with unknown/uncollected input needs. Additional facts necessary for the integration of the collected data into the new risk model for biofeedstock production were continued.

     - ✓ The risk assessment methodology was testing using deterministic values from actual Midwestern related injury and exposure data. Stochastic simulations were used to calculate the change in likelihood of injury between traditional corn production and biofuel production.

     - ✓ A selection process of using probabilistic exposure and effect to calculate the change of likelihood of injury between the production systems was tested. Area, as the exposure unit of measure, was adopted as the base unit that can be related to agricultural production systems for risk calculations.

- ✓ We submitted a technical paper proposal to the 2015 *International Society of Agricultural Safety and Health* conference. The proposed technical paper was accepted and is being prepared.

- **Explanation of Variance**

  None to report.

- **Plans for Next Quarter**

  Additional data and details necessary for the new risk assessment model will continue to be added. Complete calculations of risk between production systems will be accomplished and areas for model improvement will be identified. A technical paper will be submitted for peer review by the *International Society of Agricultural Safety and Health* professional improvement committee.

- **Publications, Presentations, and Proposal Submitted**

  None this quarter.

2. **Task 2 – Assessing Primary Dust Exposure**

- **Planned Activities**

  Receive approval for modifications to the human subjects study. Obtain the air sampling equipment that was identified from vendor. Communicate with the human subjects to who will participate in the study.

- **Actual Accomplishments**

  The modifications to the human subjects study to include the transportation location of potential subjects is still on going. Approval has not yet been obtained.

- **Explanation of Variance**

  Human subject modification was not accomplished so the modification will be resubmitted to Iowa State University Institutional Review Board to adjust the participation, detail, and collection of data to be approved. The current Human Subject approval is still in force but it does not provide the details necessary to collect the data needed until it has been modified.

- **Plans for Next Quarter**

Receive approval for modifications to the human subjects study. The air sampling equipment will be prepared for use by subjects in study. Identification of human subjects to participate in the study will begin after approval is received.

- **Publications, Presentations, and Proposal Submitted**

  No publication, presentations or proposal submitted this quarter.

Education and Outreach

Objective 8. Education

The Education Objective seeks to meet the future workforce demands of the emerging Bioeconomy through two distinct subtasks, as follow:

- To develop a shared bioenergy curriculum core for the Central Region.
- To provide interdisciplinary training and engagement opportunities for undergraduate and graduate students

  Subtask 1 is **curriculum development**. Subtask 2A is **training undergraduates** via an 8-week summer internship program modeled on the highly successful NSF REU (research experience for undergraduates) program. Subtask 2B is **training graduate students** via a 2-week summer intensive program modeled on a highly successful industry sponsored intensive program in biorenewables the team led in 2009. Subtask 2C is **training graduate students via a monthly research webinar**. The next portion of this report is broken into subtasks.

Subtask 1: Curriculum Development

1. Planned Activities

- **Module 12. Biochemical Conversion of Bioenergy Feedstocks**

  Continue development of draft module materials

- **Module 13. Thermochemical Conversion of Bioenergy Feedstocks**

  Continue development of draft module materials.

- **Evaluation Tasks**

  Continue with draft of journal manuscript.

2. **Actual Accomplishments**

- **Module 11. Introduction to Biofuel: Perennial Grasses as a Feedstock**

  ✓ Materials have been posted in the CenUSA Plant and Soil Sciences E-Library at University of Nebraska, Lincoln.

  ✓ Materials have been evaluated by class at Ohio State taught by Drew Wang.

- **Module 12. Perennial Grass Seed: Protection, Certification and Production**

  ✓ Revisions have been made to the draft materials.

  ✓ Content has been shared by biochemical and thermochemical conversion modules and organized into an additional module on biomass reprocessing.

- **Module 13. Thermochemical Conversion of Bioenergy Feedstocks**

  Continuing development of module content

- **Evaluation Tasks**

  ✓ Collected evaluation data for Module 11.

  ✓ Continuing draft of journal manuscript.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

- **Modules.** Continuing completion of final edits of existing modules in feedstock development, logistics and economics areas.

- **Module 12. Biochemical Conversion of Bioenergy Feedstocks.** Revision draft content and begin process to convert content to on-line module

- **Module 13. Thermochemical Conversion of Bioenergy Feedstocks.** Continue development of the draft module materials.

- **Module 14. Preprocessing Operations for Bioenergy Feedstocks.** Prepare draft of module outline.

- **Evaluation Tasks.** Prepare presentation of evaluation case studies for module program for *Innovate 365* distance education Conference.

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. Planned Activities

- Finish solicitation of projects from faculty.
- Determine distribution of students to sites (number of slots for each participating lab).
- Review program assessment provided by Iowa State University's *Research Institute for Studies in Education* (RISE).
- Update program website to reflect 2015 program and research project opportunities.
- Promote the undergraduate internship program and encourage application submissions, working with lists of underrepresented minority students generated by ISU graduate college, and through job-posting boards at regional institutions, and by communication with Agronomy and Engineering department chairs at partner institutions.

2. Actual Accomplishments

- Obtained research project descriptions from faculty members. In addition to promoting research project opportunities from Objectives 1 – 9, we plan to place a student at Archer Daniels Midland (ADM) as well as at the USDA NCAUR Lab in Peoria, Illinois.
- Promoted the undergraduate internship program to encourage application submissions as detailed above.
- Created a detailed schedule for the 2015 undergraduate internship program.
- Website content for the undergraduate internship program was successfully migrated to the newly framed CenUSA host website in the Iowa State University Agronomy Department.
- Applications are being accepted and inquiries regarding the program and application process are being answered.
- Secured on-campus housing for students who will be hosted by Iowa State University faculty.

3. Explanation of Variance

None.

4. **Plans for Next Quarter**

- Continue to promote the undergraduate internship program and encourage application submissions through the March 23, 2015 application deadline.
- Centrally vet and rank applications based on the letters of interest, academic achievement, previous research experience, and letters of recommendation.
- Pool of likely candidates will be given to faculty hosts for review during the week of March 30 with selections and rankings of students requested from faculty by April 3, 2015.
- Highly ranked students, as indicated by faculty hosts, will be phone interviewed the week of April 6 and April 13, 2015.
- First offers to students beginning April 6, second offers to students beginning April 13 with cohort (20 students) finalized on April 27, 2015.
- Arrange travel for accepted students.
- Secure housing for students who will be placed with faculty mentors at partner institutions.

5. **Publications, Presentations, and Proposals Submitted**

None to report this period.

Subtask 2B – Training Graduate Students via Intensive Program

1. **Planned Activities**

- Work with Dr. Mike Casler to continue planning for a one-day condensed graduate intensive program add-on to the 2015 annual meeting.
- Plan to include a career-fair or similar with industry, tailored to graduate students, plus other proposed high-value activities as follows.
- Tentative plans include a tour of some GLBRC facilities and research plots on Tuesday 28 July 2015. Consider a stop at GLBRC biomass research at the Arlington Ag Research Station and another stop at the Wisconsin Energy Institute on campus. The graduate students will see a range of biomass research that is quite different from that in CenUSA,

covering a range of topics from production/sustainability all the way to conversion processes.

2. **Actual Accomplishments**

Worked with Dr. Mike Casler just as detailed above in the planned activities.

3. **Explanation of Variance**

None.

4. **Plans for Next Quarter**

Continue to work with Dr. Mike Casler and Iowa State University's Conference Planning and Management staff to continue planning for the one-day condensed graduate intensive program add-on to the annual meeting.

- Plans include a tour of some GLBRC facilities and research plots on July 28, 2015. Consider a stop at GLBRC biomass research at the Arlington Ag Research Station and another stop at the Wisconsin Energy Institute on campus. The graduate students will see a range of biomass research that is quite different from that in CenUSA, covering a range of topics from production/sustainability all the way to conversion processes.

5. **Publications, Presentations, and Proposals Submitted**

None.

Subtask 2C – Training Graduate Students via Monthly Research Webinar

1. **Planned Activities**

Continue with planning for the restructured delivery of research webinar content

- Organizing four 1-hour sessions spread over the spring academic year (January, February, March, April of 2015). Each session will have several CenUSA objective leaders or collaborating faculty presenting on an issue listed below. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentation of viewpoints, which should last no longer than ten minutes each, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

  Scheduled topics:

  ✓ January 30 – What is the most realistic scenario for the adoption of SG (or other perennial) on marginal lands, and what policy changes would be needed to make this happen?

- Presenters: Jason Hill, Ken Moore, Raj Raman

- ✓ February 27 – What are the most realistic approaches to reducing N and P export from the Corn Belt?
    - Presenters: Cathy Kling, Keri Jacobs, Raj Raman
- ✓ March 27 – What kind of switchgrass yields are likely to be possible on marginal lands, and what would the cost of this material be?
    - Proposed presenters: TBA
- ✓ April 24 – How do yield increases and machinery changes impact cost and safety?
    - Proposed presenters: TBA

2. Actual Accomplishments

- Delivered the graduate student training via the newly formatted webinar series. The first session had several CenUSA objective leaders or collaborating faculty presenting on an issue. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentation of viewpoints, we moved to Q&A, with questions from anyone and particularly encouraged from graduate students.
    - ✓ January 30 – What is the most realistic scenario for the adoption of switchgrass (or other perennial) on marginal lands, and what policy changes would be needed to make this happen?
        - Presenters: Jason Hill, Ken Moore and Raj Raman.

3. Explanation of Variance

None.

4. Plans for Next Quarter

Continue delivery of the restructured/reformatted research webinar content

- Organizing four 1-h sessions spread over the spring academic year (March and April of 2015). Each session will have several CenUSA Objective Leaders or Collaborating Faculty presenting on an issue listed below. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentation of viewpoints, which should last no longer than ten minutes each, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

Scheduled topics:

- ✓ March 27 – What are the most realistic approaches to reducing N and P export from the Corn Belt?
  - ➢ Presenters: Cathy Kling, Keri Jacobs, Raj Raman
- ✓ April 24 – Topics under consideration:
  - ➢ What kind of switchgrass yields are likely to be possible on marginal lands, and what would the cost of this material be? (Proposed presenters: TBA)
  - ➢ How do yield increases and machinery changes impact cost and safety? (Proposed presenters: TBA)

5. Publications, Presentations, and Proposals Submitted

None to report.

Objective 9. Extension and Outreach

The Outreach and Extension Objective serves as CenUSA's link to the larger community of agricultural and horticultural producers and the public-at-large. The team delivers science-based knowledge and informal education programs linked to CenUSA Objectives 1-7.

The following teams conduct the Outreach and Extension Objective's work:

- **Extension Staff Training/eXtension Team**

  This team concentrates on creating and delivering professional development activities for Extension educators and agricultural and horticultural industry leaders, with special emphasis on materials development (videos, publications, web posts, etc.).

- **Producer Research Plots/Perennial Grass Team**

  This team covers the areas of:

  - Production, harvest, storage, transportation.
  - Social and community impacts.
  - Producer and general public awareness of perennial crops and biochar agriculture.
  - Certified Crop Advisor training.

- **Economics and Decision Tools Team**

  The Economics and Decision Tools Team focuses on the development of crop enterprise decision support tools to analyze the economic possibilities associated with converting acreage from existing conventional crops to energy biomass feedstock crops.

- **Health and Safety Team**

  This team integrates its work with the Producer Research Plots/Perennial Grass and the Public Awareness/Horticulture/eXtension 4-H and Youth teams (See Objective 7. Health and Safety).

- **Public Awareness/Horticulture/eXtension/4-H and Youth Team**

  This team focuses on two separate areas:

  - **Youth Development.** The emphasis is on developing a series of experiential programs for youth that introduce the topics of biofuels production, carbon and nutrient cycling, and biochar as a soil amendment.
  - **Broader Public Education/Master Gardener.** These programs acquaint the non-farm community with biofuels and biochar through a series of outreach activities using the Master Gardener volunteer model as the means of introducing the topics to the public.

- **Evaluation/Administration Team**

  This team coordinates CenUSA's extensive extension and outreach activities. The team is also charged with developing evaluation mechanisms for assessing learning and behavior change resulting from extension and outreach activities, compiling evaluation results and preparing reports, and coordination of team meetings.

1. Extension Staff Training/eXtension Team

- **Planned Activities**
  - ✓ Finish Master Gardener biochar video.
  - ✓ Finish biochar overview video featuring David Laird.
  - ✓ Post archived Biochar 101 and 102 presentations from annual meeting.
  - ✓ Develop one case study.
  - ✓ Upkeep CenUSA Index.

- ✓ Continue social media promotion of CenUSA Bioenergy.
- ✓ Publish the November issue of BLADES and email it out to our list via the Constant Contact platform.
- ✓ Research and write six stories for the February issue of BLADES. Publish and email it out to our list in Constant Contact.
- ✓ Set up interview with US-EPA about the status of state nutrient management plans and the role perennial grasses may play in reducing nutrient loads.

- **Actual Accomplishments**

  - ✓ Master Gardener video with Julie Weisenhorn finished. See: http://farmenergymedia.extension.org/video/university-minnesota-extension-master-gardener-biochar-research-summary.
  - ✓ Biochar Overview video featuring Dr. David Laird finished. See: http://farmenergymedia.extension.org/video/biochar-introduction-industry.
  - ✓ Submitted research review article "Reducing Hypoxia in the Gulf of Mexico – Reimagining a More Resilient Agricultural Landscape in the Mississippi River Watershed (retitled from Reducing Hypoxia in the Gulf: An Alternative Approach) to the Journal of Soil and Water Conservation)
  - ✓ Published November issue of BLADES with six news stories.
    - ➢ *Round or Square: A look at Bale Geometry.* Story on how CenUSA is tackling research on bale logistics and economics.
    - ➢ *"Liberty" is Closer Than You Think.* Story about Nebraska's Husker Genetics recent seed harvest of "Liberty" switchgrass, CenUSA's high yielding variety and the availability of seed for spring 2015 growers.
    - ➢ *Birds, Bees and Biomass*. Story detailing why National Wildlife Federation is a supporter of advanced biofuels and what they are doing about it.
    - ➢ *The New Bioenergy Prairie.* Explanation of how prairie species used for bioenergy can benefit wildlife in Nebraska and the Central United States.
    - ➢ *Energy Environment and Extension Summit: Educating for the Future.* Description of the three-day national extension conference hosted by CenUSA featuring tours, speakers, breakout sessions and the premiere of Iowa State

University's STRIPS (Science-based Trials of Rowcrops Integrated with Prairie Strips) documentary.

- *E-Media.* Announced a biochar webinar about a new renewable energy company, Advanced Renewable Technologies International, who have developed small biochar reactors that are being piloted in Iowa and Nicaragua.
- Started researching and developing stories for the February issue of BLADES.
- Assisted with the re-design of the CenUSA website.
- Planned BLADES content for 2015-2016 year.

✓ CenUSA eXtension web site: Google Analytics for CenUSA articles/Fact Sheets on the CenUSA eXtension site for this quarter reveal the following:

- The top nine states accessing CenUSA articles were Michigan, Texas, Wisconsin, Illinois, New York, Iowa North Carolina, Pennsylvania, and Nebraska

✓ **Vimeo.** During this quarter, the 37 CenUSA videos archived on Vimeo have had 346 plays or views of the videos on our Vimeo site, or on a web site that embedded a CenUSA video. The videos also had 2,177 loads; 1,701 of those loads came from our videos embedded on other sites. When a video is loaded, people see the video but they do not click "play." The means the video was saved to their hard drive (users usually do this because they have limited internet connectivity which does not allow for live streaming of video). Once the video is downloaded, it is available on their computer to watch at their convenience.

- CenUSA videos are also posted on YouTube, and those videos have been viewed 960 times between November 1, 2014 and January 31, 2015; 597 views were from the United States. Demographic information including age and gender were not available this quarter due to changes in YouTube Analytics reporting. YouTube also provides data related to how users access the videos. Videos were viewed on their associated watch page, the YouTube Channel page, or on web pages where the videos were embedded; 91.6% of the videos were viewed on their associated YouTube watch page (each video has a unique "watch page"). Embedded videos on another site accounted for 6.4% of the views, and 2.9% of video views came from the YouTube Channel page. Users find our videos through various avenues, which are referred to as "traffic sources." Our top 4 traffic sources for this quarter include: YouTube search, YouTube suggested videos, direct URL links, and referrals from other web sites. Thirty-five percent (35%) of our views came from users accessing videos through YouTube Search.

YouTube suggested videos accounted for 24% of our views. Views from mobile apps or from direct traffic (links in an e-mail or copying/pasting the direct URL) account for 12% of video views. Finally, referrals from outside YouTube (Google search or access through external websites) account for 12% of video views.

- ✓ **CenUSA Web Site.** The CenUSA web site had 790 visitors this quarter. These visitors logged a total of 3,099 pageviews during 1,142 sessions. Pageviews are the total number of pages that visitors looked at during their time on the site. A session qualifies as the entire time a user is actively engaging with the site. If activity ceases for an extended period of time, and the user returns, a new session is started.

- ✓ **Twitter.** Twitter traffic consists of followers who subscribe to our account and "follow" our tweets (announcements). Followers can "favorite" a tweet, or retweet it to share with their own followers. They can also "mention" us by tagging CenUSA bioenergy's twitter account in their own tweets. During this quarter our tweets were retweeted a total of 78 times. Followers tagged CenUSA tweets as a favorite 110 times, and mentioned us 81 times. CenUSA bioenergy also has 499 followers currently, up from 399 followers last quarter.

- ✓ **Facebook.** By the end of January, CenUSA's Facebook page had 193 likes, up from 182 the previous quarter. Our most liked post from this quarter received 10 likes. The post with the largest reach had a total reach of 133 individuals.

a. Explanation of Variance

None

b. Plans for Next Quarter.

- ✓ Prepare February issue of the BLADES newsletter.
- ✓ Launch the updated CenUSA website.
- ✓ Prepare a nitrogen decision support tool fact sheet.
- ✓ Prepare the pyrolysis fact sheet.

c. Publications, Presentations, Proposals Submitted

- ✓ Webinar: Introduction of Biochar Commercialization Opportunities by David Laird (https://vimeo.com/118376782; or http://farmenergymedia.extension.org/video/biochar-introduction-industry)
- ✓ Archived Presentation –

- Biochar 101: Intro to Biochar by Kurt Spokas (https://vimeo.com/114174570 or http://farmenergymedia.extension.org/video/biochar-101-intro-biochar)

- University of Minnesota Extension Master Gardener Biochar Research Summary (https://vimeo.com/111655127 or http://farmenergymedia.extension.org/video/university-minnesota-extension-master-gardener-biochar-research-summary)

Producer Research Plots/Perennial Grass/Producer and Industry Education Team

a. Planned Activities

✓ **Indiana (Purdue University)**

- Exhibit for the Indiana FFA Leadership Center Planning.

- Plan activities for Year 4.

✓ **Iowa**

- Teach sessions at ISU Integrated Crop Management (ICM) Conference on Use of Perennial Grasses to Manage Nutrients and on Production Costs of Perennial Grasses.

- Harvest plots and gather samples.

- Plan for Year 4.

✓ **Minnesota**

- Harvest plots and gather samples.

- Plan activities for Year 4.

✓ **Nebraska**

- Complete final biomass sampling of switchgrass plots at both Nebraska locations.

- Make arrangements with a local farmer for remaining biomass to be harvested and removed.

- Remove automated weather stations.

b. Actual Accomplishments

✓ **Indiana**

- Exhibit for the Indiana FFA Leadership Center Planning.
- Program for 20 people (18 male, 2 female, all Caucasian).

✓ **Iowa**

- Taught sessions at the 2014 Integrated Crop Management Conference:
  - "Use of Perennial Grasses to Manage Nutrients" - two sessions with 221 total attendees.
  - "Production Costs of Perennial Grasses" - two sessions with 51 total attendees
- Harvested demonstration plots for yields and switchgrass samples
- Program about switchgrass for seven Caucasian males
- Planning for Year 4 programming

✓ **Minnesota**

- Harvested demonstration plots in November 2014; currently processing samples.
- Planning for Year 4 activities.
- Anne gave lecture for Soil Science class at Carleton College (Northfield, MN) in November where she discussed switchgrass-for-biofuel, marginal soils and CenUSA. There were 14 people in the class, including the instructor (9 male, 5 female, 1 Hispanic, 11 Caucasian).

✓ **Nebraska**

- Completed biomass sampling at both locations on November 4, 2014.
- Remaining biomass cut, baled and removed from plot area in November/December 2014.
- Removed automated weather stations.
- Planning for large exhibit at Husker Harvest Days (very large farm show in central Nebraska where we should reach thousands of farmers with our message).

c. Explanation of Variance

No variance was experienced.

d. Plans for Next Quarter

- ✓ Indiana

  We will concentrate on the following activities:

  - Presentation for the *Renewable Energy Workshop* in Batesville – Chad Martin
  - Presentation to the *Wabash County Ag School* on CenUSA Bioenergy – Chad Martin
  - *Indiana Small Farms Conference* – Chad Martin
  - *National Association of Power Engineers Presentation* – Chad Martin

- ✓ Iowa
  - Apply N treatments to switchgrass plots in April 2015.
  - Finalize plans for summer/fall outreach events and maintenance of plots.

- ✓ Minnesota
  - Continue demonstration plot sample processing.
  - Planning for Year 4 programming.

- ✓ Nebraska
  - Determine exact outreach activities for 2015.
  - Apply fertilizer to both biomass plots.
  - Apply herbicides to both biomass plots in April to control weeds as needed.
  - Continue development of exhibit for Husker Harvest Days.

e. Publications, Presentations, Proposals Submitted

None submitted.

2. Economics and Decision Tools

a. Planned Activities

- ✓ Finish first draft of *Producer Decision Tool*.
- ✓ Conduct first outreach meetings to share the tool and request feedback from attendees.

b. Actual Accomplishments

- ✓ Conducted two workshops at Iowa Crop Management Conference with a total of 51 participants in two sessions sharing the first draft of the *Producer Decision Tool*.

c. Explanation of Variance

None.

d. Plans for Next Quarter

Plan training event for CenUSA Extension team to share the decision tool and train members on how to use it in workshops.

e. Publications, Presentations, Proposals Submitted

Made two presentations at the 2014 Iowa Crop Management Conference on the *Producer Decision Tool*.

3. Health and Safety

See Health and Safety Objective report, above.

4. Public Awareness/Horticulture/eXtension/4-H and Youth Team

a. Youth Development

- ✓ **Planned Activities**
  - ➢ **Indiana**
    - Present CenUSA youth activities at NSTA conference (Orlando).
    - Complete pilot test of high school curriculum for fall semester.
    - Continue pilot test of high school curriculum for spring semester participants.
    - Continue work on signage for demonstration plots.
    - Continue work on electric modules for 4-H Beginner curriculum.
    - Continue work on final edits and layout for all curriculum.
  - ➢ **Iowa**
    - Host workshop for 4-H Youth Educators for dissemination of CenUSA programs to youth.

- Edit C6 videos for final release and place on the C6 BioFarm website.
- Continue development of C6 curriculum, iBook and C6 BioFarm game.

✓ **Actual Accomplishments**

➢ **Indiana**

- Presented CenUSA youth activities at Orlando NSTA conference in November.
- Completed pilot test and received feedback from participating teachers about CenUSA high school curriculum.
- Identified spring semester pilot test participants for high school curriculum.
- Determined layouts for demonstration plot interpretive sign tour with Purdue display production team.
- Continued work on digitizing high school curriculum, 4-H curriculum and interpretive signage supplementary materials.
- Total reached through CenUSA Youth activities this quarter.
  - ❖ 30 adults (17 male, 13 female)
  - ❖ 70 youth (40 male, 30 female)

➢ **Iowa**

- Conducted workshop for 7 4-H Youth Educators. They are now trained to disseminate CenUSA programs to youth.
- Edited career videos for final release and placed on the C6 BioFarm website.
- Continued development of curriculum, iBook and C6 BioFarm game.
- Submitted abstract for CenUSA Youth C6 presentation at 2015 Energy Summit (accepted).
- Hired three new student programmers to continue the C6 game development.
- Continued iBook development. Three chapters have been completed and reviewed by faculty, staff and experts by discipline and revised as needed.

✓ **Explanation of Variance**

None.

- ✓ **Plans for Next Quarter**

  - ➢ **Indiana**

    - Start spring semester pilot test of high school curriculum.
    - Install completed interpretive signage at CenUSA demonstration plot at Indiana State FFA Center.
    - Present at 2015 HASTI conference.
    - Present at 2015 National NSTA conference in Chicago.
    - Have 4-H curriculum edited and pilot tested.
    - Begin planning 2015 CenUSA sponsored renewable energy 4-H Science Workshop.
    - Identify additional opportunities for conference submissions.

  - ➢ **Iowa**

    - Plan summer workshop series to present C6 BioFarm to youth and adult educators.
    - Complete curriculum by end of March 2015.
    - Pilot curriculum in classrooms and review results.
    - Determine strategies for embedding STEM standards.
    - Hire summer interns for C6 and Youth outreach programming.

- ✓ **Publications, Presentations, Proposals Submitted**

  - ➢ **Indiana**

    - Presented at Orlando NSTA conference.
    - Proposal for 2015 HASTI (Hoosier Association of Science Teachers, Inc.) was accepted.
    - Proposal for Chicago NSTA conference was accepted.

  - ➢ **Iowa**

- Completed three iBook chapters.
- Submitted abstract for CenUSA Youth C6 presentation at 2015 Energy Summit (accepted).
- C6 videos finalized and posted to an internal ISU Dropbox site.

b. Broader Public Education/Master Gardener Program

✓ **Planned Activities**

➢ **Iowa**

- Preparations for Year 4 demonstration gardens.
- Conduct Extension Master Gardener volunteer recruitment.

➢ **Minnesota**

- Publish an eXtension blog post on CenUSA Extension Master Gardener volunteers from the Fond du Lac site and their work on how this garden has grown to include nutrition education for youth in their community.
- Acquire results of soil moisture tests done on soil samples collected from the St. Paul Campus' silty loam site and Andover's sandy site.
- Develop the 2014 Biochar Demonstration Garden Report based on the data that was submitted by the CenUSA Extension Mater Gardener Volunteers .

✓ **Actual Accomplishments**

➢ **Iowa**

- Prepared for Year 4 demonstration gardens.
- Began recruiting Extension Master Gardener volunteers.

➢ **Minnesota**

- Meleah Maynard wrote and published a blogpost for the national eXtension Master Gardener blog: http://blogs.extension.org/mastergardener/2014/12/02/2014-cenusa-bioenergy-project/. The blog is based on the volunteer's perspective of working on this research project at the Fond du Lac site.

- Took soil samples from the St. Paul Campus' CenUSA biochar (silty loam) site and the Andover (sandy site). Kurt Spokas, USDA ARS soil scientist has offered to conduct moisture and compaction tests on the samples (control and biochar-amended soils)
- Began work on the 2014 CenUSA Biochar Demonstration Garden Report.
- Prepared and submitted a proposal for the CenUSA Extension Master Gardener Biochar Demonstration Gardens for consideration for the *International Gardener Search for Excellence* Award.

Fig. 22. CenUSA Master Gardener Biochar Demonstration Garden at Fond du Lac site

✓ **Explanation of Variance**

None.

✓ **Plans for Next Quarter**

➢ **Iowa**

- Order and start seeds for biochar demonstration garden plots.
- Yvonne McCormick will attend Story County Master Gardeners meeting to give an update on biochar research results and recognize CenUSA biochar volunteers on March 16, 2015.

- Yvonne McCormick: provide presentation on biochar and soil health at Calhoun County Garden Seminar on March 14, 2015.
- Yvonne McCormick will provide presentation on biochar project and Master Gardener participation at the Des Moines Botanical Center on March 21, 2015.

➢ **Minnesota**

- Complete the 2014 report on the CenUSA Biochar Demonstration Garden results.
- Acquire the final results of soil moisture tests done on soil samples collected from the St. Paul Campus' silty loam site and the Andover sandy site.
- Recruit approximately 12 new volunteers for the 2015 CenUSA biochar demonstration gardens.
- Contract with grower to start demonstration garden seeds.
- Update applications, position descriptions, forms and garden procedures for CenUSA biochar volunteers.
- Update garden design.
- Schedule demonstration garden leader team meeting in March 2015.
- Promote the CenUSA Biochar Research Project via a display at the Anoka County Extension Master Gardeners Home Landscaping and Garden Fair event on April 11, 2015.

✓ **Publications, Presentations, Proposals Submitted**

- Meleah Maynard wrote and published a blogpost for the national eXtension Master Gardener blog: http://blogs.extension.org/mastergardener/2014/12/2014-cenusa-bioenergy-project/. The blog is based on the volunteer's perspective of working on the CenUSA research project at the Fond du Lac site.

5. Evaluation and Administration

a. Planned Activities

✓ Collect information from CenUSA Extension teams and prepare reports.

- ✓ Continue support for development of CenUSA C6 Youth app, videos, and iBook publication.
- ✓ Schedule meetings with CenUSA Extension teams to plan and budget for Year 5 activities.
- ✓ Meet with ISU Animal Science faculty to plan beef feedlot switchgrass feeding trials for 2015.
- ✓ Develop abstracts to recruit CenUSA interns for summer 2015.
- ✓ Contact government and non-profit groups in Pella, IA region to explore opportunities to include Vermeer plots in field days planned for summer/fall 2015.

b. Actual Accomplishments

- ✓ Collected information from CenUSA Extension teams and prepared reports.
- ✓ Continued development of the C6 Youth programs.
- ✓ Scheduled meetings with CenUSA Extension teams in each state to plan for 2015 work and budgets.
- ✓ Worked with Nebraska and Ohio to develop new subcontract for CenUSA Extension team members working with videos, fact sheets, research summaries, newsletters and social media.
- ✓ Met with Animal Science faculty to plan beef feedlot switchgrass feeding trials for 2015.
- ✓ Submitted abstract for evaluation presentation at 2015 Energy Summit (accepted).
- ✓ Posted survey results report on Beaver Crossing/Dawson, NE perennial grass management field days (Exhibit 2).
- ✓ Analyzed survey results from MN organic field day (*Managing Perennial Grasses for Bioenergy*).
- ✓ Wrote report on survey results from *Managing Perennial Grasses for Bioenergy* (Minnesota) (Exhibit 3).
- ✓ Analyzed survey results for biofuel harvest field days.
- ✓ Contacted government, non-profit and for-profit groups in Pella, Iowa region to offer Vermeer plots for field days/tours planned for summer 2015.

c. Explanation of Variance

None

d. Plans for Next Quarter

- ✓ Collect information from CenUSA Extension teams and prepare reports.
- ✓ Meet with CenUSA Extension teams in each state to make plans for Year 5 and discuss no-cost extension opportunities and prepare budgets for Year 5.
- ✓ Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing impact of CenUSA Extension efforts.
- ✓ Support C6 team to continue development of educational materials targeting K-12 youth.
- ✓ Meet with all CenUSA Extension teams to continue planning and orchestrating to meet deliverables in CenUSA Work Plan.
- ✓ Collect information from CenUSA team members and prepare reports.
- ✓ Hire a trucker to haul switchgrass from Lincoln, Nebraska to two locations in Iowa where beef feedlot research will take place.

- **Publications, Presentations, Proposals Submitted**

  None this quarter.

Objective 10. Commercialization

Objective 10A. Archer, Daniels, Midland.

Sub-Objective 1

1. Planned Activities

Fast pyrolysis of ADM's fractions using a free-fall reactor to recover sugars and other value-added products was planned.

Previously, a proprietary pretreatment method was developed to treat lignin for pyrolysis in a fluidized bed reactor. As a result, the agglomeration of lignin during pyrolysis is completely inhibited and continuous operation in a fluidized bed reactor was achieved. Several trials of pyrolysis experiments using different pyrolysis temperatures were successfully performed. The GPC results show that the pyrolysis oils are mainly composed of low molecular weight phenolic compounds.

In this period, pyrolysis experiments of pretreated lignin were repeated at temperature range of 450°C to 600°C for better mass balance calculation and the resulting pyrolysis products were analyzed using different analytical methods.

2. Actual Accomplishments

- **Fast Pyrolysis of ADM's integrated soluble fractions (Fraction D & E) using a free-fall reactor**. Fast pyrolysis using a continuous free-fall reactor was performed. Figure 23 shows a schematic diagram of the free-fall reactor used. The reactor consisted of a feeder, a 35-mm diameter stainless steel reactor of 3.05 m height, a char collection system, and a bio-oil collection system. For the all pyrolysis tests, nitrogen sweep gas was introduced into the reactor at 60 standard L / min. In this test, both samples (Fraction D and E) were prepared to have 50 wt % moisture content to feed into the reactor. Each solution was released and atomized into a spray by helium around the nozzle. All heaters were set at 600 ˚C and the pyrolysis vapors inside the reactor maintained around 550 ˚C as monitored by thermocouples.

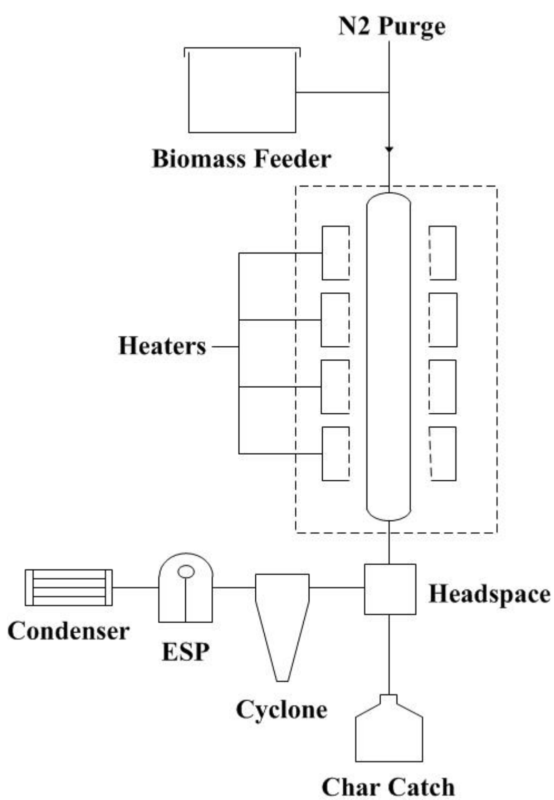

Fig. 23. A schematic diagram of free-fall reactor

Agglomerated char chunks were found inside the reactor bed after all pyrolysis tests as shown in Figure 24 and 25. The visual observation of the agglomerates clearly indicates that they were formed from liquid intermediates. In this test, non-volatile and viscous sugars (mostly hemicellulose derived) are most likely turned into char agglomerates. Due to the formation of agglomerates, a heavy fraction of bio-oil was not collected from the electrostatic precipitator. However, a light fraction of bio-oil was collected from the condenser and subjected to further analysis including water and acids content. Figure 26 shows the composition of the light fraction of bio-oils obtained from fraction D and E. Both fractions contained approximately 90 wt% of water and the yield of acetic acid was 4.8 and 7.7 wt% from fraction D and E, respectively. Recalling the content of acetic acid in original feedstock, most of the acetic acid was selectively recovered from light fraction of bio-oil. Although the recovery of sugars was not possible due to their non-volatile and viscous nature, this work had a partial success in recovery of acids.

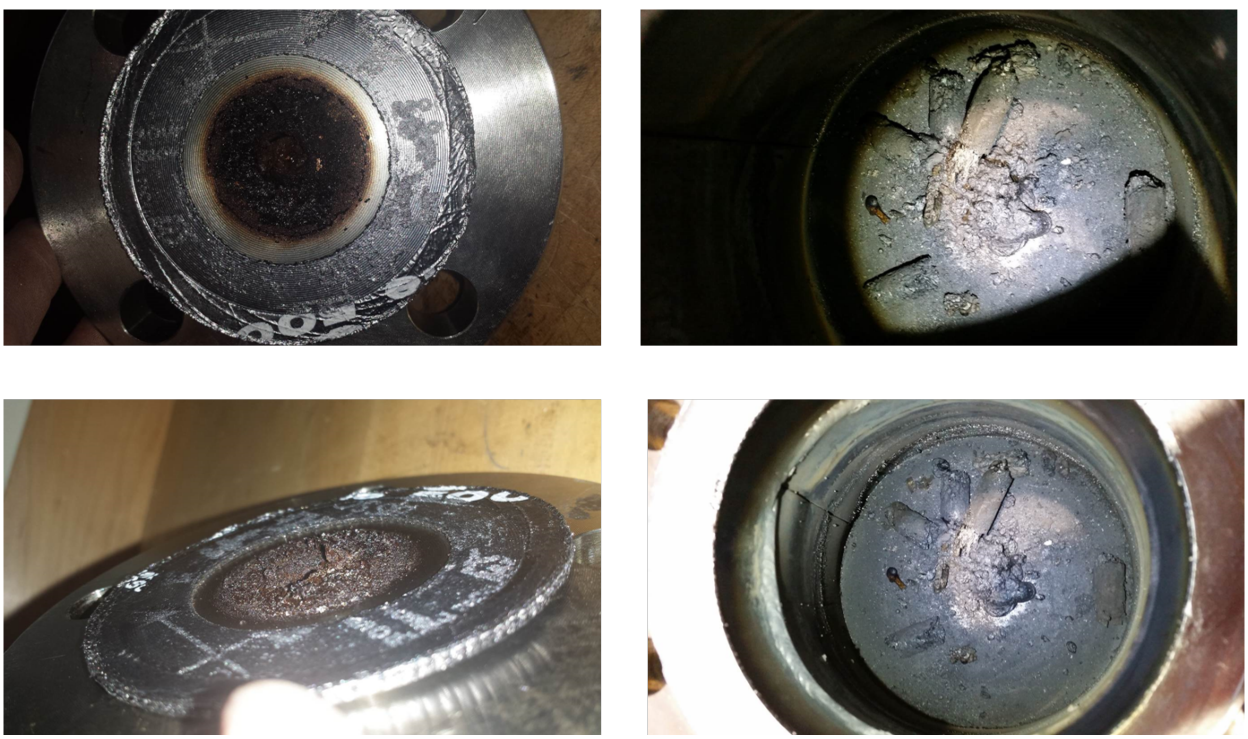

Fig. 24. Formation of agglomerates inside the reactor and recovery from char catch

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Fig. 25. Char agglomerates recovered from the free fall reactor upon completion of pyrolysis.

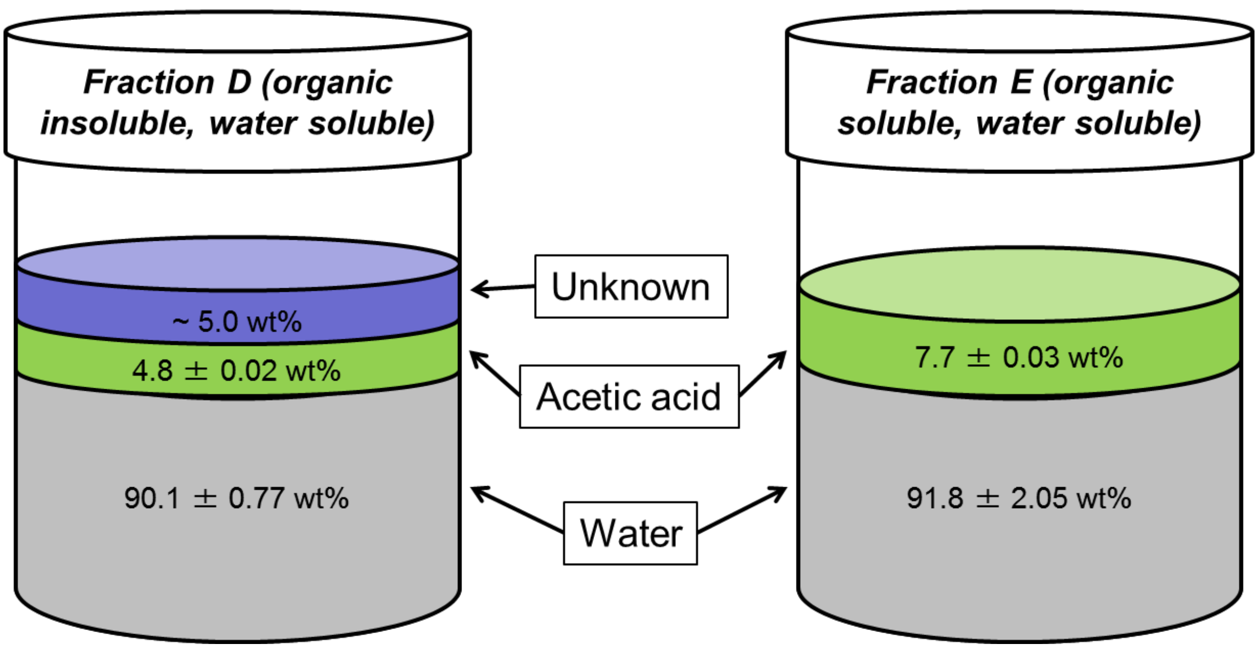

Fig. 26. Compositional analysis of light fraction of bio-oil from fraction D and E.

- **Pyrolysis of pretreated lignin in fluidized bed reactor at different temperatures**. Figure 27 summarizes the yield of liquid, non-condensable gases, and char from lignin pyrolysis in a fluidized bed reactor at 450, 500, 550, and 600°C.

For all the pyrolysis experiments, mass balances of greater than 85% were attained. The temperature did not have significant effect on the liquid yield as pyrolysis temperature changed from 450 and 600°C (37.4% at 450°C, 36.7% at 500°C, 38.3% at 550°C, and 37.0% at 600°C). However, temperature has much more effect on the yields of char and gases. With temperature increased, the char yields decreased from 38.4% to 30.4%. Accordingly, the yields of non-condensable gases increased from 12.6% to 19.5%. It is found that the reduction of the char at higher temperatures was accompanied by the increase in light gases. The 7% increase of gases (lignin based) is comparable to the 8% decrease of char yield.

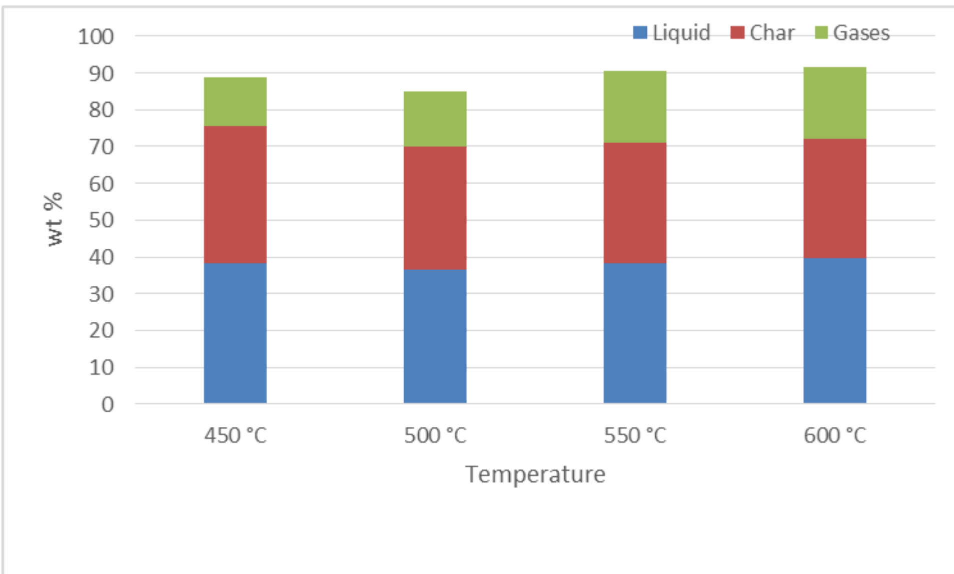

Fig. 27. Yield of liquid, char, and gases of pretreated lignin pyrolysis in fluidized bed reactor at different temperatures.

The major non-condensable gas products are methane, carbon monoxide, and carbon dioxide. Carbon dioxide is the most abundant gas product among them. Small amounts of hydrogen, ethane, and ethylene were also detected. The yields of these non-condensable gases are plotted in Figure 28 and 29, and the selectivity of different gases is shown in Figure 30.

As shown in Figures 28 and 29, the production of all six gas species was enhanced at higher temperatures (550 and 600°C).

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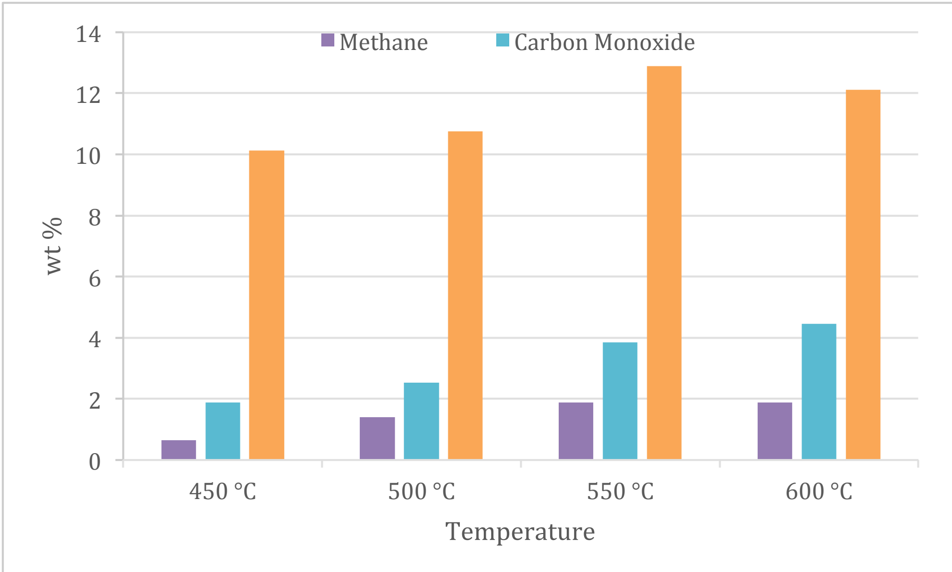

Fig. 28. Composition of gases (methane, carbon monoxide, and carbon dioxide) at different temperatures.

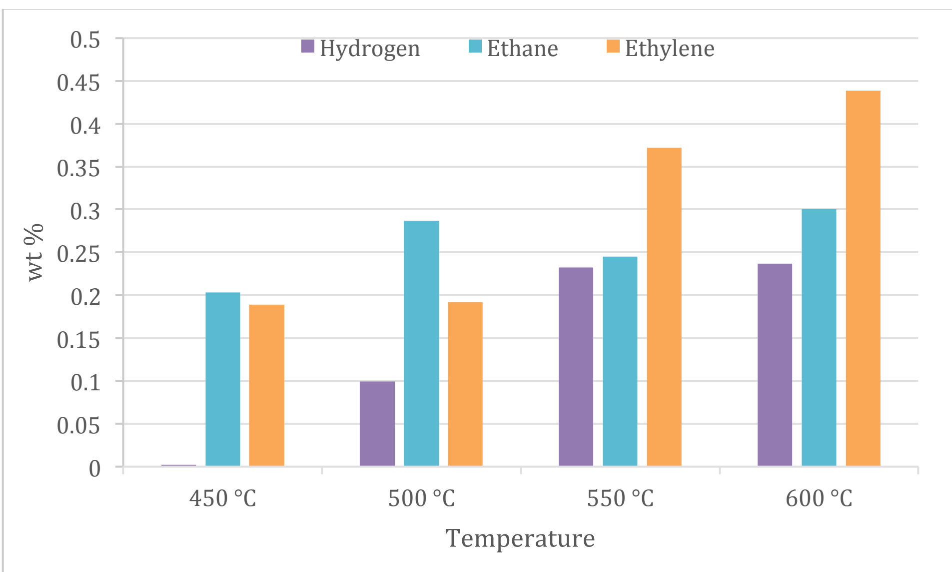

Fig. 29. Composition of gases (hydrogen, ethane, and ethylene) at different temperatures.

- **Selectivity of non-condensable gas species**. The temperature also affects the selectivity of non-condensable gas species (Figure 30). For CO_2, its selectivity dropped from 77.6% at 450°C to 62.3% at 600°C. The selectivity of CO increased from 14.4% to 23%, CH_4 increased from 4.9% to 9.7%, H_2 increased from 0.015% to 1.2%, ethylene increased from 1.5% to 2.3%. The selectivity of ethane did not show a clear trend. The results suggest that higher temperatures enhance the cracking of pyrolytic products to form more light gases.

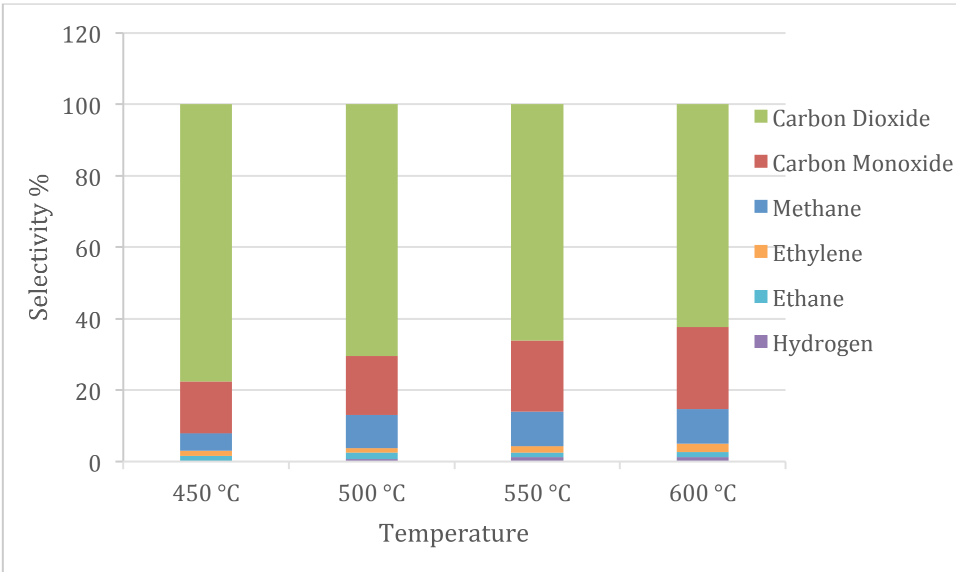

Fig. 30. Selectivity of gases at different temperatures.

The water content of the oils was measured by Karl-Fisher titration (Figure 31). Stage fraction 1 (SF1) is an organic phase that contains minimal water whereas stage fraction 2 (SF2) is an aqueous phase that collects most of water. The water content in SF1 and SF2 were combined and total water content based on lignin feedstock weight are given in Figure 34. During pyrolysis at given temperature range, about 12.8-13.8% of water was produced, indicating varying pyrolysis temperature does not affect water yield significantly.

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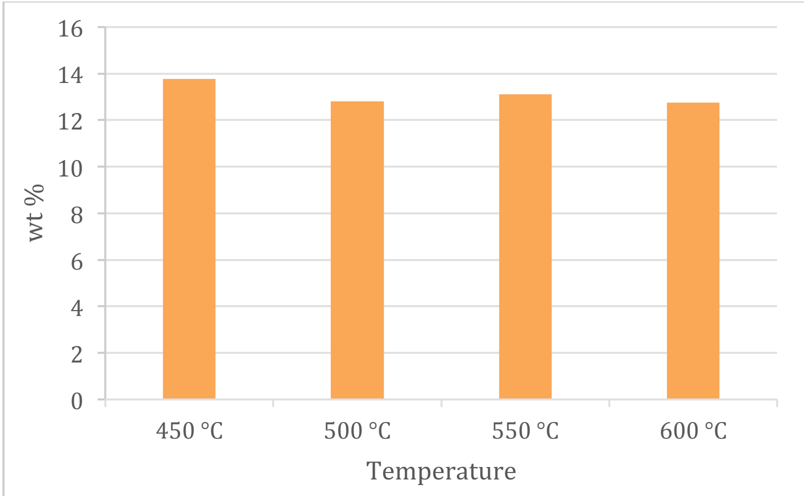

Fig. 31. Water content of pyrolysis oils at different temperatures (lignin-based).

The pyrolysis oils were condensed into two fractions: SF1 and SF2. A majority of phenolic compounds were collected in SF1 while a small amount of phenolic compounds were also found in aqueous phase of SF2. The composition of liquid products was analyzed by GC/MS. In total, fifteen phenolic compounds were quantified and the results are given in Table 15.

Two phenols with vinyl groups (4-vinylphenol and 2-methoxy-4-vinylphenol) are the major phenols in the liquid products. Yields of other phenols were no more than 1%. Although the total yields of liquid products were similar with different pyrolysis temperatures, the selectivity of the phenolics changed with temperature. The yield of phenol increased at 600°C compared to lower temperatures. Creosol and p-cresol showed similar trends. The change of 2-methoxyphenol was not significant. For other phenolic compounds with side chains and methoxy groups, their yields decreased as temperature increased. The results indicate that higher temperatures promote the cracking of side chains and demethoxylation of the phenolic compound. The increase of the non-condensable gases also confirmed this conclusion.

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Table 15. Yield of monomeric phenols in pyrolysis oils at different temperatures (calculation based on lignin).

Products	450°C	500°C	550°C	600°C
Phenol	0.33	0.33	0.36	0.58
2-methoxy-Phenol	0.23	0.22	0.17	0.24
p-Cresol	0.13	0.15	0.16	0.25
Creosol	0.18	0.16	0.14	0.24
Phenol, 4-ethyl-	0.23	0.18	0.17	0.18
Phenol, 4-ethyl-2-methoxy-	0.18	0.13	0.13	0.17
4-Vinyl-Phenol	2.13	2.29	2.46	1.50
2-Methoxy-4-vinylphenol	1.22	1.03	0.71	0.75
Phenol, 2,6-dimethoxy-	0.24	0.18	0.11	0.08
Isoeugenol	0.14	0.12	0.11	0.12
1,2,4-Trimethoxybenzene	0.10	0.06	0.04	0.01
Vanillin	0.14	0.11	0.09	0.07
Benzene, 1,2,3-trimethoxy-5-methyl-	0.05	0.04	0.03	0.02
3',5'-Dimethoxyacetophenone	0.20	0.15	0.11	0.09
Phenol, 2,6-dimethoxy-4-(2-propenyl)-	0.16	0.10	0.06	0.04

- **Brief Summary Based on Results**
  - Fast pyrolysis of ADM's integrated soluble fractions (Fraction D and E) were performed using a continuous free-fall reactor
  - Sugars and sugar derived compounds were not able to be recovered due to their non-volatile and viscous nature but most of acetic acid was selectively recovered
  - Pyrolysis of pretreated lignin were performed at 450, 500, 550, and 600°C in a fluidized bed reactor, the highest liquid yield of 38.3% and lowest char yield of 30.4% were obtained. Higher than 85% of mass balance was reached at all pyrolysis temperatures.
  - High temperatures enhanced the production of gases while reducing the production of char.
  - The selectivity of carbon dioxide in the gas stream decreased as temperature increased.
  - High temperature promotes the cracking reaction and demethoxylation reactions.

3. Explanation of Variance

None noted.

4. **Plans for Next Quarter**

- Tests will be conducted to convert furfural derived from hemicellulose streams into value-added furan compounds such as 2-methylfuran or tetrahydrofuran. 2-methylfuran is a promising furan compound as it can be used as a fuel additive. The test will be performed using a continuous reactor with various catalysts and varying reaction conditions.
- New results will be added to a manuscript.
- A new lignin feedstock extracted from wood by supercritical hydrolysis will be studied.

Sub-objective 2: Prepare and characterize biochar

1. **Planned Activities**

The work documenting the effects Fe and Al pre-treatments of biomass on biochar AEC will be prepared as a manuscript for publication.

2. **Actual Accomplishments**

- Preparation of a manuscript documenting the effects of Fe and Al pre-treatments of biomass on biochars AEC was initiated. Data for this manuscript has been compiled and preliminary figures, tables have been developed.

  Analysis of albumin biochar was completed to provide additional supporting data for the manuscript entitled "Anion Exchange Capacity of Biochar." The albumin biochar is a high N-biochar, which allows us to test the hypothesis that protonated N-heterocycles (pyridinium groups) contribute anion exchange capacity of biochars. In the following data sets the results for the albumin biochar produced at 500 and 700^{o}C are new; results for cellulose, corn stover, and alfalfa meal biochars produced at 500 and 700^{o}C have been previously reported.

  Chemical analysis indicated that the 500 and 700^{o}C albumin biochars contained 10.8 and 8.39% N, respectively (Table 15). Oxygen content of the fresh albumin biochars could not be determined because these samples contained significant levels of ash, which interferes with O determination by difference. However, acid treatments (both HF+HCl) removed most of the ash allowing O contents of 8.41 % and 11.84 % to be determined for the 500 and 700^{o}C acid treated-albumin biochars, respectively. FTIR analysis of the fresh albumin biochars (Figure 32) revealed little indication of oxygen containing functional groups (carbonyl, hydroxyl, and either groups), however a prominent either band (~1200 cm^{-1}) was evident in the FTIR spectra of the acid treated albumin biochar (Figure 33), suggesting that the sample had undergone significant oxidation during the acid treatments. The 1590 cm^{-1} band in the FTIR spectra has previously been attributed to O-heterocycles (oxonium groups), which may contribute pH-independent AEC to biochars. The intensity of the 1590 cm^{-1} band was weaker in the spectra of the albumin biochars than in the spectra of the cellulose, corn stover, and alfalfa biochars, however the presence of some oxonium groups in the albumin biochars cannot be ruled out. The FTIR analysis provided no evidence of pyridine groups, however, N1s X-ray Photoelectron Spectroscopy (XPS) of the 500°C and 700°C albumin biochars indicated that a significant fraction of the total N in the albumin biochars was present as pyridine N. Analysis of anion exchange capacity of the albumin biochars revealed substantial AEC under acidic conditions (pH=4) and non-zero levels of AEC under alkaline (pH=8) conditions (Table 16). The results thus indicate that both pH-dependent pyridinium groups and pH-independent oxionium groups may contribute AEC to biochars.

Table 16. Properties of the untreated biochars, including mass yields, elemental composition, pH, ash content, specific surface area, and particle density.

Feedstock	HTT (°C)	Yield (%)	O	C	N	H	S	pH	(%)	(m2/g)	(g/cm3)
Albumin	500	24.2	60.81	10.8	2.91	0.34	a	12.5	19.49	0.9	*
Albumin	700	21.2	62.05	8.39	1.71	0.34	a	12.7	26.36	2.6	*
Alfalfa	500	29.8	66.03	3.4	2.43	0.18	a	10	28.84	39	1.61
Alfalfa	700	29.0	68.8	3.23	1.45	0.25	a	10	30.89	176	1.9
Cellulose	500	27.9	84.8	0	2.98	0.08	10.82	8.3	0.87	321	1.34
Cellulose	700	26.0	90.3	0.01	1.72	0.12	6.12	8.6	0.92	229	1.68
Corn Stover	500	31.5	75.45	1.48	2.67	0.08	a	10.1	20.03	150	1.56
Corn Stover	700	29.8	77.54	1.23	1.48	0.13	a	10.2	21.93	259	1.74

[a] Cannot be determined from the methods used. [*] Not measured

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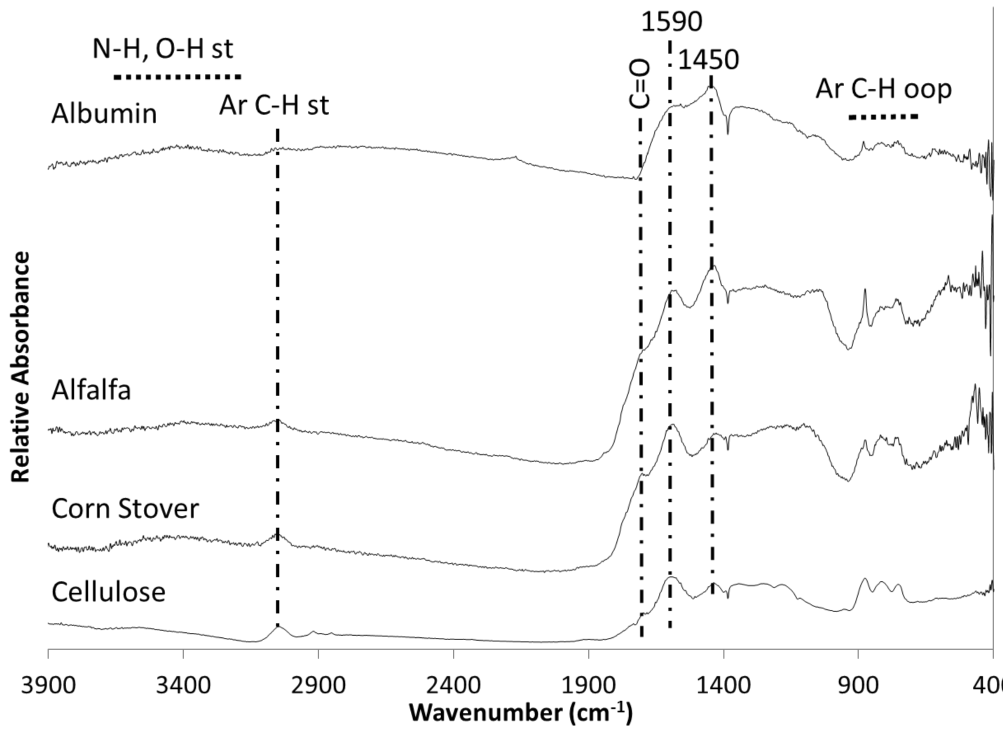

Fig. 32. FTIR spectra of dialyzed biochars slow pyrolyzed at a HTT of 500 °C. N-H, O-H st indicate hydroxyl or amine/amide H-stretching bands; Ar C-H st is aromatic C-H stretching, C=O is carbonyl stretching, and Ar C-H oop indicates aromatic C-H out of plane vibrations.

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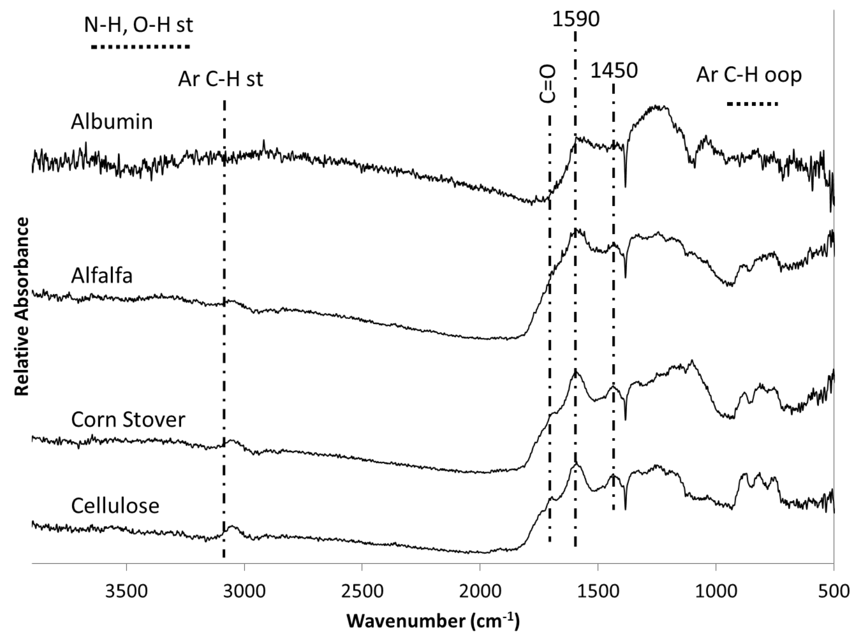

Fig. 33. FTIR spectra of HCl treated 500 °C HTT biochars. N-H, O-H st indicate hydroxyl or amine/amide H-stretching; Ar C-H st is aromatic C-H stretching, C=O is carbonyl stretching, and Ar C-H oop indicates aromatic C-H out of plane vibration.

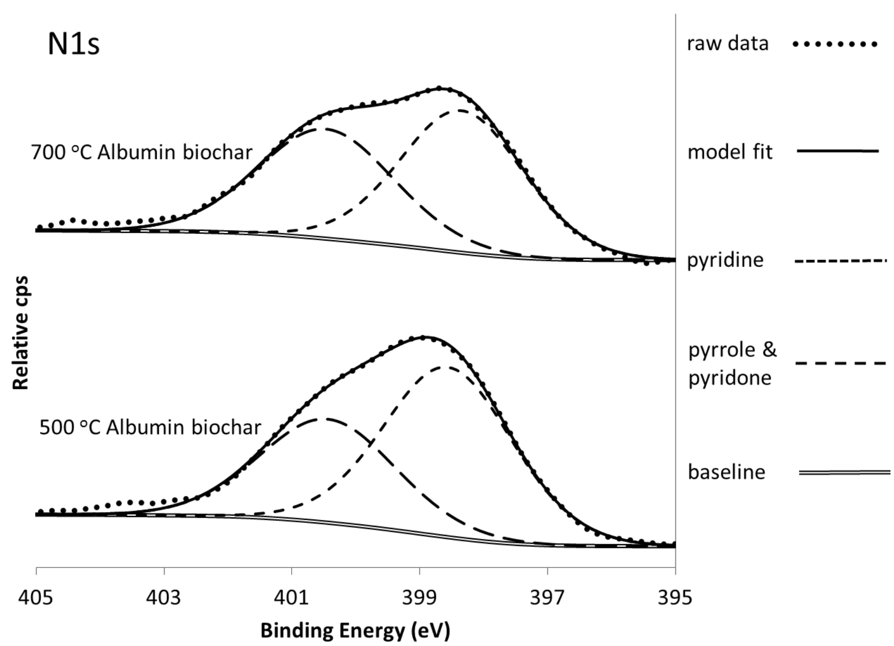

Fig. 34. The N1s XPS spectra of the 500°C and 700°C albumin biochars.

Table 17. Anion exchange capacity of biochars produced from three feedstocks at 500 and 700 °C HTT. Analyses performed in triplicate and data is presented as average (standard deviation)

Feedstock	HTT (°C)	pH 4 (cmol kg^{-1})	pH 6 (cmol kg^{-1})	pH 8 (cmol kg^{-1})
Albumin	500	14.7 (1.05)	2.45 (0.464)	1.65 (0.948)
Albumin	700	15.5 (1.71)	5.95 (1.10)	2.32 (0.881)
Alfalfa	500	10.9 (2.46)	3.1 (0.28)	0.94 (0.34)
Alfalfa	700	25.8 (4.08)	9.6 (1.07)	2.1 (0.87)
Cellulose	500	7.8 (1.94)	2.6 (0.21)	0.60 (0.37)
Cellulose	700	24.2 (5.94)	18.1 (8.66)	4.1 (0.18)
Corn Stover	500	17.5 (5.81)	3.8 (0.66)	1.0 (0.21)
Corn Stover	700	27.8 (9.10)	13.8 (4.22)	7.2 (1.39)

3. Explanation of Variance

Publishing the manuscript entitled "Anion Exchange Capacity of Biochar" is a high priority, therefore we focused on obtaining new data for the albumin biochars, which was needed to revise the manuscript in response to reviewer comments.

4. Plans for Next Quarter

The manuscript entitled "Anion Exchange Capacity of Biochar" will be re-submitted for publication. Changes in the physical and chemical properties of biochars on aging in soil environments will be quantified.

Objective 10B. Renmatix

1. Planned Activities

- **Task 10c-1:** Initial physical and chemical characterization of feedstocks provided by CenUSA.
- **Task 10c-1.3:** Biomass characterization: Conduct full chemical and physical characterization of biomass samples. Lignin characterization by NMR will be also accomplished.

2. Actual Accomplishments

- **Task 10c-1:** Initial physical and chemical characterization of feedstocks provided by CenUSA.

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- **Task 10c-1.3:** Renmatix received nine out of 11 biomass samples for full chemical and physical characterization. A complete report of biomass characterization will be issued under separate cover. Full chemical characterization was completed for five of the biomasses. Physical characterization was completed for all nine biomasses.

Table. 18. Status of biomass characterization to date.

No.	Biomass	Harvest		Chemical characterization	Physical characterization
		Month	Year		
1	Switchgrass	Aug.	2014	25	100
2	Switchgrass	Nov.	2013	100	100
3	Low diversity mix	Aug.	2014	100	100
4	Low diversity mix	Nov.	2013	100	100
5	Big bluestem	Aug.	2014	100	100
6	Big bluestem	Nov.	2013	100	100
7	Corn stover	Oct.	2014	25	100
8	Indiangrass	Nov.	2014	25	100
9	Bio-energy big bluestem	Nov.	2014	25	100

- **Technical discussions around corn stover and switchgrass milling.**

  As part of our work in this Commercialization Objective, we will be processing ground corn stover and ground switchgrass through our pilot unit later this year. The plan was for Iowa State to grind the stover and switchgrass, provided by Rob Mitchell of the USDA, to the particle size that is needed to feed our pilot unit and then ship it to Renmatix. While ISU worked diligently to get the stover to the required particle size, the yield of material from the ISU mills was too low to generate enough material for our pilot work. We found a third party, HV2 Enterprises of Easton, PA, and through small-scale tests, who demonstrated that they could mill to the required particle size in sufficient quantities. ISU approved this deviation from the original plan, and HV2 Enterprises will mill both biomasses next quarter.

3. **Explanation of Variance**

- **Task 10c-1**. Initial physical and chemical characterization of feedstocks provided by CenUSA.

- **Task 10c-1.3**. Due to trouble with a key piece of analytical equipment, chemical characterization for four samples was not completed by the time of this report. However, the equipment issue has now been resolved and the complete chemical characterization is ongoing. Results for these four samples will be reported next quarter when their analyses are complete and data is compiled. Table 18 shows status of biomass characterization to date.

As indicated in the previous quarterly report, two biomass samples (indiangrass and bio-energy big bluestem) were received later than originally planned due to the decision to harvest them after the frost. The 2014 corn stover sample was also received at that time. Therefore, full chemical characterization was not completed by the end of the year as scheduled for these three biomass species. This was discussed with Rob Mitchell and it was agreed that it should not adversely impact the general plan of the project.

The same equipment issue mentioned above also affected the start of lignin isolation for lignin characterization by NMR. With the equipment issue resolved, sample preparations are started and are currently in progress. Results should to be reported by next quarter.

4. **Plans for Next Quarter**

- **Task 10c-1:** Initial physical and chemical characterization of feedstocks provided by CenUSA.
- **Task 10c-1.3:** Continue chemical characterization of remaining biomasses. Samples will be prepared for lignin structure characterization by NMR analysis.
- **Task 10c-2:** Kinetics study for hemicellulose removal by hot water extraction. A select number of samples will be subjected to hot water extractions at different conditions of temperature and time to study the release of hemicellulose.

5. **Publications, Presentations, Proposals Submitted**

None submitted.

Objective 10C. USDA-ARS, Lincoln, Nebraska

1. **Wildlife Habitat Studies**

- **Visual obstruction measurements (VOM) on high-yielding perennial energy crops.** VOM provides a rapid and repeatable method for estimating biomass, as well as monitoring height and vertical density of standing vegetation. The VOM not only estimates standing biomass, but gives an indication of the wildlife habitat characteristics, information currently lacking for high-yielding perennial biomass feedstocks. VOM and elongated leaf height were collected at weekly intervals from the middle of the growing season until post-frost harvests in 2013 and 2014. All VOM and elongated leaf height data are being summarized.

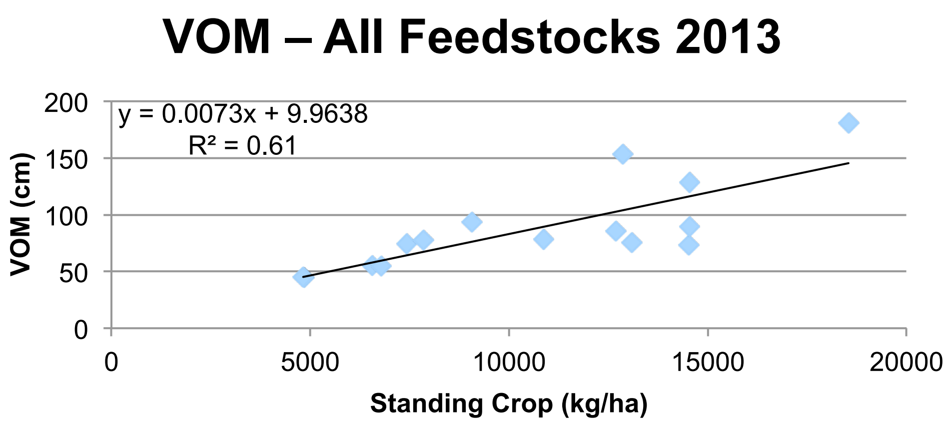

Fig. 35. The relationship between VOM and standing crop for switchgrass, big bluestem, and low diversity mixtures near Mead, NE in 2013.

- **Perennial grass options for degraded wetlands in the Great Plains.** In 2014, a small-plot herbaceous perennial feedstock research and demonstration site was established on a floodplain in cooperation with Vermeer Manufacturing near Pella, Iowa. The site flooded after grass seedling emergence and provided the first confirmation of seedling flood tolerance in Liberty switchgrass and Savoy prairie cordgrass. This has led us to collaborate with Dr. Jack Norland, NDSU, to place a native perennial grass trial on two farmed wetland sites in eastern North Dakota and one farmed wetland site in eastern Nebraska in 2015. If successful, we will be able to provide new native perennial grass options for grazing, bioenergy, and wildlife habitat in degraded wetlands in the Great Plains.

- **Effect of harvest date and harvest height on yield.** In 2013, work with the National Wildlife Federation and a CenUSA Advisory Board member elucidated the need for data on how harvest height affects perennial grass yield. They wanted to know how much yield is reduced by harvesting perennial grasses at a 12” stubble height rather than at a 4” stubble height. With this information, they could then offer economically reasonable landowner incentives to leave more biomass in the field for over-wintering wildlife habitat. In 2013, we initiated a study to harvest Liberty switchgrass, big bluestem, and low diversity mixtures at 2”, 4”, 6”, 8”, 10”, and 12” stubble heights at anthesis and after a killing frost. Average yield reduction in 2013 ranged from 0.7 tons/acre by going from 4” to 6” harvest height to 2.2 tons/acre by going from a 4” to 12” harvest height. The 2” harvest height resulted in a lot of soil in the samples, especially as the soil dried after a killing frost.

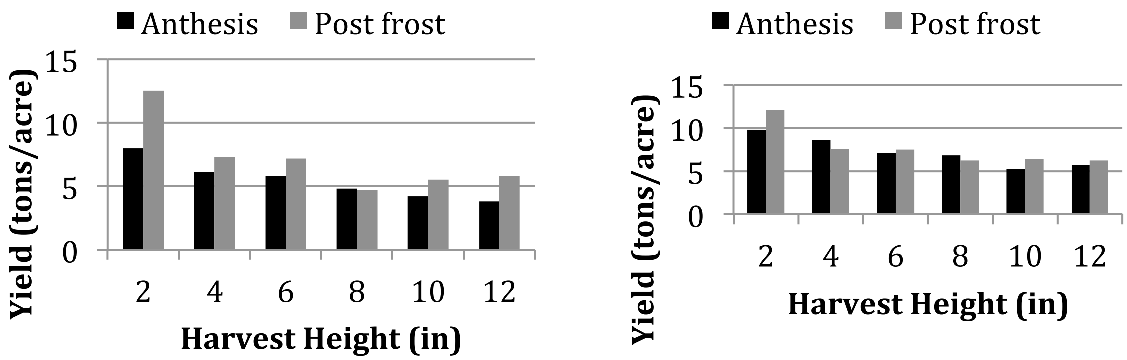

Fig. 36. The effects of harvest height on harvested yield for switchgrass, big bluestem, and low diversity mixtures harvested at 2", 4", 6", 8", 10", and 12" stubble heights at anthesis and after a killing frost near Mead, NE in 2013.

2. Field Scale Biomass

- **Yield and production costs for native perennial warm-season grasses grown at the field scale.** Yield is the primary factor determining the feasibility of perennial bioenergy feedstocks. Baled and transported yields were about 2 tons per acre lower than expected based on our growing season standing crop estimates. The limited precipitation in 2012 and 2013 is still impacting biomass yield. Herbicide damage in early summer 2014 reduced switchgrass yield. There was no clear response to N fertilization after 2 years of N treatments. The transported yield represents the biomass that was harvested, baled, and transported off the field to a bale storage facility. Research is in progress to determine biomass losses in the harvest, baling, and transport phases. Cost of production in 2014 ranged from $66 to $77/ton of biomass delivered to the field edge with land rental rates of $150/acre (Table 19).

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Table 19. Baled dry matter yields for switchgrass, big bluestem, and low diversity mixture fields fertilized with 50 or 100 lb N/acre. Feedstocks were harvested and baled in November 2013 and 2014 from fields near Mead, NE.

Feedstock	2013	2014	2014 Cost of Production
	----- Dry Matter Yield (tons/acre) -----		
			$/ton
Switchgrass	5.1	4.5	$76.76
Big bluestem	4.1	4.7	$74.66
Low diversity mix	5.0	5.7	$66.37

- **Demonstrating commercial production and harvesting of perennial warm-season grasses.** We established and managed a field-scale herbaceous perennial feedstock research and demonstration site in cooperation with Vermeer Manufacturing near Pella, Iowa. These feedstocks were harvested and baled by Vermeer Corporation on November 12 – 13, 2014. Baled yield on a dry matter basis was 1.8 tons/acre for Liberty, 1.1 tons/acre for big bluestem, and 1.2 tons/acre for the LDM. Bales were sampled for future analysis.

3. Alternative Uses for Native Perennial Warm-season Grasses

- **Livestock performance on native perennial warm-season grasses.** Completed Year 3 of the warm-season (WS) grass grazing trial comparing switchgrass (PV), Indiangrass (SN), big bluestem (AG), and 2 WS grass mixtures. Grazing is a very profitable option and can mitigate the risk for growing perennial grasses for bioenergy. The average of the first 3-year body weight gains ranged from 144–225 lbs BW/acre. At current market prices of greater than $2/lb, gross returns range from $290-450/acre. These WS grasses may provide dual use for grazing and biomass production with appropriate management.

Table 20. Average daily gain (ADG) and body weight (BW) gain for switchgrass, big bluestem, Indiangrass, Mix 1 (big bluestem, Indiangrass, and sideoats grama) and Mix 2 (big bluestem, Indiangrass, switchgrass, little bluestem, and sideoats grama) pastures grazed for three years near Mead, NE.

Feedstock	ADG (lb/hd/day)	BW Gain (lb beef/acre)
Switchgrass	1.0	144
Big bluestem	1.5	221
Indiangrass	1.5	218
Mix 1	1.5	212
Mix 2	1.6	225

- **Native grass pellets for home heating.** Perennial warm-season grasses have been pelletized to increase density to about 38 lb ft^{-3}, comparable to low-grade coal. Liberty switchgrass, big bluestem, and the low diversity mixture were pelleted and bagged in 50# bags for $65/ton. Compared with wood pellets, warm-season grass pellets will have higher ash and mineral content. Locally, premium wood pellets sell for $249/ton in 40# bags. Assuming warm-season grasses have a market value of $100/U.S. ton and pelleting and bagging costs $65/ton, warm-season grass pellets could realize $84/ton profit. Warm-season grass pellets have been shipped for comparison testing with wood pellets in a home boiler.

Treatment of Mature Switchgrass and Cornstalks with Calcium Hydroxide and Comparison of Untreated Mature Switchgrass and Cornstalks as Roughage in Beef Cattle Feedlot Diets

C.A. Clark[1], G.R. Dahlke[2], D.L. Maxwell[1], S.K. Clark[2], M.L. Van Emon[2], D.D. Loy[2], S.L. Hansen[2]

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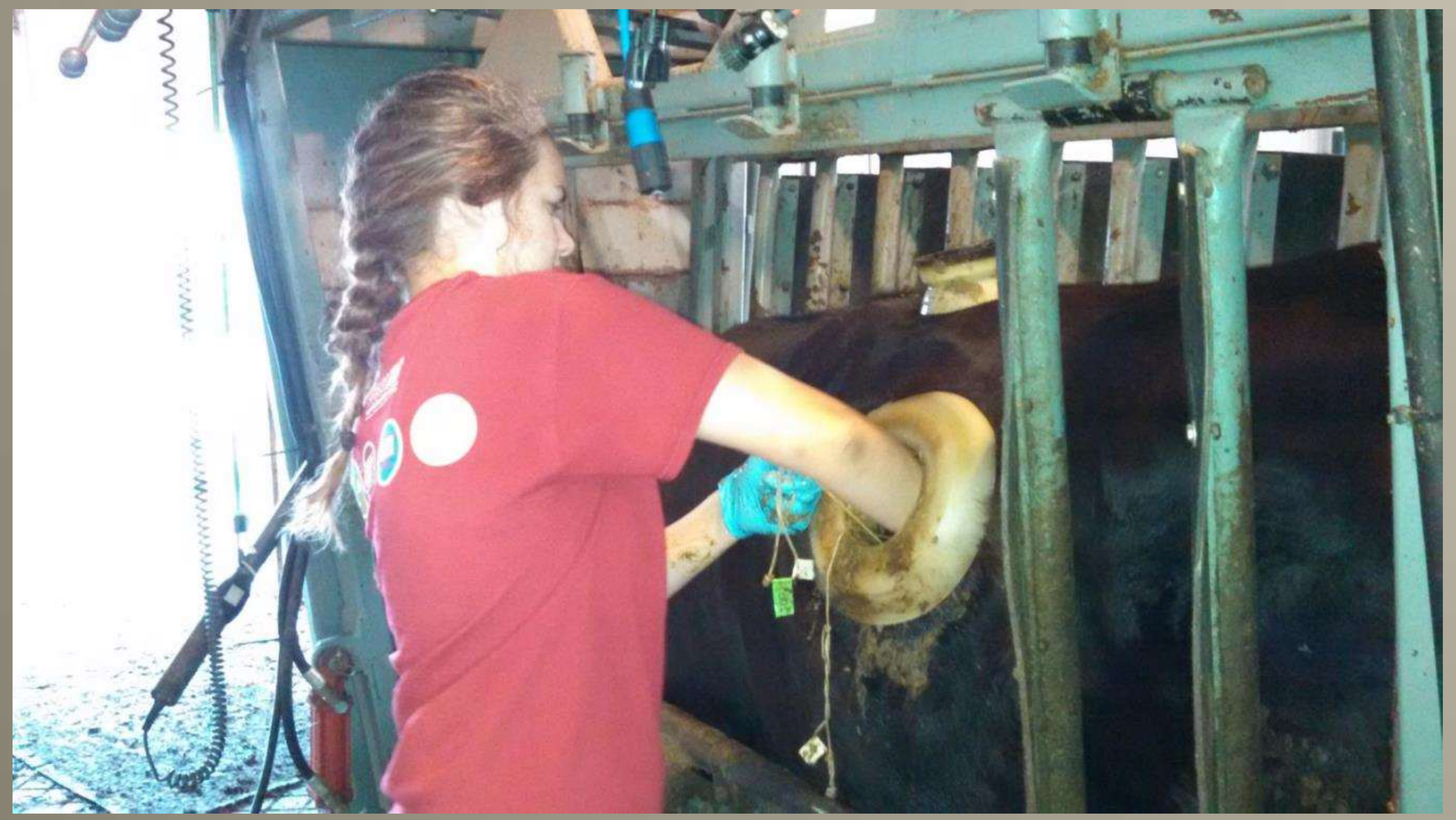
Abstract

- Experiment 2. An *in situ* digestibility study was completed to evaluate the effect of calcium hydroxide treatment of switchgrass and cornstalks. Bales of cornstalks and mature switchgrass were ground and water was added to achieve 60% DM. A 2 x 2 x 2 factorial of treatments was utilized with the factors of roughage source (cornstalks or switchgrass), chemical treatment (none or calcium hydroxide at 7%), and duration of incubation (1 or 4 wk). After the allotted time, barrels were emptied and samples were collected, dried, ground, weighed, and placed into Dacron bags (n = 3 bags·sample^{-1}time point^{-1}). Bags were incubated in the rumen of a cannulated steer for 24, 36, or 48 h, then dried and weighed. There was an interaction between treatment and wk ($P < 0.001$). Digestibility of both roughages was improved by chemical treatment and wk of chemical treatment ($P < 0.0001$); however, digestibility of untreated cornstalks did not differ due to wk of incubation ($P > 0.2$) while untreated switchgrass digestibility tended to be lesser after 4 wk of incubation ($P = 0.15$).



Dacron bags being submerged into the rumen for the *in situ* digestibility analysis.

Introduction

Treatment of cornstalk residue with a strong alkali such as calcium hydroxide improves the digestibility of the cornstalk fiber, making available more usable calories to cattle that may consume this treated product. The growing interest in the use of switchgrass to produce liquid biofuels may stimulate more production of this perennial forage. In the case where the biofuel market cannot make complete or immediate use of this material, an alternative market may be needed. Cattle feed could provide one outlet, however, the maturity of the switchgrass used for biofuel production renders it very low in digestibility and limits overall usefulness in cattle rations. Since cornstalk consistency, after grain harvest seems to have similar characteristics to mature switchgrass, it was proposed that alkali treatment which improves the digestibility of cornstalks may also work to improve the digestibility of switchgrass.

Objective

- Evaluate the effect of calcium hydroxide treatment of switchgrass compared to calcium hydroxide treatment of cornstalks.
- Evaluate the effect of duration of alkaline treatment on *in situ* digestibility of switchgrass and cornstalks.

Click here to view results of Experiment 2

Click here to view Experiment 1 (beef cattle feed trial)

Methods

- Bales of cornstalks and mature switchgrass were ground to pass a 17.78 cm sieve and water was added to achieve 60% DM.
- A 2 x 2 x 2 factorial of treatments was utilized with the factors of roughage source (cornstalks or switchgrass), chemical treatment (none or calcium hydroxide at 7%), and duration of incubation (1 or 4 wk).
- 32 barrels were sealed to create an anaerobic environment (n = 4 barrels·treatment^{-1}incubation time^{-1}).
- After the 1 wk and 4 wk incubation times, barrels were emptied and samples were collected, dried at 70° C for 48 h, ground to pass a 1 mm screen, weighed, and placed into Dacron bags (n = 3 bags·sample^{-1}time point^{-1}).
- Bags were incubated in 39° C water for 20 minutes (at 0 hr) to allow disappearance of readily soluble material.
- Bags were incubated in the rumen of a cannulated steer for 24, 36, or 48 h, then again were dried and weighed.
- Data were analyzed using the MIXED procedure of SAS.

Ground cornstalks and switchgrass being loaded for transport to Ames, IA for the *in situ* digestibility study.

Treatment of Mature Switchgrass and Cornstalks with Calcium Hydroxide and Comparison of Untreated Mature Switchgrass and Cornstalks as Roughage in Beef Cattle Feedlot Diets

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Results

- Performance and carcass data are reported in Table 1.
- When compared to STALK cattle, SWITCH cattle had lesser marbling scores ($P = 0.0095$).
- Backfat, HCW, KPH, ribeye area, and yield grade did not differ between treatments ($P \geq 0.19$).
- Carcass-adjusted ADG did not differ between treatments ($P = 0.43$).
- Cattle fed SWITCH had lesser DMI than did STALK cattle ($P = 0.0004$) but G:F did not differ between treatments ($P = 0.9783$).

Penn State Particle Separator showing cornstalk TMR shaken and separated into the four trays.

Table 1. Comparison of cornstalks and switchgrass as roughage sources in feedlot beef diets.

	Treatment[1]			
Item	STALK	SWITCH	SEM	P-Value
Performance measurements				
Average daily gain[2], kg	1.77	1.70	0.051	0.43
Dry matter intake, kg	12.02	11.53	0.007	0.0004
Gain:feed, kg:kg	0.1471	0.1473	0.005	0.99
Carcass characteristics				
Hot carcass wt, kg	386.36	378.63	4.64	0.36
12th rib back fat, cm	1.24	1.13	0.05	0.26
KPH, %	2.35	2.25	0.05	0.29
Ribeye area, cm^2	87.26	87.97	0.98	0.66
Yield grade	3.09	2.87	0.08	0.19
Marbling score[3]	1047.5	1022.0	1.77	0.0095
Quality grade[4]	16.95	16.60	0.04	0.02

[1]Treatment based on roughage fed: STALK fed cornstalks and SWITCH fed switchgrass.
[2]Carcass-adjusted ADG calculated from HCW and 63% dressing percentage.
[3]Marbling score: 900 = Slight 0, 1000 = Small 0, 1100 = Modest 0, etc.
[4]Quality grade: 15 = Select^{-}, 16 = Select^{+}, 17 = Choice^{-}, 18 = Choice^{0}, 19 = Choice^{+}, etc.

Click here to view Experiment 1 Objectives and Methods

Click here to view Experiment 2 (*in situ* digestibility)

Conclusions

- These data support the hypothesis that mature untreated switchgrass may replace cornstalks at low inclusions in beef feedlot finishing diets. Although mature switchgrass is low in digestible nutrients, it seems to offer enough effective fiber to maintain rumen function and promote digestive health.
- These findings support that the feedlot industry could utilize mature switchgrass as an alternative roughage source thereby providing an additional marketing option for switchgrass beyond the biofuel industry.

Treatment of Mature Switchgrass and Cornstalks with Calcium Hydroxide and Comparison of Untreated Mature Switchgrass and Cornstalks as Roughage in Beef Cattle Feedlot Diets

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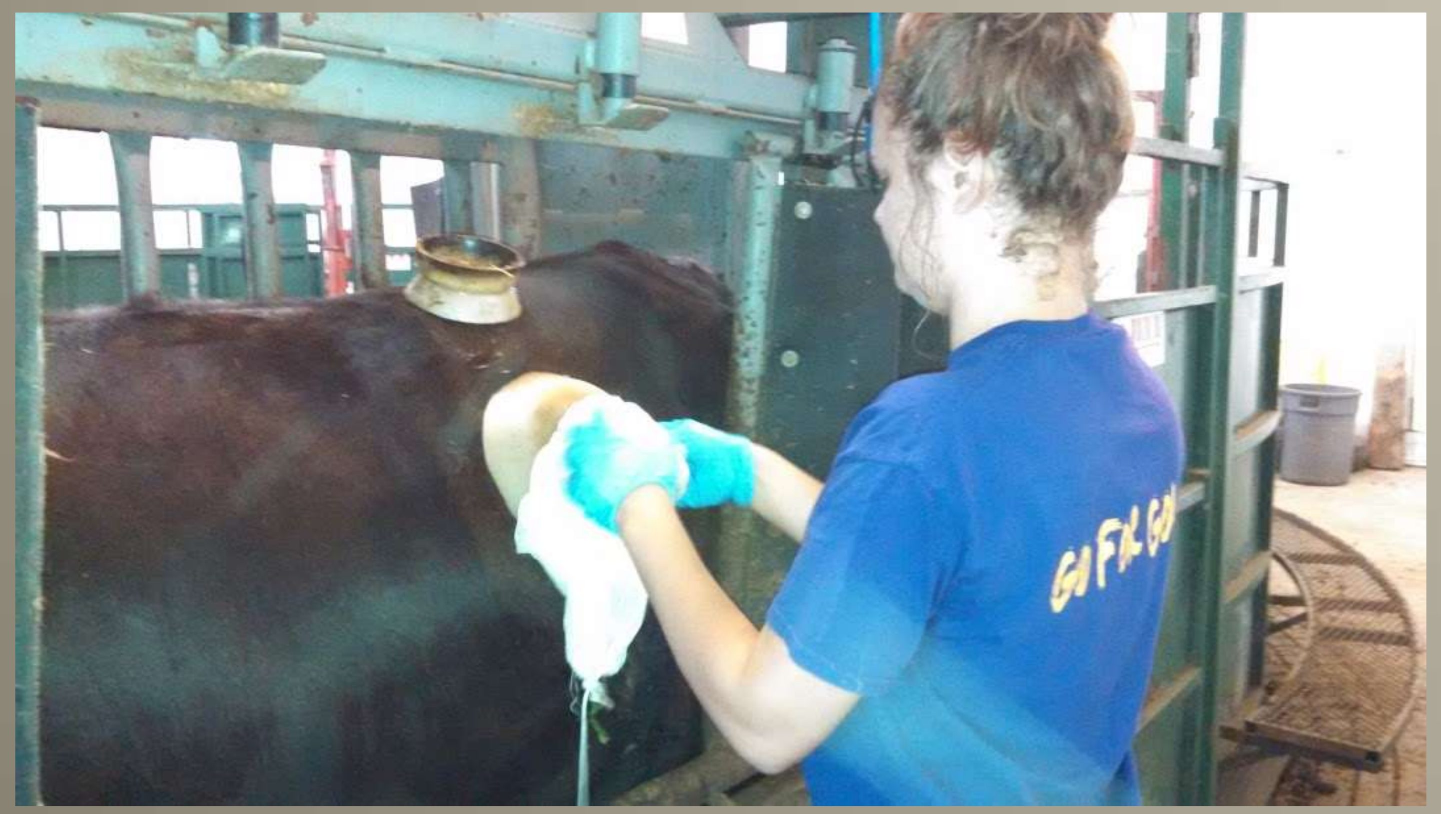
Iowa Beef Center

Results

- Digestibility of both roughages was improved by chemical treatment ($P < 0.0001$).
- Digestibility of both roughages was improved with greater rumen incubation time ($P < 0.0001$).
- There was an interaction between treatment and hr of ruminal incubation ($P < 0.001$).
- There was an interaction between treatment and wk ($P < 0.001$) demonstrating that for both roughages, 4 weeks of calcium hydroxide treatment was associated with a greater improvement in digestibility than 1 week of calcium hydroxide treatment.
- Digestibility of untreated cornstalks (STALK) did not differ due to wk of incubation ($P > 0.2$).
- Untreated switchgrass (SWITCH) digestibility tended to be lesser after 4 wk of incubation ($P = 0.15$).



Dacron bags being prepared for placement into the rumen for the *in situ* digestibility analysis.

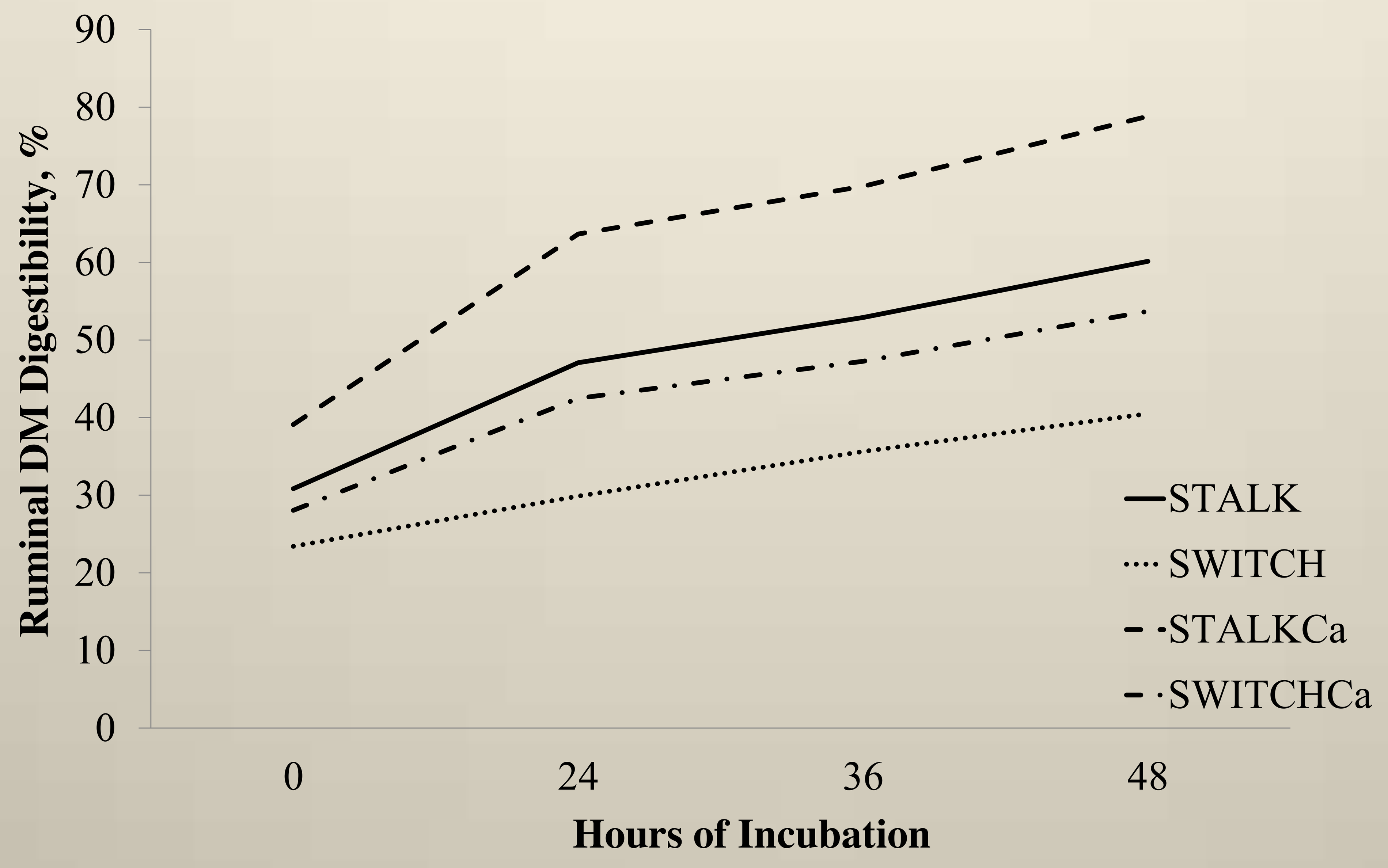


Figure 1. Ruminal DM digestion of untreated cornstalks (STALK), treated cornstalks (STALKCa), untreated switchgrass (SWITCH), and treated switchgrass (SWITCHCa). Treatment: $P < 0.001$ Hour: $P < 0.001$ Treatment x hour: $P < 0.001$ Standard Error Mean: 1.31

Click here to view Experiment 2 Objectives and Methods

Click here to view Experiment 1 (beef cattle feed trial)

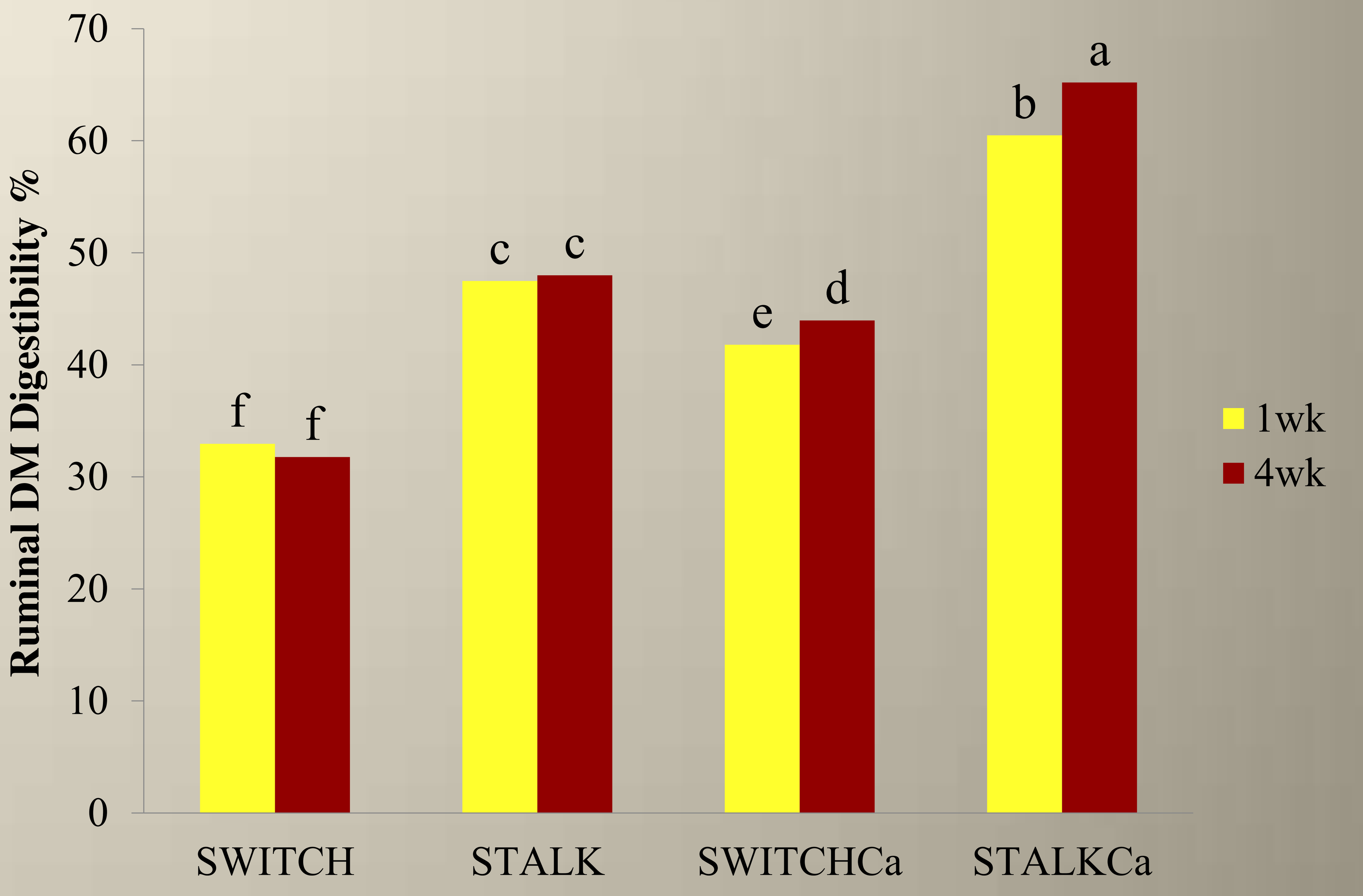


Figure 2. Ruminal DM digestion of untreated and treated cornstalks and switchgrass as affected by duration of chemical treatment. Superscripts that differ are different ($P < 0.05$). Treatment x week: $P < 0.0001$ Standard Error Mean: 1.25

Conclusions

- These data support the hypothesis that ruminal DM digestibility of mature switchgrass can be improved through alkaline treatment.
- Significant improvement in DM digestibility can be achieved with 1 week of alkaline treatment.
- Improving digestibility through alkaline treatment can potentially increased the utility of switchgrass in the feedlot industry.

Acknowledgements

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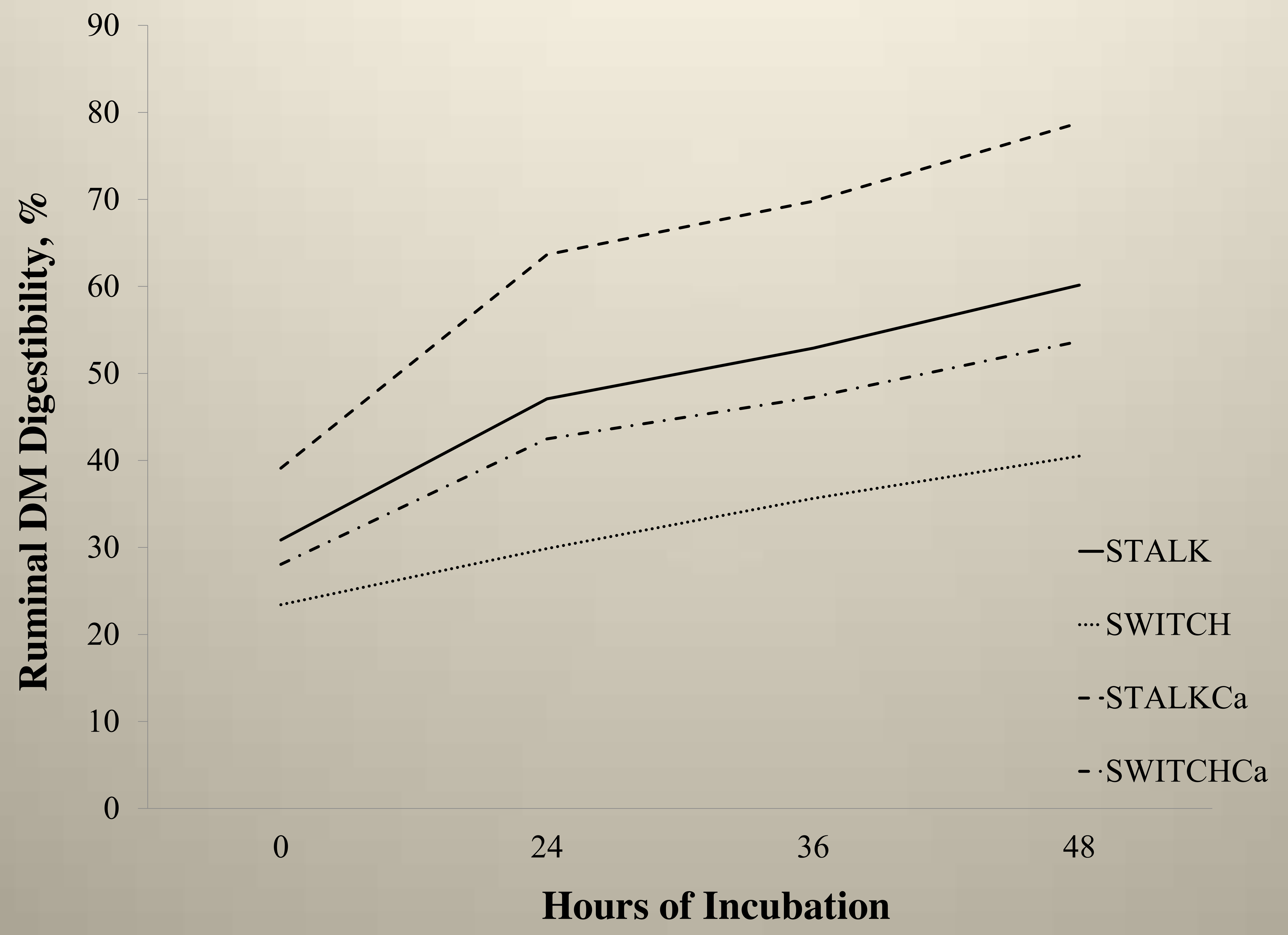

Figure 1. Ruminal DM digestion of untreated or treated corn stalks and switchgrass. Treatment: $P < 0.001$ Hour: $P < 0.001$ Treatment x hour: $P < 0.001$ Standard Error Mean: 1.31

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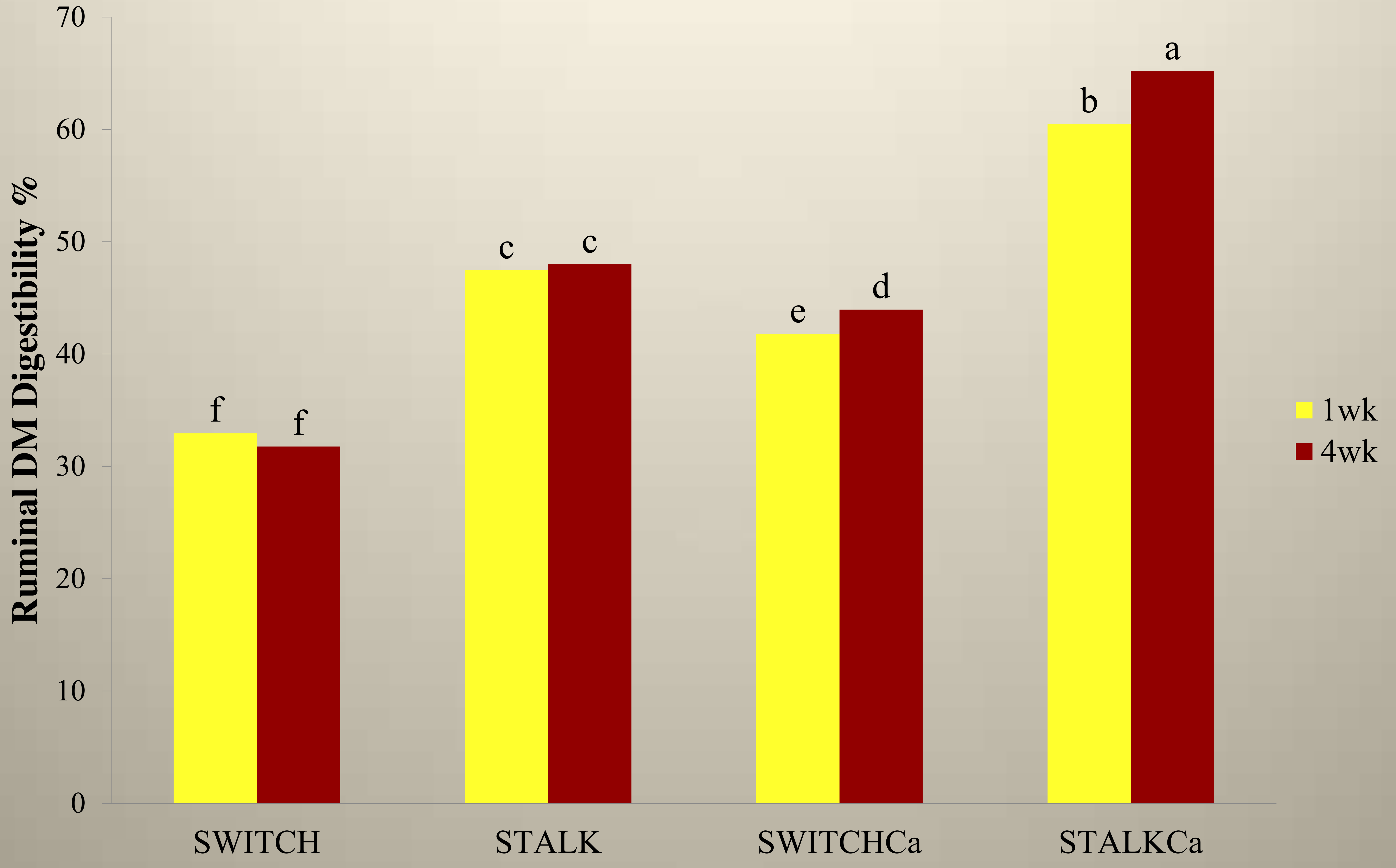

Figure 2. Ruminal DM digestion of untreated and treated cornstalks and switchgrass as affected by duration of chemical treatment.
Treatment x week: $P < 0.0001$
Standard Error Mean: 1.25

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This project is supported by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the National Institute of Food and Agriculture.

Iowa State University Armstrong Research Farm Staff

Iowa State University Beef Nutrition Farm Crew

Iowa State University Hansen Lab

Tri County Steer Carcass Futurity Cooperative

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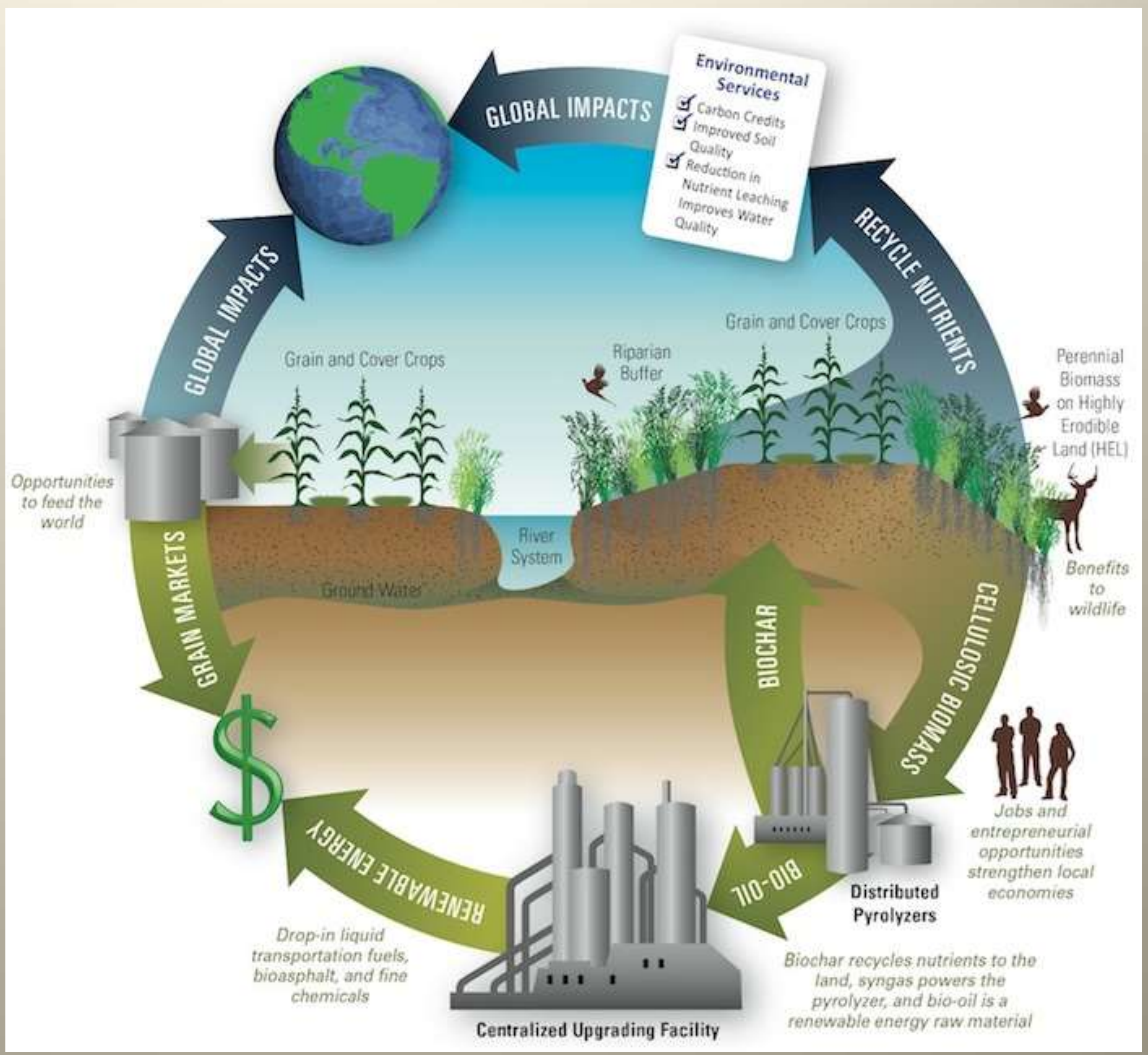
The CenUSA Bioenergy Vision

Our vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed system will improve the sustainability of existing cropping systems by reducing agricultural runoff of nutrients and soil and increasing carbon sequestration.



Perennial Grass Management Survey Results (Beaver Crossing & Dawson, Nebraska)

Sorrel Brown, PhD
Iowa State University Extension
sorrel@iastate.edu
Guang Han, Graduate Student
The Ohio State University

cenusa bioenergy

Exhibit 2

CenUSA Outreach and Extension educators in Nebraska held two field days about establishing and managing perennial grass for bioenergy in two different locations. Participants who attended both field days were asked to indicate how their knowledge regarding several aspects of perennial grass production and marketing increased. Their responses are as follows:

Knowledge gain was significant for:

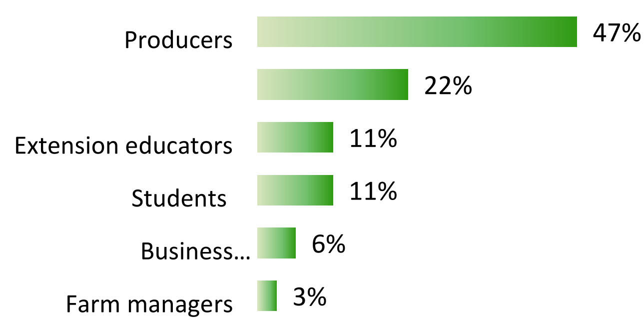
- Establishing perennial grasses (n=35)
- Stand measurement of perennial grasses (n=36)
- Herbicide use in perennial grasses (n=35)
- Positive environmental effects of perennial grasses (n=36)
- Energy created from perennial grasses (n=36)
- Insects and diseases in perennial grasses (n=35)
- Beneficial environmental effects (n=36)
- Energy created from perennial grasses (n=36)

Intentions:

- 36% of **all** respondents said they will consider planting a perennial grass if a market develops in their area (n=36)
- 70% of respondents **who indicated they are producers** said they will consider planting a perennial grass if a market develops in their area (n=17)
- 59% of respondents **who indicated they are producers** will consider using perennial grasses for nutrient management, erosion, or livestock production (n=17).

About 6% of participants (n=17) currently contract to harvest stover or other biomass for bioenergy production.

Occupation



The research presented at the two field days significantly improved participants' knowledge of perennial grass management. A considerable proportion of participants intend using perennial grass as a result of what they learned at the field days. A substantial number indicated an interest in receiving additional information regarding perennial grass and provided their email addresses.

For more information on perennial grasses, contact:
Keith Glewen, Extension Educator
University of Nebraska-Lincoln
Phone: (402) 624-8030
Email: kglewen1@unl.edu

F. John Hay, Associate Extension Educator
Biological Systems Engineering
University of Nebraska-Lincoln
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This project is supported by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the National Institute of Food and Agriculture.

Managing Perennial Grasses for Bioenergy Survey Results – 2014 Minnesota

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Guang Han, Graduate Student
The Ohio State University

cenusa bioenergy

Exhibit 3

CenUSA Outreach and Extension educators in Minnesota held several educational field days about establishing and managing perennial grass for bioenergy. Participants were surveyed to determine their level of understanding after the presentations; responses (n=24) indicated the following:

***Knowledge about*:**

- Establishing perennial grasses was significantly increased.
- Herbicide use in perennial grasses was significantly increased.
- The positive environmental effects of perennial grasses was significantly increased.
- Energy created from perennial grasses was significantly increased.

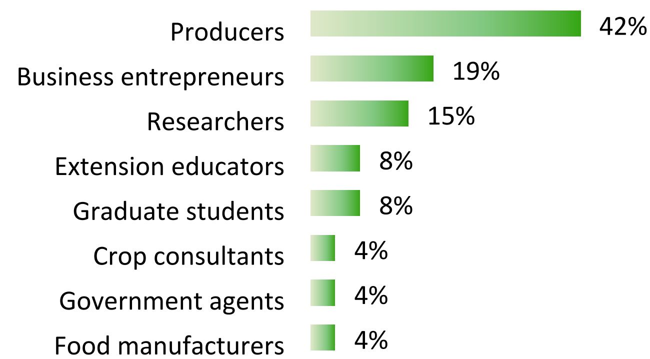
Respondents' interest:

Because of their newly acquired awareness about producing perennial grasses for bioenergy, interest in learning more increased significantly (n=24).

Respondents' intentions to take action (n=26):

- 58% will consider planting a bioenergy crop, such as a perennial grass, if a market developed in their area.
- 50% will consider using perennial grasses for nutrient management, erosion control, or livestock production.
- 15.3 % provided their email addresses to receive additional information about perennial grasses for bioenergy.

Occupation (n=26)*:*



Although the variation of respondents' occupations was broad, producers comprised the largest proportion, followed by entrepreneurs, researchers, extension educators, and graduate students.

In summary, the field day presentations on establishing and managing perennial grasses for bioenergy increased participants' knowledge on

- establishing a perennial crop,
- herbicide use in perennial grass production, and
- the positive environmental effects of perennial grasses.

More than half of the respondents indicated they would consider planting a bioenergy crop when a market is available. At the same time, more than half said they would consider using perennial grasses for nutrient management, erosion, or livestock production.

For more information on perennial grasses, contact:

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Department of Soil, Water and Climate
University of Minnesota
Phone:
Email: sawye177@umn.edu

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