cenusa bioenergy

Quarterly Progress Report

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

October 2014

Agriculture and Food Research Initiative Competitive Grant
No. 2011-68005-30411

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LEGAL NOTICE

This report was prepared by Iowa State University and CenUSA Bioenergy research colleagues from Purdue University, United States Department of Agriculture-Agricultural Research Service, University of Illinois, University of Minnesota, University of Nebraska, Lincoln, University of Vermont, and the University of Wisconsin in the course of performing academic research supported by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the United States Department of Agriculture National Institute of Food and Agriculture ("USDA-NIFA").

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

Quarterly Report: August 1, 2014 – October 31, 2014

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.

- **Featured First Quarter Activity**

  CenUSA hosted and co-sponsored the "2014 Extension Energy and Environment Summit" in Ames, Iowa September 23-26.[1] The purpose of the summit was to provide "a forum for the exchange of biorenewables and sustainability research findings and educational ideas, methods, and techniques for Extension Educators, NGO's and outreach and policy professionals with agriculture, energy, and natural resource interests and/or appointments." Over 70 Extension educators attended the event, including representatives from the USNDA-NIFA AFRI CAP grantee programs (Exhibit 1. E3 Conference Agenda; more information is also available at http://www.2014e3.org).

- **New Commercialization Objective**

  The work on the new Commercialization Objective has started and is on track. Additional details are available in the Commercialization Objective update.

Table 1. Year 4 CenUSA Bioenergy Commercialization Activities

Partner	Project Description
ADM	Recovery of high value products from ADM's biorefinery co-product streams
Renmatix	Evaluation of switchgrass in the Plantrose™ Process
Vermeer	Established a 30+ acres across from the Vermeer Global Pavilion in Pella, Iowa. (Planting took place in May 2014).
ARS-Lincoln	▪ Pelleting perennial feedstocks for bioenergy evaluations. ▪ Perennial grass biochar commercialization for field and greenhouse evaluations and comparison to hardwood biochar

[1] Additional sponsors: Iowa-NSF EPSCoR, North Central SARE (Sustainable Agriculture Research and Education, and the ISU Leopold Center.

▪ Bio-oil production of herbaceous feedstocks processed in the Battelle mobile pyrolyzer. ▪ Feasibility of perennial grass feedstocks to supply combined heat and power to an advanced ethanol fermentation plant. ▪ Grazing mitigates risk potential for perennial warm-season grasses grown for biomass energy.

- **CenUSA Bioenergy Advisory Board**

  Our Advisory Board continues to be a real force for CenUSA. We had an exceptional turnout of Advisory Board members at our Year 3 Annual meeting. We have featured several members of the Advisory Board in our BLADES newsletter and expect to continue to do so throughout Year 4.

- **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 – 30. Our host will be Dr. Michael Casler (ARS Madison/University of Wisconsin). The focus will be on CenUSA graduate and undergraduate students. We will feature an agenda which will provide significant opportunities for interaction between CenUSA Advisory Board members, CenUSA personnel and our graduate and undergraduate students. Student participation has been favorably reviewed by students and non-students 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) (Exhibit 2. CenUSA Comm. Team Social Media Resources).

- **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 first quarter we published September (http://blades-newsletter.blogspot.com/p/september.html) and November issues (http://blades-newsletter.blogspot.com/p/november.html)

  BLADES circulation has increased to 750 subscribers (up from 650 in the last quarter).

  ✓ **November 2014 Articles**

    - 'Liberty' is closer than you think,
    - Birds, Bees and Biomass,
    - Round or Square: A look at bale geometry,
    - Energy, Environment & Extension Summit,
    - The New Bioenergy "Prairie"

  ✓ **September 2014 Articles**

    - CenUSA Commercialization Objective Update from Rob Mitchell
    - Energizing Cows: Potential Market for Switchgrass
    - ADM teams with CenUSA Bioenergy on Treeless Paper Products
    - Switchgrass Superstar - Now Commercially Available
    - Virtually Growing the C6 Biofarm
    - Renmatix: Building a Bridge to Renewable Biofuels

- **Twitter and Facebook**

We continue to experience steady growth on both sites. We have started using a new hashtag "#GrassAcademy" on Twitter site. We use the hashtag to feature the academic side of CenUSA; tweeting information on academic articles.

- **CenUSA Website**

  We have been revamping our website with the assistance of the Iowa State University Agronomy Department. We anticipate launching our new website in early February 2015.

- **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**

   This quarter saw progress on the objective's goals as summarized below.

2. **Planned Activities**

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

     ✓ Conduct routine plot maintenance on all field trials and breeding nurseries.

     ✓ Finish 2014 biomass harvesting, sample collection, and data collection.

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

     ✓ Analyze set of biomass samples that have and have not been pelleted to better understand the effect of pelleting on chemical composition.

     ✓ Begin to work on new samples as they become available.

- ✓ Continue analysis of switchgrass set for biochemical conversion using hydrothermal pretreatment.
- ✓ Prepare new manuscripts on switchgrass pyrolysis.
- ✓ Continue to analyze new diverse switchgrass samples to assist in the establishment of an NIR model.

- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Coordinate with project collaborators in other states to obtain pathogen samples.
  - ✓ Sample switchgrass plants for the presence of PMV and satellite PMV to investigate changes in virus titer during from plant dormancy through the growing season.
  - ✓ Obtain DNA sequences for Uromyces graminicola and use DNA sequences from U. graminicola and Puccinia emaculata in developing multiplex PCR method for identifying both rust species in infected switchgrass plants.
  - ✓ Complete sampling for Year 3.
  - ✓ Process samples from Nebraska and Wisconsin to identify potential pests and beneficial arthropods and characterize their seasonal abundance.

3. **Actual Accomplishments**

- **Breeding and Genetics – Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**
  - ✓ Conducted routine plot maintenance on all field trials and breeding nurseries.
  - ✓ Completed harvesting of all nurseries and plots.
  - ✓ Collected ~7000 biomass samples for grinding and scanning during winter.
  - ✓ Harvested seed on three new big bluestem populations and two new switchgrass populations.
  - ✓ Collected seed on 14 new lowland switchgrass accessions from Alabama, Mississippi, and Louisiana.
  - ✓ Germinated seedlings to begin first cycle of genomic selection within Liberty and WS4U-C2 populations.

- **Feedback Quality Analysis (Bruce Dien and Akwasi Boateng)**
  - ✓ Analyzed set of biomass samples that had and had not been pelletized to better understand the effect of pelleting on chemical composition. The sample set consisted of baled, ground, and pelletized switchgrass, big bluestem, and low diversity mixed herbaceous plants.
  - ✓ Began work on new samples as they became available: Ten additional samples of switchgrass were analyzed for complete composition and results are in the process of being communicated with collaborators at ERRC.
  - ✓ Continued analysis of switchgrass set for biochemical conversion using hydrothermal pretreatment. Hydrothermal pretreatment conditions were optimized for switchgrass MPV6 and dosage response curves for two different generations of commercial cellulases were generated. The determined conditions were used to evaluate the pelletized and ground sample set described above for enzymatic sugar release at a low and medium enzyme dosage.
  - ✓ All switchgrass samples from Ken Vogel and the select set of switchgrass samples from the STICH projects have been analyzed for pyrolysis products on the py-GC/MS. Ash content and mineral content via ICP were also analyzed. These data sets will be incorporated into the NIR models to develop predictive models for pyrolysis product yield.
  - ✓ Analyzed data in preparation for new manuscripts on switchgrass pyrolysis.
  - ✓ Ash content and ICP results of STICH samples was sent to Mike Casler.
  - ✓ New grass samples for py-GC/MS analysis have not been received yet.
- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Arrangements were made with collaborators in Illinois, Indiana, Missouri, South Dakota and Wisconsin involved in CenUSA switchgrass varietal trial to send leaf samples to Nebraska for assessment of rust severity and identify rust pathogen.
  - ✓ Switchgrass plants infected by PMV alone or the PMV/SPMV combination in previous years were found to retain PMV in the crowns and exhibit relatively stable titer throughout the growing season. Thus, the apparent “disappearance” of PMV from plants found in previous year was not confirmed. Instead, the frequency of plants infected with PMV alone or the dual virus combination increases on a yearly basis.

- ✓ DNA sequences for the rust fungus Uromyces graminicola, provided by collaborators at Cornell University, were used to develop PCR primers specific for that species. The primers have been found to be effective in detecting the presence of the rust fungus in switchgrass leaf samples at various stages during disease development, i.e. prior to pustule development, uredinial stage, and telial stage. The effectiveness of the primer set for detecting U. graminicola at the two earlier stages is particularly significant because U. graminicola cannot be distinguished by morphological methods from the other rust pathogen Puccinia emaculata prior to the telial stage.
- ✓ A total of 160 pitfall and sticky board traps were collected every two weeks from May to September in Nebraska and Wisconsin.
- ✓ All samples have been processed for the 2014 season and we are currently compiling the data.
- ✓ The composition of arthropods collected at the two locations (Wisconsin and Nebraska) was similar.

4. Explanation of Variances

None to report.

5. Plans for Next Quarter

- **Breeding and Genetics (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 and Akwasi Boateng)**
  - ✓ Measuring behavior of ground and pelletized samples for grinding to finer particle sizes using a hammer mill.
  - ✓ Analyze additional switchgrass sample set supplied by CenUSA collaborator 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.

- **Pathology and Entomology (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 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.

6. Publications / Presentations/Proposals Submitted

- Biomass conversion to ethanol. Poster presentation. 2014 Frontiers in Biorefining Conference Oct 22-24, 2014, St. Simons, GA.
- Yuen, G., Ma, Y., Jochum, C. & K. Vogel. (2014). Infection of biofuel switchgrass populations by two rust species in Nebraska. Abstract of poster presented at 2014 APS-CPS Joint Meeting. http://www.apsnet.org/meetings/Documents/2014_meeting_abstracts/aps2014abP366.htm
- Nichols, V.A., Miguez, F.E., Jarchow, M.E., Liebman, M.Z., & B.S. Dien (2014). Comparison of cellulosic ethanol yields from midwestern maize and reconstructed tallgrass prairie systems managed for bioenergy. Bioenergy Research. DOI: 10.1007/s12155-014-9494-9.
- Stewart, C.L., Jochum, C., Yuen, G., Vogel, K., Pyle, J. D., & K. B. G. Scholthof. (2014). Incidence and impact of dual infection by Panicum mosaic virus and its satellite virus in switchgrass breeding fields. Abstract of poster presented at 2014 APS-CPS Joint Meeting. www.apsnet.org/meetings/Documents/2014_meeting_abstracts/aps2014abP407.htm

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**

  - **Long-term Rotation Plot Research Updates**

    Study Site. The long-term rotation plots (LTRP) were established in 2006 at the Iowa State University Sorenson Research Farms in Boone County, Iowa. The study was initiated to evaluate the effect of growing corn in rotation with a small grain such as triticale and switchgrass as opposed to a more conventional continuous corn or corn-soybean rotation. The LTRP study design compares five different cropping rotations:

    - ✓ Continuous corn
    - ✓ Corn-soybean- corn-soybean- corn-soybean
    - ✓ Corn-soybean-triticale/soybean- corn-soybean-triticale/soybean
    - ✓ Corn-corn-corn/switchgrass- switchgrass - switchgrass – switchgrass
    - ✓ **Continuous switchgrass.** Using a split-plot design biochar has been applied to selected plots (first corn phase of each rotation) every year since 2012 and thus at present three ages of biochar exist within these rotations (based on biochar applications in 2012, 2013, and 2014).
    - ✓ **Importance and Overview.** At present corn residue removed from Midwestern farms is the largest source of biomass for cellulosic bioenergy production in the US. Long-term harvesting of biomass for bioenergy production, however, may lead to the degradation of soil and water quality unless new management practices are used to increase carbon inputs to soils. Alternative cropping systems which include small grains, perennial grasses and biochar amendments may help reduce negative effects of biomass harvesting on soil and water quality.

      This research site allows for the evaluation of multiple bioenergy crops (corn stover, triticale and switchgrass) in more diversified cropping systems. Furthermore it provides the opportunity to investigate issues of soil quality in non-traditional rotations with and without biochar. Here, we report preliminary results for a study

initiated in spring 2014 designed to evaluate the effect of biochar, biochar age and cropping systems on soil physical and chemical properties. It was hypothesized that crop rotations that include small grains, perennial grasses and/or biochar treatments will enhance the sustainability of bioenergy cropping systems and secondly that the impact of biochar on soil quality is influenced by biochar age. Intact soil cores were collected from all 208 split plots and are being analyzed (ongoing) for the following soil physical and chemical properties:

- Physical properties using intact soil cores:
  - Solute transport
  - Saturated hydraulic conductivity (K_{sat})
  - Bulk density
  - Porosity
  - Gravity drained water content
- Chemical properties soil sample from cores:
  - pH (leachate)
  - Electrical conductivity of leachate
  - Total carbon
  - Total nitrogen
  - C/N ratio of the soil
  - Cation exchange capacity (CEC)
  - Anion exchange capacity (AEC)

✓ **Preliminary Results.** Chemical breakthrough curves, the relationship between relative concentration (Cr) and relative pore volume (RPV), indicate possible effects of biochar and the various crop rotations on solute transport. Chemical breakthrough curves averaged for soil cores with and without biochar amendments (w/BC and w/o BC, respectively), indicate that biochar amendments may retard ion transport (Fig. 1). Crop rotations that include small grains or switchgrass may impact both solute dispersivity and retardation of soil relative to soil from continuous corn and corn soybean rotations (Fig. 2). Statistical analyses are pending.

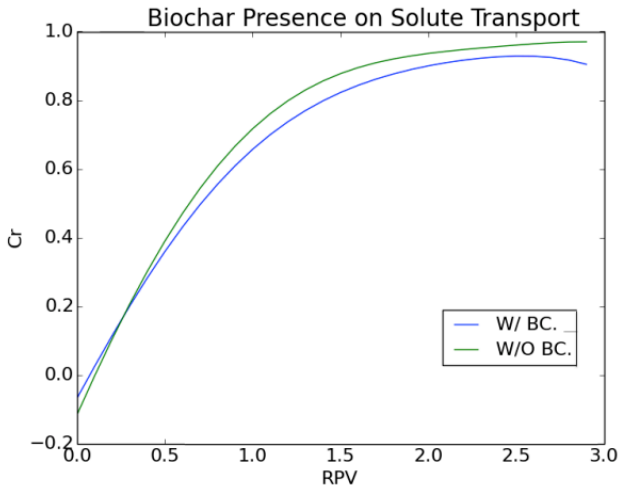

Fig. 1. Biochar Presence on Solute Transport

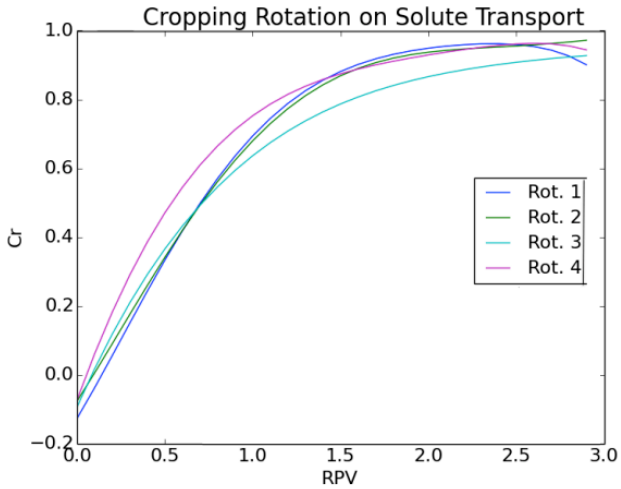

Fig. 2. Cropping Rotation on Solute Transport.

Across all crop rotations there was an increase in the soil C/N ratio, an increase in gravity drained moisture content, and a decrease in bulk density for soils treated with biochar relative to no-biochar controls (In the following graphs green bars are soils with biochar and blue bars are soils without biochar). Error bars show standard deviations complete statistical analysis is pending.

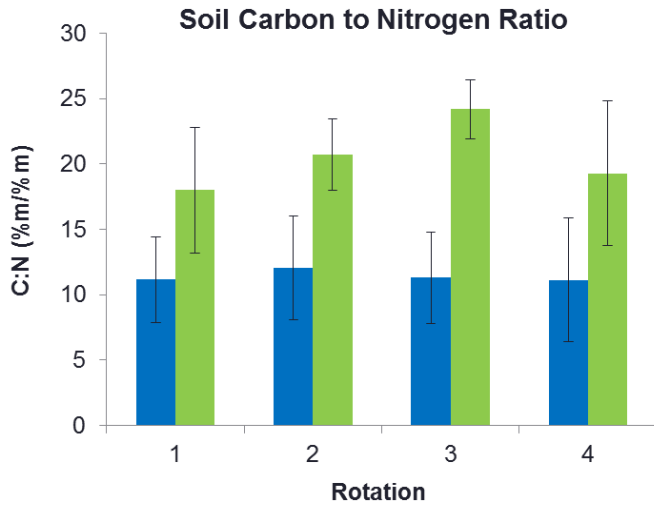

Fig. 3. Soil Carbon to Nitrogen Ratio.

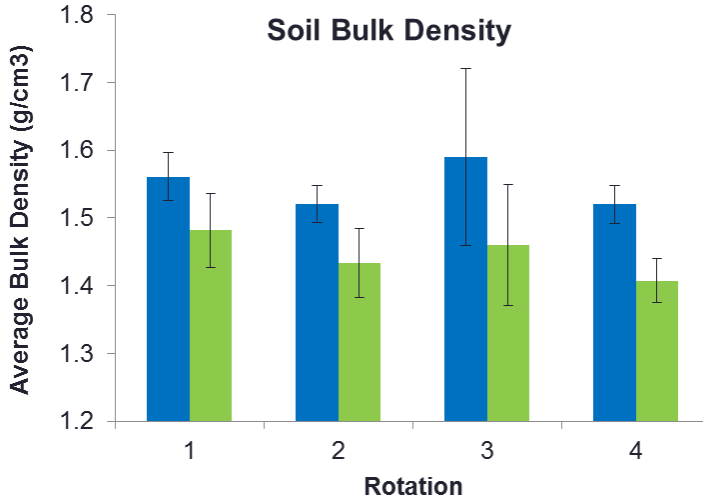

Fig. 4. Soil Bulk Density.

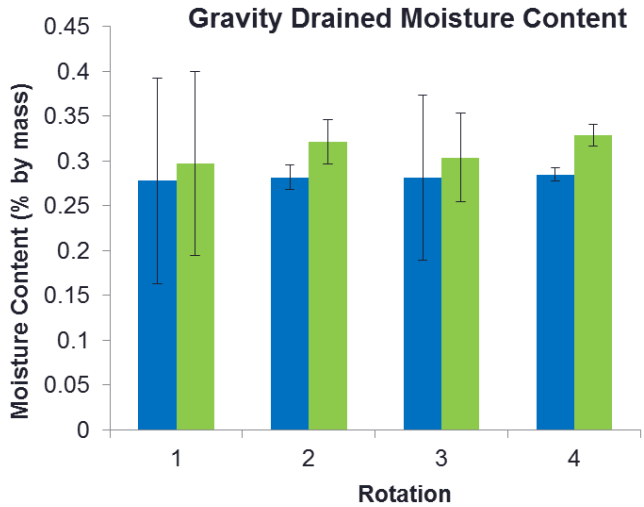

Fig. 5. Gravity Drained Moisture Content.

- **Greenhouse Gas Emissions (laboratory experiment).** Soil from the system plots on the Armstrong Research and Demonstration Farm (Exira silty clay loam, "soil A") and from the biochar plots on the Boyd farm in Boone County, Iowa (Clarion sandy clay loam, "soil B") were incubated with six different biochars in a full factorial design at a 0.5% rate (equivalent to 10 Mg/ha). These biochars were analyzed for bicarbonate-extractable organic carbon (C) and inorganic C because both of these C sources were anticipated to contribute to GHG emissions. To account for the effect of biochar carbonates, control soils were amended with a quantity of carbonate approximately equivalent to that found in the biochars (C0, C1, C2). Un-amended and biochar-amended soils were preincubated for 50 days prior to the addition of corn stover (0.5% w/w) and NPK fertilizer (~150 kg N/ha - eq). During the equilibration period and following fertilization, gas samples were collected regularly and analyzed for CO_2, CH_4 and N_2O via GC. CH_4 emissions were found to be negligible during the entire incubation, while N_2O emissions were negligible during the equilibration phase and CO_2 emissions were significant at all times. Significant differences in N_2O and CO_2 emissions were observed following fertilization (Figures 1 and 2). Most biochars had non-significant or negligible effects on CO_2 emissions, but five out of six biochars (all except CS5s) significantly reduced N_2O emissions from soil A, and one biochar (CS3s) significantly reduced N_2O emissions from soil B. Comparing biochar carbonate content and bicarbonate extractable C content with emissions suggests that the effect of biochar on emissions is not solely due to one factor but rather complex-interactive effects. Analysis of soils and soil-biochar mixtures is ongoing in an effort to determine mechanisms behind the observed biochar-soil interactions.

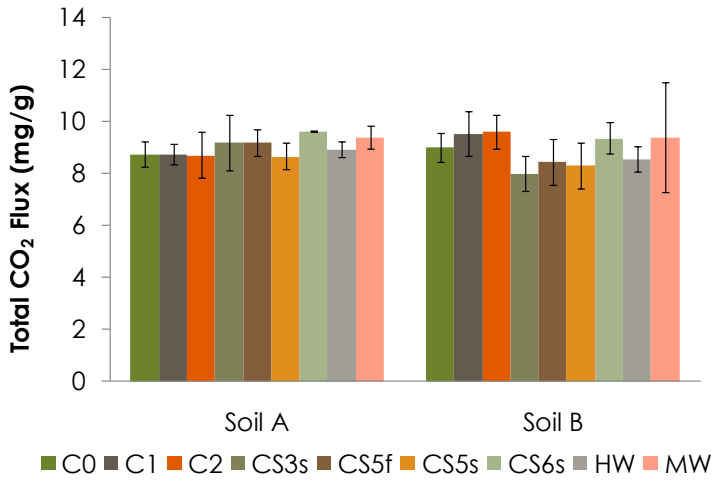

Fig. 6. Total soil CO_2 emissions accumulated over 140 days of incubation following the addition of corn stover (0.5%) and NPK fertilizer to biochar-amended soils.

(Treatments: C0 = zero carbonate control, C1 = 0.5 mg/g $CaCO_3$, C2 = 1 mg/g $CaCO_3$, CS3s = 300°C slow pyrolysis corn stover char, CS5f = 500°C fast pyrolysis corn stover char, CS5s = 500°C slow pyrolysis corn stover char, CS6s = 600°C fast pyrolysis corn stover char, HW = 500°C slow pyrolysis hardwood char, MW = 600°C gasification mixed wood char)

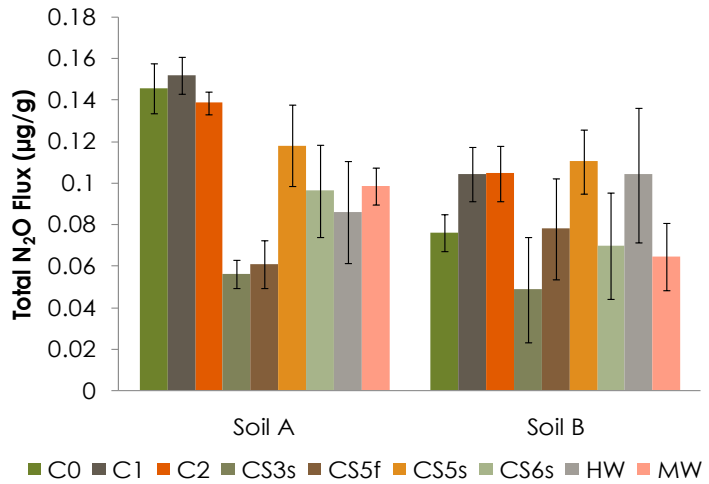

Fig. 7. Total N_2O emissions from soil incubated with six biochars over the first 8 days following the addition of corn stover (0.5%) and NPK fertilizer. Emissions after the first 8 days were below the limit of detection.

- **Update of activities at System Plots on the Armstrong Research and Demonstration Farm in SW Iowa**. Due to high weed (undesirable plant species) abundance, the high diversity plots were mowed on August 19, 2014 to a height of 16 inches. This should help prevent weed species from setting seed and reduce weed abundance next year. The

switchgrass and low diversity plots had higher abundance of sown species and were not mowed. We plan to spray a broadleaf herbicide in the early spring 2015 on these grass-only plots.

End-of-season biomass harvests could not occur until the first hard freeze, which happened on October 31, 2014. End-of-season biomass harvests will be sampled in mid-November using protocols similarly to the August peak season sampling. We plan to randomly select two 0.25m^2 areas for hand harvest and will sort plants to assess sown forbs, sown grasses, and unsown weedy species. Samples of sown species within each plot from the low diversity and switchgrass plots will be recombined, ground and a subsample swill be shipped to Rob Mitchell for tissue quality analysis.

Corn control plots were harvested on October 28, 2014 showed possibly lower yields for biochar-amended plots relative to the no-biochar control plots; 143 bu/acre for biochar amended plots vs. 155 bu/acre for control plots. Due to heavy spring and early summer rains nitrogen deficiency may have limited corn yields, which were down from an average yield 181 bu/Ac in 2013.

- **Update of activities on Biochar plots on the Sorenson, Boyd and Agronomy and Ag Engineering Farms in Central Iowa.** All crops have been harvested and work is ongoing to analyze samples. Surface soil samples (0-5, 5-15 cm) were collected from the Boyd plots and Field 70&71 plots and will be analyzed for potentially mineralizable nitrogen. Fall stock nitrate tests for corn controls indicate nitrogen deficiencies again likely due to heavy spring and summer rains. A manuscript is being prepared documenting the impact of biochar amendments on soil quality for the Field 70&71 plots.

- **Purdue University**

  - Plot harvesting preparations were initiated. This included:

    - ✓ Sub-sampling plants needed for laboratory analysis from the large Systems Analysis plots; and

    - ✓ Harvesting equipment maintenance/repair.

  - Laboratory analyses were completed for most plant and soils characteristics.

  - Data from the first three years of the CenUSA project were compiled and uploaded into the Purdue University Research Repository (PURR; https://purr.purdue.edu/). This web portal (hub) is one option for making CenUSA data publically available to the public in accordance to the open access mandate of the President's Office of Science and Technology Policy (OSTP, http://www.whitehouse.gov/the-press-

office/2013/05/09/executive-order-making-open-and-machine-readable-new-default-government-). This repository currently contains 60 data files related to CenUSA research, and these reside behind a "firewall" that restricts access to project participants. Access is available upon request; send an email to Jeff Volenec (jvolenec@purdue.edu) if access to these data is desired.

- **Concentrations and content of sugars, starch and total nonstructural carbohydrates (TNC) of perennial grasses grown for biomass in 2013.** Native perennial grasses (switchgrass, big bluestem and indiangrass) contained approximately equal amounts of sugar and starch whereas *Miscanthus* biomass contains more sugar than starch. Plants were harvested at the Southeastern Purdue Agricultural Center (SEPAC), Throckmorton Purdue Agricultural Center (TPAC) and the Northeast Purdue Agricultural Center (NEPAC).

Table 2. Concentrations and content of sugars, starch and total nonstructural carbohydrates (TNC) of perennial grasses grown for biomass in 2013

Species	Location	Sugars, g/kg	Starch, g/kg	TNC, g/kg
Switchgrass	SEPAC	n.d.	n.d.	n.d.
	TPAC	9.35	4.50	13.85
	NEPAC	7.42	2.05	9.47
Miscanthus	SEPAC	25.91	15.53	41.44
	TPAC	27.57	11.59	39.16
	NEPAC	23.18	4.58	27.77
Indiangrass/Big Bluestem	SEPAC	n.d.	n.d.	n.d.
	TPAC	4.48	5.78	10.27
	NEPAC	4.45	2.67	7.12

n.d.: not determined

- **Biomass yield and yield of total nonstructural carbohydrates (TNC) of perennial grasses grown for biomass in 2013.** Yield of total nonstructural carbohydrates was associated with biomass yield with the miscanthus grown at TPAC producing 766 kg TNC/ha. Plants were harvested at the Southeastern Purdue Agricultural Center (SEPAC), Throckmorton Purdue Agricultural Center (TPAC) and the Northeast Purdue Agricultural Center (NEPAC).

Table 3. Biomass yield and yield of total nonstructural carbohydrates (TNC) of perennial grasses grown for biomass in 2013			
Species	**Location**	**Biomass, g/kg**	**Biomass TNC g/kg**
Switchgrass	SEPAC	0	0
	TPAC	12611	174
	NEPAC	12739	121
Miscanthus	SEPAC	5190	204
	TPAC	19486	766
	NEPAC	8657	240
Indiangrass/Big Bluestem	SEPAC	0	0
	TPAC	4444	46
	NEPAC	4380	31

- **Biomass yield and nitrogen (N) concentrations (g/kg DM; values inside bars) of Miscanthus as influenced by N management when grown on a sandy-textured soil at Buck Creek, Indiana.** N management scenarios indicating rate and year of application are indicated below the bars and ranged from 0 N both years (0-0, dark blue bars) to 150 kg N/ha both years (150-150, light blue bars). Where N was applied the two-year total was the same for all N treatments (150 kg N/ha) except for the 150-150 high-N control. Letters indicate significant differences at $P<0.05$. Data were averaged over four Miscanthus germplasms (Illinois clone; Mississippi clone; Nagara clone and an Open Pollinated Nagara population). Biomass N concentrations increased as expected as N fertilizer rate increased. Year 1 biomass yields of N-fertilized plots were greater than the unfertilized control. In Year 2, the 0-0 N and 150-0 N plots had similar yield, and these were reduced relative to the 75-75 N and 0-150 N plots. Total two-year yields were significantly lower for the 0-0 N plots when compared to N-fertilized plots, however, yields did not differ among N management strategies.

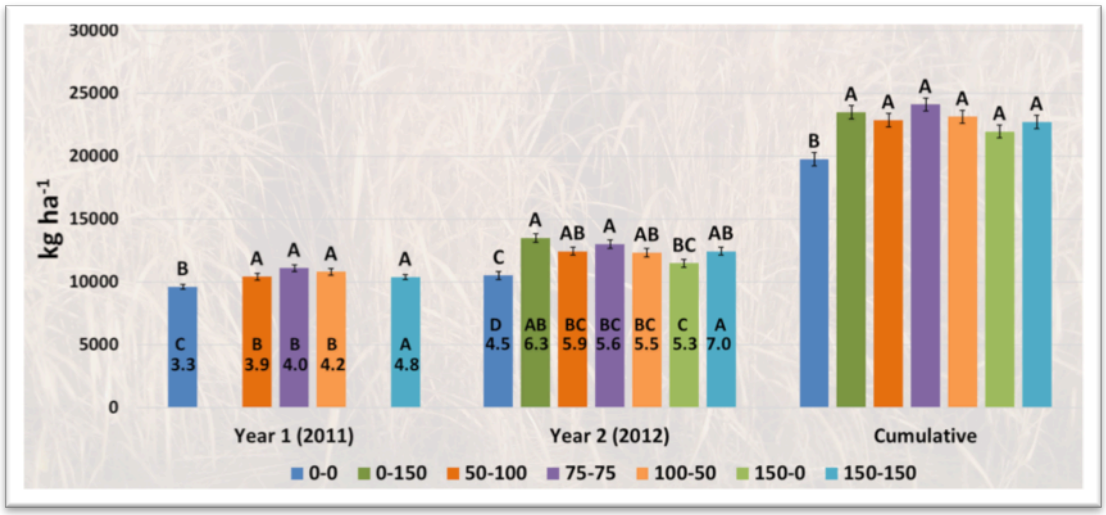

Fig. 8. Biomass yields and nitrogen (N) concentrations (g/kg DM; values inside bars) of Miscanthus as influenced by N management when grown on a sandy-textured soil at Buck Creek, Indiana.

- **Biomass yield of Miscanthus germplasms (Illinois clone; Mississippi clone; Nagara clone and an Open Pollinated Nagara population) grown on a sandy-textured soil at Buck Creek Indiana. Data are averaged over N managements.** Letters above bars indicate significant differences in yield among germplasm within a year. In Year 1 biomass yields of the Illinois clone was lower than that of the Nagara clone and the Open Pollinated Nagara population. Biomass yield increased in Year 2, but did not differ among germplasm. Total two-year yields were significantly lower for the Illinois clone and the Open Pollinated Nagara population when compared to the Nagara clone.

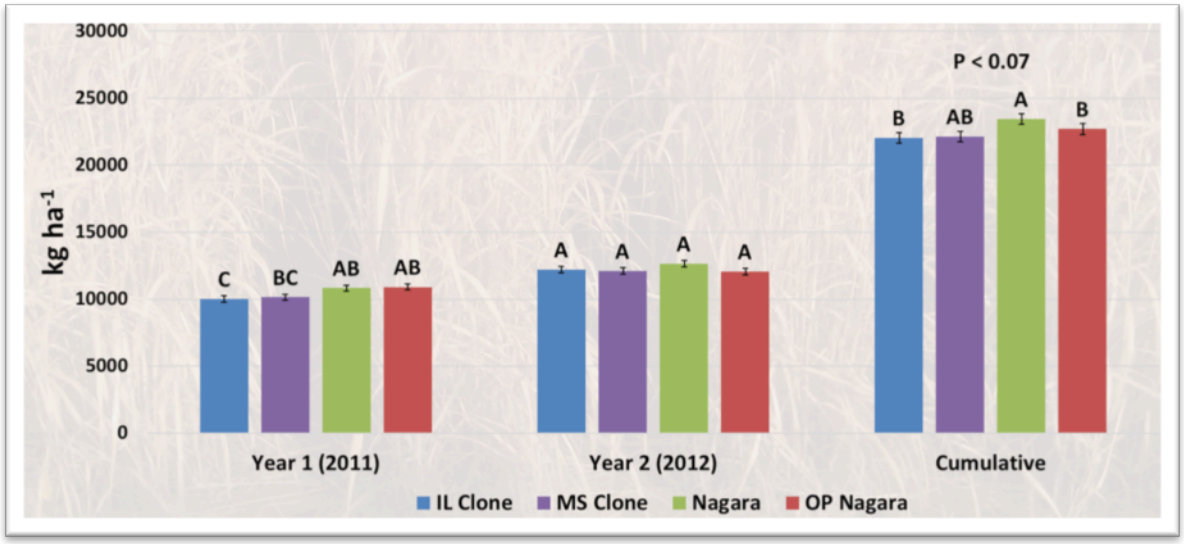

Fig. 9. Biomass yields of Miscanthus germplasms (Illinois clone; Mississippi clone; Nagara clone and an Open Pollinated Nagara population) grown on a sandy-textured soil at Buck Creek Indiana. Data are averaged over N managements.

- **Biomass composition of Miscanthus germplasms (Illinois clone; Mississippi clone; Nagara clone and an Open Pollinated Nagara population) grown on a sandy-textured soil at Buck Creek, Indiana. Data are averaged over N managements. Letters within a year-column indicate significant differences among germplasm.** In Year 1 concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose, and cellulose of the Illinois and Mississippi clones were higher than the OP Nagara population and Nagara clone (except cellulose). The Nagara clone and OP also differed for these traits in Year 1. Similar differences were observed in Year 2. Leaf retention ratings taken in Year 2 indicate much higher rates of leaf retention in the Nagara clone and OP population when compared to the IL and MS clones; a difference likely to result in the variation in biomass composition that was observed.

Indiana Year 1 (2011)							
Genotype	NDF	ADF	ADL	Hemicellulose	Cellulose	Total Ash	Leaf Retention
	---g kg^{-1}---						
IL Clone	798.9 **A**	522.4 **A**	98.6 **A**	276.4	423.8 **A**	20.4 **B**	
MS Clone	796.8 **A**	511.0 **A**	95.6 **A**	287.0	413.1 **A**	21.2 **B**	
Nagara	776.8 **B**	489.8 **B**	76.6 **B**	285.8	415.4 **A**	21.7 **B**	
OP Nagara	746.4 **C**	461. 1 **C**	72.0 **C**	285.2	389.0 **B**	25.6 **A**	
Indiana Year 2 (2012)							
	---g kg^{-1}---						
IL Clone	797.6 **A**	497.4 **A**	84.5 **A**	300.3 **A**	413.0 **A**	36.2	2.0 **A**
MS Clone	793.1 **AB**	498.3 **A**	85.7 **A**	294.8 **A**	412.6 **A**	34.3	2.1 **A**
Nagara	783.3 **B**	466.9 **B**	66.5 **B**	316.5 **B**	400.6 **B**	35.2	5.0 **B**
OP Nagara	748.1 **C**	418.5 **C**	63.3 **C**	329.6 **C**	355.2 **C**	40.0	4.9 **B**

Fig. 10. Biomass composition of Miscanthus germplasm (Illinois clone; Mississippi clone; Nagara clone and an Open Pollinated Nagara population) grown on a sandy-textured soil at Buck Creek, Indiana.

Fig. 11. Differences in leaf retention at harvest are apparent in the photograph of the IL clone (left) and the Nagara clone (right).

- **University of Illinois Urbana-Champaign**
  - **Factor Analysis Plots**
    - ✓ Biomass was harvested on August 28, 2014 for the H1 (post-anthesis stage) harvest treatment. Dry matter was determined for all samples.
    - ✓ The H2 (after killing frost) and H3 (Alternate H1 and H2 plots) treatments will be harvested within two weeks after the killing frost.
    - ✓ Stand frequency will be measured using the frequency grid in all the factor analysis plots.

Fig. 12. The H1 (post-anthesis stage) treatment plots for both 2012 and 2013 plantings were harvested on August 28, 2014.

- **Comparison Field Trial**
  - ✓ Plant height and light interception data were measured until the end of August in the comparison field trial of Kanlow switchgrass, IL ecotype big bluestem, four populations of prairie cordgrass (20-107, 46-102, 17-109, 17-104), and Miscanthus x giganteus.
  - ✓ The plots were harvested on November 13, 2014 and biomass samples were collected.
  - ✓ The samples will be used to calculate dry matter content and tissue samples will be analyzed for chemical composition as well as fiber content.

Fig. 13. The Comparison Field Trial was harvested on November 13, 2014.

- **Abiotic Stress Trial**
  - ✓ Growth measurements were periodically taken for prairie cordgrass and switchgrass growing on salt affected soil (EC>20 dS m-1) in Salem, IL.
  - ✓ The growth measurements were also taken in two poorly drained locations in Pana, IL and Urbana, IL.
  - ✓ Biomass will be harvested in Mid-November 2014 in all three locations.
  - ✓ Samples will be collected at harvest and dry matter yield will be estimated.
  - ✓ Tissue samples will be analyzed for chemical composition and fiber content.

- **University of Minnesota**

The early harvests at Lamberton and Becker were completed on August 14, 2014 and August 1911, 2014, respectively. The late harvest at Becker was completed on October 29, 2014. The late harvest at Lamberton was completed on November 13, 2014.

- **Factor plots at Becker, Minnesota**

The H1 plots at Becker (Figure 14) were harvested on August 10, and the H2/N3 plots (Figure 15) were harvested on October 29. Visually, growth was much better than last year as a result of abundant early and mid-season rainfall. The August dry matter (DM) yields (Figure 16) were much improved relative to last year, when all grass plots had DM yields below 0.4 Mg ha^{-1} due to drought. However, weed pressure was high, and plots had to be hand-weeded in July, despite attempts at control using 2,4-D.

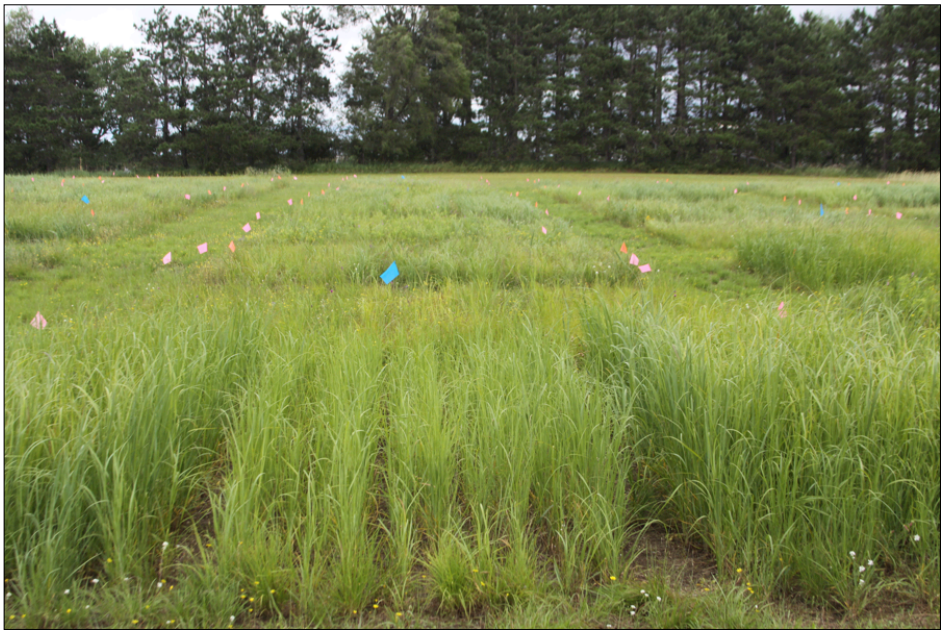

Fig. 14. Becker plots on July 17, 2014 prior to the start of a long dry period.

Fig. 15. Post-frost harvest at Becker, October 29, 2014.

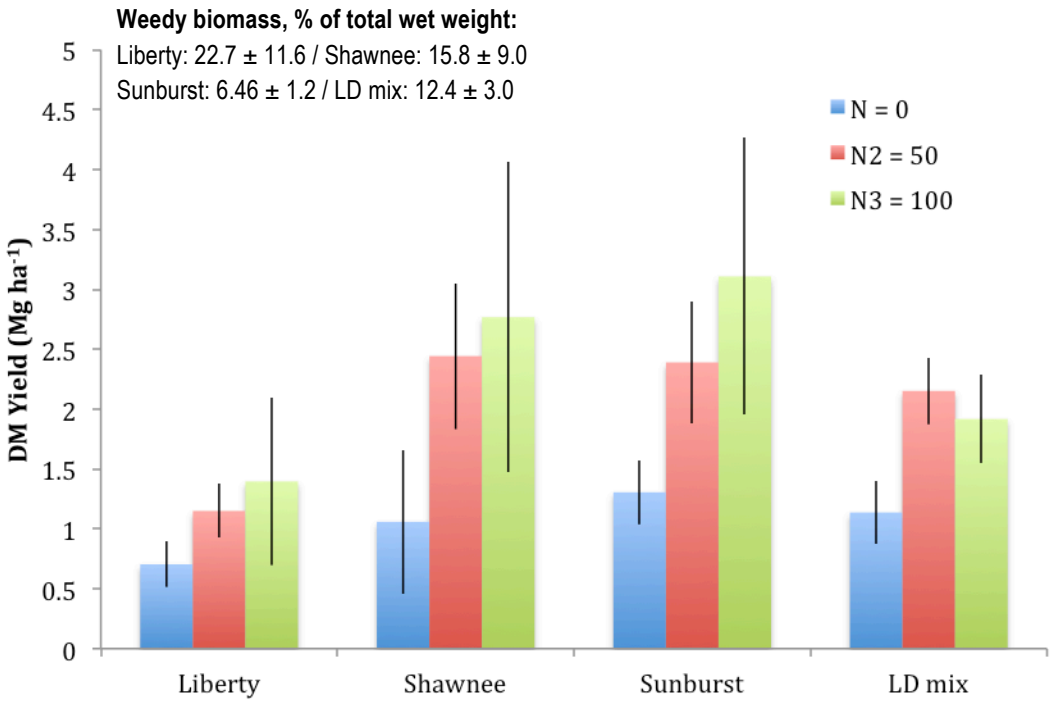

Fig. 16. August 10, 2014, dry matter yield on grass plots at Becker.
N = nitrogen application in lbs ac^{-1}. Error bars denote one standard deviation.

- **Factor plots at Lamberton, Minnesota**

  Both H1 and H3 plots were harvested at Lamberton on August 19, 2014 (Figure 17) and the H2 plots were harvested on November 13, 2014 (Figure 18). H1/H3 have not yet experienced harvest treatment differences, so August harvest results are combined in Figure 19. 'Liberty' experienced some stand loss during the harsh 2013-2014 winter, allowing gaps to be filled with weeds (see weedy biomass comparison in Figure 6).

Fig. 17. Factor plots at Lamberton, MN, immediately prior to August 19, 2014 harvest.

Fig. 18. Post-frost harvest at Lamberton, MN, November 13, 2014.

Weedy biomass, % of total wet weight:
Liberty: 18.4 ± 18.4
Shawnee: 7.8 ± 4.3

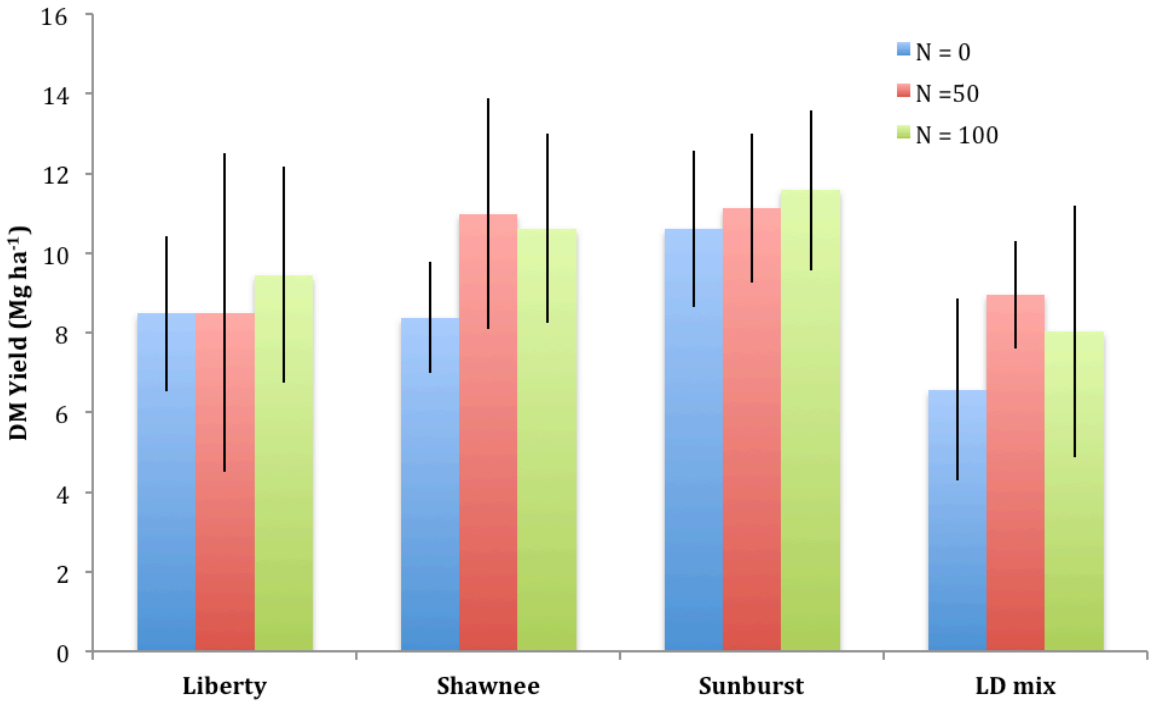

Fig. 19. August 20, 2014, dry matter yield on grass plots at Becker.
N = nitrogen application in lbs ac^{-1}. Error bars denote one standard deviation.

- **USDA-ARS, Lincoln**
  - **Factor Analysis Plots**
    - ✓ Anthesis harvest treatments and sample collection were completed as scheduled.
    - ✓ Feedstock samples collected in 2012 and 2013 from Nebraska have been processed, scanned, and are being predicted.
    - ✓ A late killing frost has delayed post-frost harvests until at least mid-November.
  - **System Analysis Plots**
    - ✓ Growing season harvests in the harvest height and harvest date study have been completed.
    - ✓ The feedstock samples collected in 2012 and 2013 from Nebraska have been processed and waiting NIRS scanning and compositional prediction.

- ✓ Greenhouse gas (GHG) sampling for the 2014 growing season continues. Soil water content and GHG have been sampled at weekly intervals in the System Analysis plots to compare the perennial grass feedstocks and N rate to continuous corn.
  - 2014 data will be collected until fields are harvested in November 2014.
  - 2013 data are being summarized.
- ✓ Visual obstruction measurements for the 2014 growing season will continue until fields are harvested in November 2014.
- ✓ A late killing frost has delayed post-frost harvests until at least mid-November.

- **Biochemical and Thermochemical Evaluation**. Biochemical and thermochemical evaluation of switchgrass, big bluestem, and low diversity mixture pellets is in process to compare the composition of milled and pelleted material.
  - ✓ Glucose conversion efficiencies were better or similar for pelleted versus milled biomass.
  - ✓ Trends for switchgrass and big bluestem are different.
  - ✓ Xylose conversion efficiencies were unaffected by pelleting.
- An additional pellet project is in process with collaborators from the University of Illinois to evaluate the particle size distribution and energy required to process pelleted vs. chopped feedstocks at the conversion facility to determine value-added potential of pelleting. Samples are being evaluated.
- Continued to manage a field-scale herbaceous perennial feedstock research and demonstration site in cooperation with Vermeer Manufacturing near Pella, Iowa. These feedstocks will be harvested and baled in mid-November.
- Continued to manage a small-plot herbaceous perennial feedstock research and demonstration site on a floodplain in cooperation with Vermeer Manufacturing near Pella, Iowa.
  - ✓ This site provided the first confirmation of seedling flood tolerance in Liberty switchgrass.
  - ✓ Liberty switchgrass and prairie cordgrass may provide an opportunity to re-vegetate reed canarygrass-invaded wetland sites.

- Feasibility of annual & perennial feedstocks to supply CHP to an advanced ethanol fermentation plant. Harvested the annual feedstock biomass trial evaluating the potential for growing teff and biomass sorghum in a double cropping system with winter wheat or oats.
  - ✓ Average biomass DM yields were 2.6 tons/acre for sorghum and 1.4 tons/acre for teff.
  - ✓ Winter wheat has been planted and oats will be planted in early spring.
- 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.
  - ✓ Appropriate management is critical.
  - ✓ Grazing WS grasses provides revenue & mitigates risk for bioenergy.
  - ✓ 2-year average gains of 191–274 lbs BW/acre.
  - ✓ At $2 per pound, gross returns range from about $400-550 per acre per year.
  - ✓ WS grasses may provide dual use for grazing and biomass production with appropriate management.

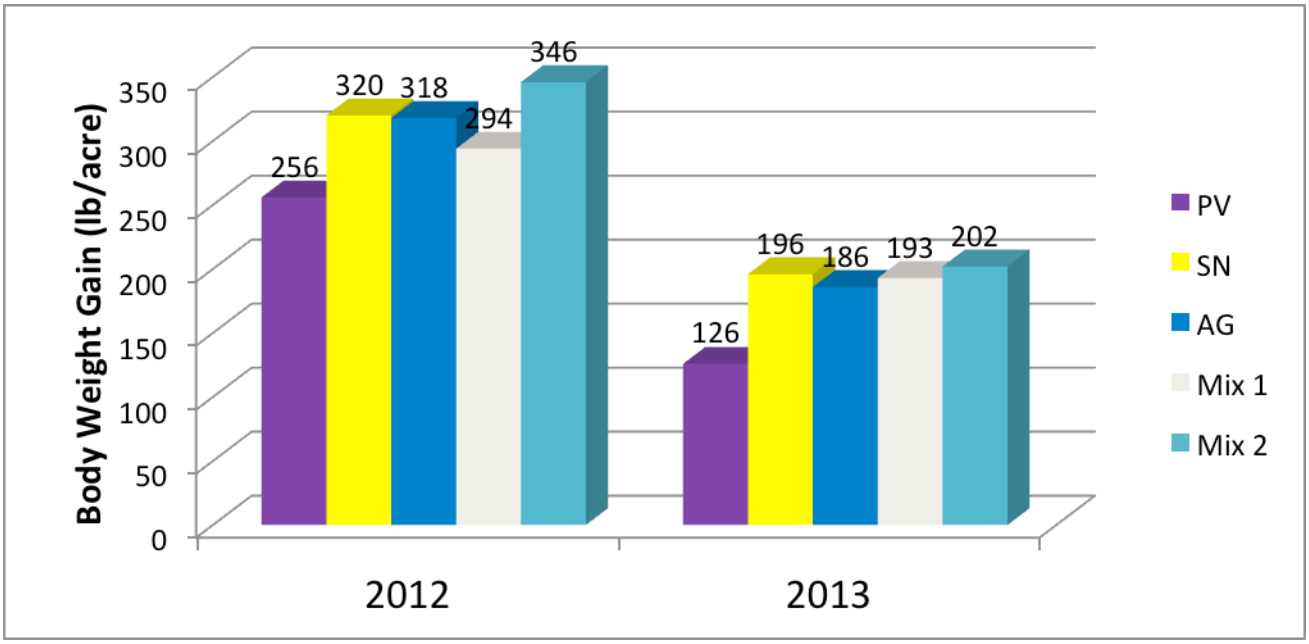

Fig. 20. Year 3 warm season grass grazing trial body weight gain.

- 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 and Dr. Chad Hart. 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.

- Completed Tasks from Last Quarter

  - ✓ Planted triticale cover crop in continuous corn System Analysis plots. Stands are excellent.

  - ✓ Processed and shipped 4 switchgrass, 2 big bluestem, 2 low diversity mixture, and 2 corn stover biomass samples to Renmatix.

  - ✓ Submitted switchgrass and corn stover samples from long-term study for mineral analysis.

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.

University of Wisconsin

1. Planned Activities

Planned activities in this quarter included:

- Collection of perennial grass harvest energy requirements using large-square baler;
- Continued development of compaction and re-shaping system for round bales;
- Establishment of storage study to compare losses between perennial grasses and corn stover;
- Evaluation of treatments to enhance the ruminant feed value of very mature grasses; and
- Harvest of switchgrass at our research/demonstration field.

2. Actual Accomplishments

- Over the past several years we have collected data on the energy requirements to harvest and process perennial grasses. We have an extensive data set that includes data from forage harvesters; round balers –with and without pre-cutters; and tub grinders. We also have comparison data when harvesting and processing corn stover with these machines. What was missing from the data set was harvest of perennial grasses and corn stover with a large-square baler. This quarter we harvested switchgrass and native grasses with a large-square baler and quantified productivity, fuel use and bale density. Weather permitting we will complete the comparison data set by harvesting corn stover with the large-square baler.

- We have developed a process that reshapes and compacts conventional size round bales into a parallelepiped or cuboid shape. We have begun bale compaction experiments to quantify compression forces, bale density, and bale expansion rate. Initial results have shown that less energy is required when the bale is compacted in both the vertical and horizontal directions as compared to trying to achieve the desired density by single axis compression. Improvements to the compression process were conducted this quarter. In particular, we:

  - ✓ Improved the system to compact the bales by re-designing the compression platens with the goal of reducing parasitic friction losses; and

  - ✓ Developed an improved method of restraining the material using polyethylene strapping. Round bales of switchgrass and reed canarygrass were harvested and put into storage to support planned activities in the next quarter.

- Previous work had shown the value of storing perennial grasses indoors or in a tube of stretch plastic film. This work was expanded in 2014 to compare perennial grass storage to that of corn stover. Four crops were considered: switchgrass, reed canarygrass, traditional corn stover (shred/rake/bale) and EZ Bale corn stover (stover exiting the combine was windrowed without any subsequent shredding or raking). Yield and fuel requirements were quantified at baling. Bales were placed into three storage treatments:indoor, outdoor/uncovered, and wrapped in tube of plastic film. Half the bales will be removed from storage in early spring and the remainder in mid-summer (Figure 21).

Fig. 21. Storing bales with and without stretch plastic film.

- When perennial grasses are more established across the landscape, additional or alternative markets need to be considered beyond biomass feedstocks. For instance, if yields are exceptional for several years, available supply may outstrip demand from nearby biorefineries. An obvious alternative market would be to use excess supply as ruminant roughage feed. However, the very mature grasses harvested in the late fall have challenging nutritional composition. Therefore, we began experiments to improve mature grass digestion by mechanical and chemical means. This fall we produced the following treatments using switchgrass harvested at the end of October: (a) control; (b) treated with calcium hydroxide @ 5% by weight; and (c) treated with ammonium hydroxide @ 4 % by weight. Treatments a, b and c were placed in 2 gal bucket silos at 45% DM content and stored anaerobically. Treatments a and c were also stored as "dry hay" at 82% DM and stored aerobically. All five treatments were also split into two physical treatments – chopped or shredded by hammermilling. We intended to add an additional treatment using an exogenous fibrolytic enzyme (EFE) additive but have yet to make needed arrangements with an enzyme supplier. Sufficient switchgrass was stored so that if an EFE source is found, this treatment can be added to the experiment. We plan to make the same treatments using corn stover for comparison purposes. All treatments will stay in storage for 120 days and then will be analyzed for appropriate nutritional composition.

- Finally, we have rented 35 acres of marginal land in which to establish mixtures of switchgrass, big bluestem, and indiangrass. This land serves as a test site for our equipment and we have conducted outreach activities here as well. In this quarter we harvested crops using both large-square and large-round balers. We established an additional 5 acres using the Liberty variety of switchgrass developed by cooperators

Mitchel and Vogel. Weed control will be vital to improve this plot in 2015. Yields have not yet been determined, but by observation grasses established in 2013 produced excellent stands in 2014. However, extensive lodging occurred due to wet, windy conditions in the fall of 2104. Terrain and machine limitations resulted in very long stubble, which reduced yield. We plan to quantify this yield loss before the snow covers the field.

Fig. 22. Harvesting biomass from marginal land.

3. Explanation of Variance

We are still behind in completing manuscripts for publication. The manuscript drafts are written but additional data collected in this quarter need to be added to complete the conclusions. We still need to harvest some corn stover for comparison of harvest energy requirements and quantify yield loss from lodged switchgrass, but early winter weather is making these tasks challenging.

4. Plans for Next Quarter

Our efforts in the next year will include:

- Continued 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;

- Continued work on system to compact and re-shape round bales;
- Maintain bales used in the storage study; and
- Remove and analyze treatments to enhance the feed value very mature switchgrass.

5. Publications, Presentations, and Proposals Submitted

None

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. A paper was published 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 Llubljiana, Slovenia in August. 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 are working with developing a set of scenarios to represent how farmers indicate that they plan to respond to climate change over the next few decades.

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.

5. Publications, Presentations, and Proposals Submitted

- Kling, C.L. (2014, July). Robust Optimization of Agricultural Conservation Investments to Cost-Efficiently Reduce the Northern Gulf of Mexico Hypoxic Zone. Presentation to the World Congress of Environmental and Resource Economists, Istanbul, Turkey and at the Department of Agricultural and Resource Economics, University of California, Davis (October 2014).

- 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., Panagopoulos, Y., Valcu, A., Gassman, P.W., Rabotyagov, S., Campbell, T., White, M., Arnold, J.G., Srinivasan, R., Jha, M.K., Richardson, J., Moskal, L.M., Turner, G. & N. Rabalais (2014). Land Use Model Integrating Agriculture and the Environment (LUMINATE): Linkages between Agricultural Land Use, Local Water Quality and Hypoxic Concerns in the Gulf of Mexico Basin. European Review of Agricultural

Economics, (2014): doi: 10.1093/erae/jbu009, presented at the European Agricultural Economics Association World Congress, 2014.

- 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), and 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

We continued our investigation into yield gaps, biomass production costs, and potential industrial synergies with biomass feedstocks other than switchgrass. We increased our focus on the air quality impacts of biofuels.

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

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

5. Publications, Presentations, and Proposals Submitted

- Mu, D., Min, M., Krohn, B., Mullins, K., Ruan, R., & J. Hill. Life Cycle Environmental Impacts of Wastewater-Based Algal Biofuels. *Environ. Sci. Technol.* 48: 11696–11704**.** http://dx.doi.org/10.1021/es5027689.

- Mullins, K., Tessum, C., Marshall, J. & J. Hill. Spatial Economic Input-Output Life Cycle Assessment of Air Pollutants. LCA XIV Conference. October 6–8, 2014. San Francisco, CA.

- Nickerson T. & J. Hill. A Regional Approach to Assessing the Economics of Switchgrass Biomass Production in the United States. Poster Presentation. American Coalition for Ethanol Annual Conference. August 4–6, 2014. Minneapolis, MN.
- Tessum, C., Hill, J., & J. Marshall. Environmental Justice and Equality Aspects of Conventional and Alternative Light-Duty Transportation in the United States. International Society for Environmental Epidemiology Annual Conference. August 27, 2014. Seattle, WA.
- Tessum, C., Marshall, & Hill, J. A Reduced-Complexity, Variable Grid Resolution Model for PM 2.5 Transport and Transformation. American Association for Aerosol Research Annual Conference. October 22, 2014. Orlando, FL.

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**.

   Micro-scale mass balance analysis for lignin fast pyrolysis was planned to understand the monomeric and oligomeric proportions of the lignin bio-oil with the total conversion. More specifically, the intention of this analysis was to provide the degree of polymerization for lignin in fast pyrolysis, while providing a benchmark for maximum conversion to bio-oil, with the negligible heat and mass transfer limitations present in micro-scale pyrolysis.

2. **Actual Accomplishments**

   - **Quantifying Micro-scale Lignin Fast Pyrolysis Products**. Analysis was carried out in a micro-scale pyrolyzer, where eluted vapor is condensed in a nitrogen bath. Collected bio-oil was categorized as monomers and oligomers according to their solubility in toluene.

In a separate run, total bio-oil was dissolved in a deuterated acetone solvent to analyze the water content using H-NMR spectrometry. Py-GC/MS/FID /TCD system was used to quantify remaining products such as other organics, gases and char.

Results show that lignin can be effectively converted to 39 wt% of dry bio oil, where approximately half of it was toluene soluble monomers. Total bio-oil with water accounts for 59 wt% of the feed lignin. Water content was significant at 17 wt%, possibly with additional atmospheric moisture condensed while handling. Gas and char quantities were significantly lower around 20 to 25 wt%, in contrast to higher values reported for larger scale lignin fast pyrolysis experiments.

This study shows that lignin can be effectively converted in micro-scale fast pyrolysis with comparatively higher yields. Lower yields reported for larger scale runs could be attributed to heat and mass transfer limitations prevalent in those systems. Even at micro-scale, considerable amount of oligomers are formed during lignin fast pyrolysis. This indicates the importance of finding ways to effectively convert these oligomers, either in pyrolysis or in upgrading steps to obtain useful monomeric products.

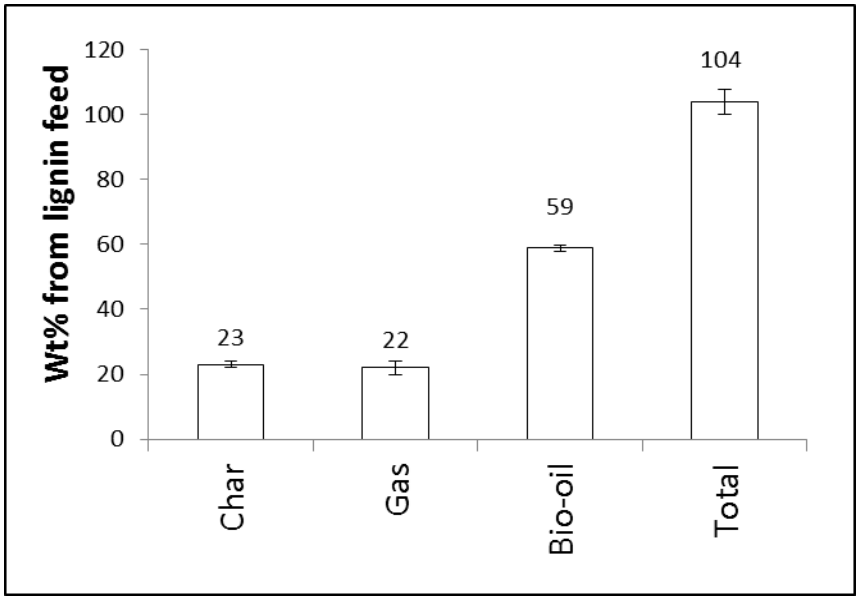

Fig. 23. Mass balance for organosolv lignin micro-scale fast pyrolysis products at 600^{0}C.

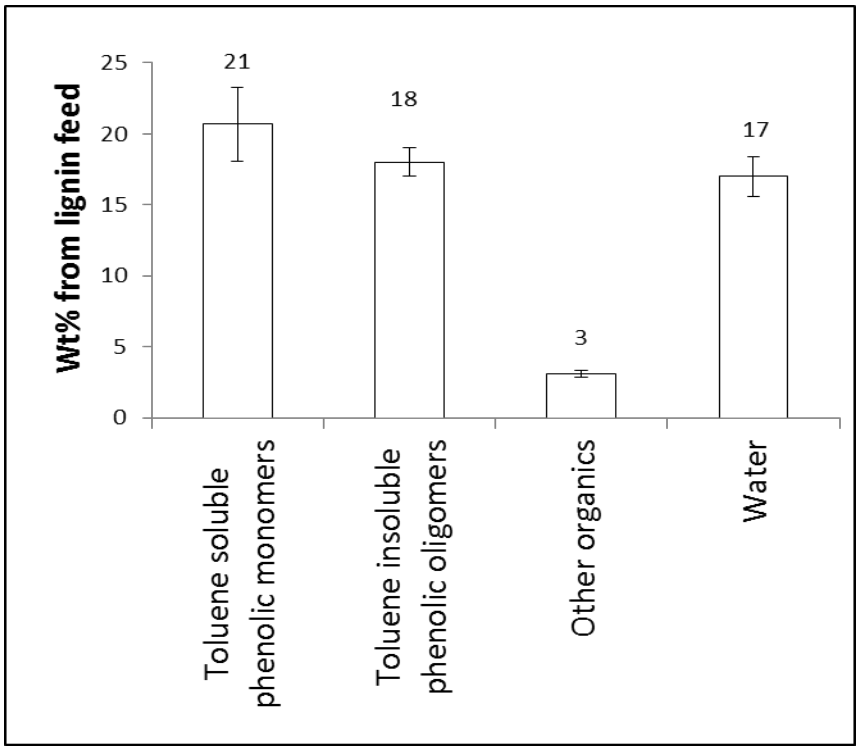

Fig. 24. Mass balance for organosolv lignin bio-oil constituents in micro-scale fast pyrolysis products at 600^{0}C.

3. Explanation of Variance

None to report.

4. Plans for Next Quarter

As a part of the study for converting lignin derived monomers over zeolite catalyst to aromatic hydrocarbons, mechanistic analysis will be performed using phenol and anisole as most basic representative lignin model compounds. In this study we expect to understand the influential factors in lignin catalytic pyrolysis over zeolites to reduce coke generation and improve the conversion to aromatic hydrocarbons.

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 was planned to be prepared as a manuscript for publication.

2. Actual Accomplishments

The C1s Spectrum of biochars in addition to that of a graphite sample and a model compound: 2, 4, 6 triphenyl pyrylium sulfate are presented in Figure 25. Spectra are shifted to the large carbon maxima. The region of binding energy in the C1s spectrum of this standard ranging from 286.7 eV to 288.5 eV is attributed to carbon bound to oxonium. The broad band observed in this region in the standard is also observed in the spectrum of the 700 ˚C HTT biochar produced from corn stover which also exhibited the greatest AEC at pHs 4 and 8 and is not observed in the spectra of other biochars. The spectrum of the 700 ˚C HTT biochar produced from cellulose does not have a prominent band in this region, however it does show increased signal in this region relative to the spectrum of the 500 ˚C HTT biochar produced from cellulose in this region and likewise exhibited much greater AEC than biochar produced at 500 ˚C. This band is interpreted as electron deficient carbon bound to oxonium, which manifests higher binding energy. The spectrum of graphite is also shown to illustrate the spectrum of condensed aromatic carbon with negligible hetero oxygen content.

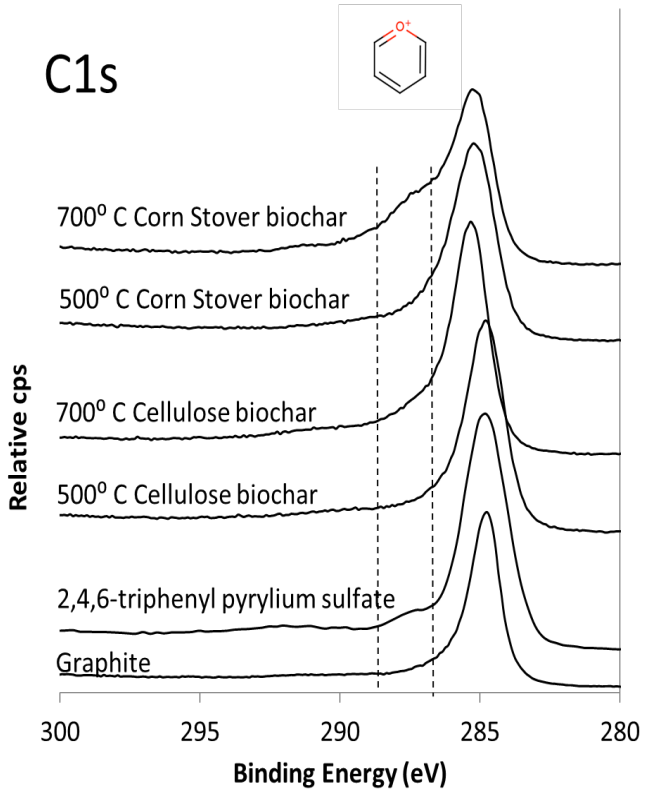

Fig. 25. C1s spectrum of biochars.

The O1s spectra of selected biochars, our standard (2, 4, 6 triphenyl pyrylium sulfate), and graphite are depicted in Figure 26. Similar to the C1s spectrum, the O1s spectrum of the standard also displays two broad peaks representing pyrylium O and sulfate O. In the O1s spectrum, the oxonium heterocycle O is assigned as ranging from 534.0 to 536.6 eV. Much of the signal in the spectra of graphite and biochars represents lower binding energies consistent with the spectra of most O containing organic functional groups found in solids (mostly phenols, ethers, and carboxyl groups). The small portion of biochar O1s spectra in the range of 534.0 to 536.6 eV is related to electron deficient O. Surprisingly, almost half of the signal in the graphite spectrum is also in this region, however, the graphite employed in this study was cleaved from a monochromator which may have undergone significant aging.

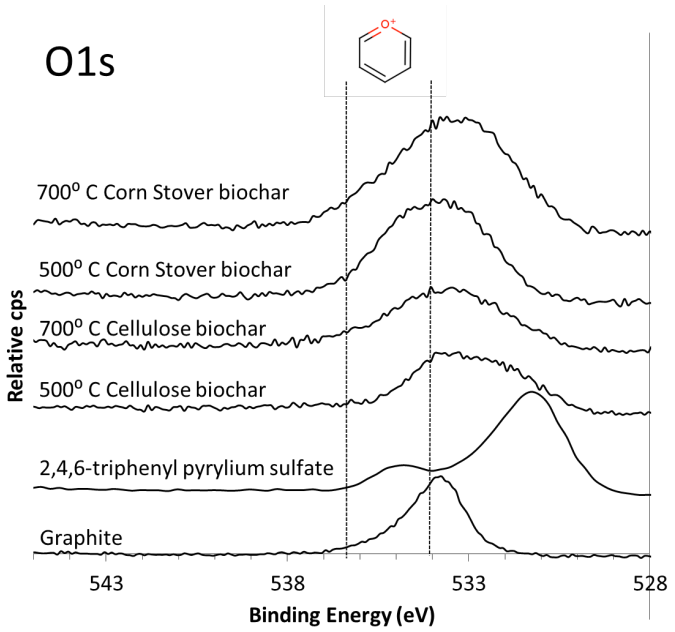

Fig. 26. O1s spectrum of biochars.

Attempts to obtain MULTI CP MAS 13C NMR quantitative spectra of biochars produced at 700 ˚C HTT were complicated by the low H content, long dipolar coupling time of non-protonated carbon, and the high electrical conductivity of carbon in this biochar. Figure 27 depicts 13C NMR spectra of biochars produced from cellulose at 700 ˚C HTT obtained by direct polarization. Peak broadening adds difficulty in assigning non aromatic carbon with chemical shifts close to that of aromatic carbon, thus we cannot be sure what changes occurred in biochar due to the weathering treatments. Large peak breadth in these spectra is due to chemical shift anisotropy induced by unpaired electrons in the sample, which act as paramagnetic centers.

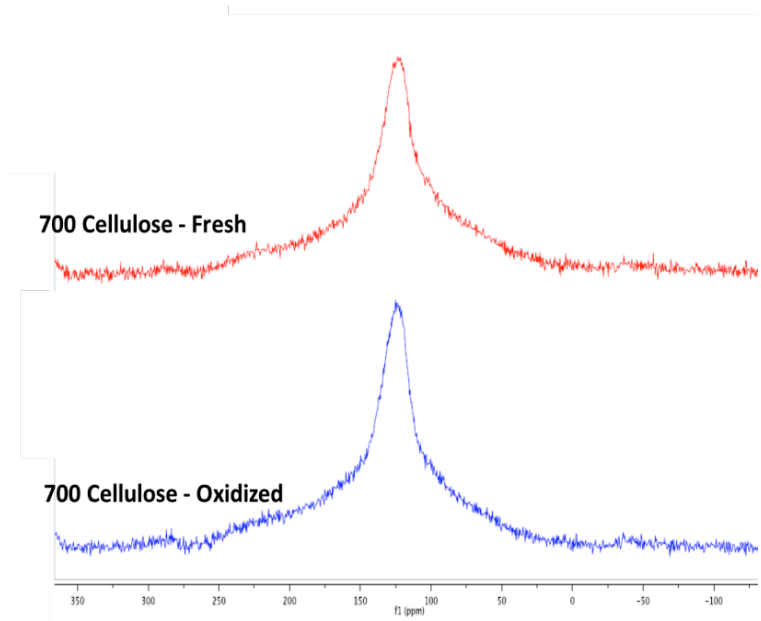

Fig. 27. DP MAS ^{13}C NMR spectra of fresh and oxidized biochars produced from cellulose at 700 ˚C.

Electron probe resonance spectra of biochars produced from cellulose prove existence of unpaired electrons in these samples (Figure 28). The weathering treatments had negligible impact on total unpaired electron content. This is likely due to the stability of free radicals delocalized over a condensed aromatic structure, which also contributes to electron mobility, hence the conductivity of this type of carbon. Magnetically induced charge imbalance encountered during NMR experimentation effects paramagnetic centers, which in turn contribute to wide spectral peaks. The EPR spectrum of the 500 ˚C HTT biochar derived from cellulose was scaled to fit the spectra of the 700 ˚C HTT counterpart by dividing by 1000. EPR is semi-quantitative, yet the larger unpaired electron count evinced in the 500 ˚C HTT biochar demonstrate that unpaired electrons alone do not contribute to paramagnetization of biochar, but it is their mobility which is related to sharing over larger, degenerate molecular orbitals.

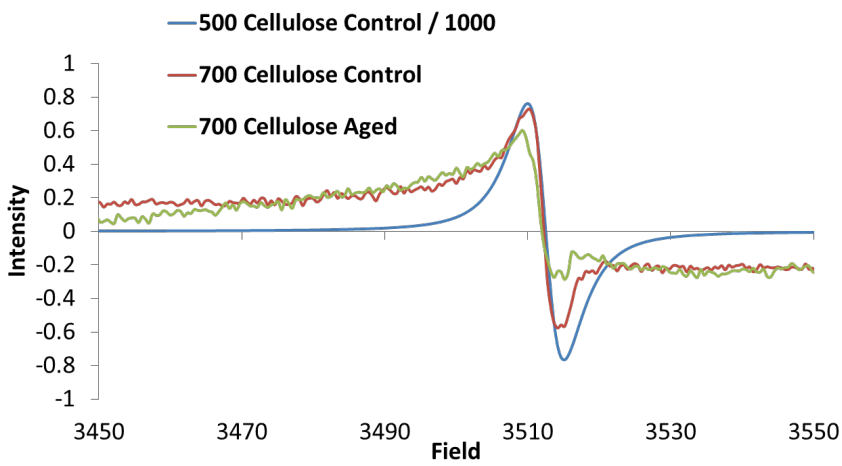

Fig. 28. EPR spectra of biochars produced from cellulose.

3. Explanation of Variance

Variance between plans and actual outcomes is due to the urgency to publish the manuscripts "Anion Exchange Capacity of Biochar" and "Oxidative weathering of biochar by $^1O_2$, effects of pyrolysis temperature and feedstock, and impact on anion exchange capacity." It was imperative to address the reviews concerns by obtaining additional data to support our findings so these manuscripts can be published.

4. Plans for Next Quarter

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

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 for the 4th quarter of year 3 (Y3 Q4) 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 a BEI 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. 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**

   During the second quarter (November 2014 – January 2015) our team will continue work as outlined in the planned activities. Planned activities (B), (C), and (D) will continue.

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

   None this quarter.

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**

     The new risk assessment model evaluation will continue and preliminary calculations for the risk will be started for actions that currently have data. Additional data and detail necessary for analysis in the other identified action will be collected. Refinement of the current data sets for exposures and frequencies will be accomplished.

   - **Actual Accomplishments**

     The standardization of this new risk assessment model for purpose of creating repeatable results has started. Current projections indicated that the expected outcome from this new risk model will be closer to other industry standards and better positioned for additional refinements as more data is collected. The risk assessment model is:

$$Risk = \sum_{year=1}^{6} \sum_{i=1}^{m} \left(\sum_{action=1}^{n} [\mathrm{P(exposure)}]_{action} \times [\mathrm{P(injury)}]_{action} \right)_{i_{year}}$$

Where the probability of exposure and the probability of injury are defined by these generic equations:

$$\mathrm{P}(exposure) = \frac{\#\ of\ acres\ (crop\ type\ operation\ performed)}{\#\ of\ crop\ type\ farmed\ acres}$$

and

$$\mathrm{P}(injury) = \frac{\#\ injuries\ (from\ a\ type\ of\ specific\ operation)}{\#\ of\ people\ performing\ that\ specific\ operation}$$

Fig. 29. Risk assessment model.

Data about exposures and frequencies for certain actions in the major headings (*i* terms) have been collected. Collection of additional facts necessary for the integration of the data into the new risk model for biofeedstock production was started. Specific coding procedures for data in the MS Excel spreadsheet were developed.

The cooperative arrangement with the investigator at Penn State University yielded one paper in published for the *Journal of Agromedicine* and one in the *Journal of Agricultural Safety and Health*.

- **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 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 *International Society of Agricultural Safety and Health* 2015 conference.

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

✓ Schaufler, D. H., Yoder, A.M., Murphy, D. J. Schwab, C. V. & A. F. Dehart. (2014). Safety and Health Hazards in On-Farm Biomass Production & Processing. *Journal of Agricultural Safety and Health*. 20(4): 283-299.

- ✓ Yoder, A. M., Schwab, C. V., Gunderson, P. & D. J. Murphy. (2014). Safety and Health in Biomass Production, Transportation and Storage. *Journal of Agromedicine.* 19:83-86.

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

- **Planned Activities**

  Receive approval for modifications to the human subjects study. Purchase the air sampling equipment that was identified from vendor. Line up human subjects to participate in the study.

- **Actual Accomplishments**

  The modifications to the human subjects study to include the transportation location and potential of subjects is still on going.

  We are preparing to purchase air-sampling equipment from the identified vendor.

- **Explanation of Variance**

  None to report.

- **Plans for Next Quarter**

  Receive approval for modifications to the human subjects study. The air sampling equipment will be purchased. Identification human subjects to participate in the study will begin after approval.

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

  No publication, presentations or proposal submitted from this task.

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**

   - **Modules.** Complete final editing of existing modules in feedstock development and economics areas.

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

     Develop outline of module content.

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

     Develop outline of module content.

   - **Evaluation Tasks**

     Continuing draft of journal manuscript.

2. **Actual Accomplishments**

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

     Final revisions completed and evaluation questions being prepared for use of module in class at OSU.

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

     Developed the module content outline.

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

     Developed the module content outline.

   - **Evaluation Tasks**

     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**

  Continue development of draft module materials.

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

  Continue with draft of journal manuscript.

5. **Evaluation Tasks**

Continuing preparation of draft of journal manuscript

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

None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. **Planned Activities**

- All 16 interns will return to Iowa State University from the CenUSA annual meeting for the conclusion of the program

- On August 1, 2014 all CenUSA student interns will participate in the ISU university-wide undergraduate research poster session and reception. This poster session, the culminating event of the CenUSA Bioenergy Internship Program, will include all undergraduate research interns who have participated in summer research internships at Iowa State University. This event will showcase over 100 students.

- All students will complete a post-program survey conducted by Iowa State University's Research Institute for Studies in Education (RISE). The purpose of this assessment is to (1) assess the program's activities; (2) evaluate immediate program successes and challenges; (3) promote continued interest in the program by alumni after they complete their research experience; and (4) track the career paths of our graduates.

- On August 2, 2014 all student interns depart Iowa State University.
- Finalize and process all payments related to the internship program.

2. Actual Accomplishments

- The 16 undergraduate student interns returned to Iowa State via CIT charter bus from the CenUSA annual meeting in Chaska, Minnesota.
- On the morning of Friday, August 1, 2014 all student interns and some faculty mentors and graduate student mentors attended a celebration breakfast at the Iowa State University's Memorial Union.
- On the afternoon of Friday, August 1, 2014 all the CenUSA interns participated in the ISU university-wide undergraduate research poster session and reception.
- Interns completed post-program survey and participated in focus groups conducted by Iowa State University's Research Institute for Studies in Education (RISE).
- All 16 interns departed Iowa State University for home on Saturday, August 2, 2014.
- All internship-relevant payments processed.
- Created tentative calendar and program content outline for the 2015 program.
- Begin soliciting faculty hosts for the summer 2015 program.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- 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.

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

None to report this period.

Subtask 2B – Training Graduate Students via Intensive Program

1. **Planned Activities**

None. This is a PY4 activity, and forward planning will begin in summer 2014.

2. **Actual Accomplishments**

N/A

3. **Explanation of Variance**

N/A

4. **Plans for Next Quarter**

Work with Dr. Mike Casler to continue planning for a one-day condensed graduate intensive program add-on to the annual meeting.

- ✓ Plan to include a career-fair or similar activity with industry, tailored to grad students, plus other proposed high-value activities as follows.
- ✓ Tentative 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**

N/A

Subtask 2C – Training Graduate Students via Monthly Research Webinar

1. **Planned Activities**

Restructure the delivery of research webinar content.

- Propose four 1-hour sessions spread over the academic year (October, November, January, February). Each session would have several CenUSA co-project directors 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 20 minutes each, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

- Potential Topics:

  - ✓ What are the most realistic approaches to reducing N and P export from the Corn Belt?

  - ✓ What kind of switchgrass yields are likely to be possible on marginal lands, and what would the cost of this material be?

  - ✓ How do yield increases and machinery changes impact cost and safety?

  - ✓ 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?

2. Actual Accomplishments

As planned, no graduate research webinars were hosted during this time period.

3. Explanation of Variance

None.

4. Plans for Next Quarter

Continue with planning for the restructures delivery of research webinar content.

- Organize four 1-hour sessions spread over the spring academic year (January, February, March, April of 2015). Each session will have several CenUSA co-project directors 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, 2015** – 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, Raj Raman

✓ **February 27, 2015** – 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, 2015** – 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, 2015** – 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**

  - ✓ Use footage captured with CenUSA team members at annual meeting to create general biochar video and home horticulture video.

  - ✓ Host webinar about biochar.

  - ✓ Produce issue of BLADES newsletter.

  - ✓ Capture video at UNL field days.

- ✓ Create exhibit and share CenUSA information at E3 conference.
- ✓ Create CenUSA Fact Sheets about biochar.
- ✓ Monitor use and impact of CenUSA materials and social media.

- **Actual Accomplishments**
  - ✓ Shared footage from annual meeting with video contractors and began the editing process for the biochar videos.
  - ✓ Hosted biochar webinar on October 31, 2014 featuring three ISU graduate students who have developed a biochar business.
  - ✓ Produced fall edition of BLADES newsletter and distributed the newsletter in September (CenUSA Comm. Team).
  - ✓ Took pictures and captured video of presentations at UNL and uploaded to the CenUSA Flickr site (https://www.flickr.com/photos/cenusabioenergyimages/).
  - ✓ Began work on CenUSA Fact Sheet "Biochar Prospects of Commercialization."
  - ✓ CenUSA eXtension web site: Google Analytics for CenUSA articles/Fact Sheets on the CenUSA eXtension site for this quarter reveal the following:
    - ➢ CenUSA eXtension site received 1,787 page views by 1,225 users.
    - ➢ Seventy-eight percent (78%) of the page views *new* sessions, averaging 1.3 pages per visit. average time on page is 1:16 minutes.
    - ➢ Traffic sources are 80% search engines, 13% direct traffic and 7% referring sites
    - ➢ Compared to last quarter, usage is steadily increasing; page views are up by 26% and users are up 27%. The top nine states accessing CenUSA articles were Michigan, Texas, Wisconsin, Illinois, New York, Iowa, North Carolina, Pennsylvania and Nebraska.
  - ✓ **Impact of CenUSA's Vimeo Channel**. During the first quarter (August 1-October 31, 2014), the 35 CenUSA videos archived on Vimeo have had 132 plays and 1,549 loads; 1,255 of those loads came from our videos embedded on other sites.[2] The embedded videos were played 81 times. Our Vimeo videos were downloaded 16 times. 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

[2] When a video is loaded, people see the video but they do not click "play."

streaming of video). Once the video is downloaded, it is available on their computer to watch at the user's convenience.

- ✓ **Impact of CenUSA's YouTube Channel**. CenUSA videos are also posted on YouTube and those videos have been viewed 798 times between August 1, 2014 and October 31, 2014. 515 views were from within the United States. Demographic information including age and gender were not available this quarter due to changes in YouTube Analytics reporting. All of the videos were viewed on their associated YouTube watch page (each video has a unique "watch 'age"). Users find our videos through various avenues, which are referred to as 'traffic sources". Our top 4 traffic sources for the quarter include: YouTube playlist, YouTube channel page, direct links, and referrals from other web sites. 46% of our views came from users accessing videos through the playlist. The YouTube channel page accounted for 23% of our views. Views from mobile apps or from direct traffic (links in an e-mail of copying/pasting the direct URL) account for 23% of the video views. Finally, referrals from outside YouTube (Google search or access through external web sites) account for 7.7% of video views.

- ✓ **CenUSA Web Site**. The CenUSA web site had 717 visitors this quarter. These visitors logged a total of 3,239 pageviews during 1,026 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 a period of time, and the user returns, a new session is started.

- ✓ **CenUSA Social Media**

  - ➢ **Facebook**. By the end of October 2014, CenUSA's Facebook page had 182 likes, up from 176 the previous quarter. Out most liked post this quarter received 12 likes. The past with the largest reach had a total reach of 294 individuals. This quarter's post's included the E3 conference, photos from the annual meeting, the Nebraska CenUSA field days in Dawson and Beaver Crossing, and other various related bioenergy topics.

  - ➢ **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. CenUSA Bioenergy has 399 followers currently, up from 352 followers last quarter. During this quarter our tweets were retweeted a total of 43 times. Followers tagged CenUSA tweets as a favorite 229 times, and mentioned us 101 times.

- **BLADES Newsletter**. The CenUSA communications team released two newsletters this quarter (September and November 2014). BLADES features stories related to research coming from CenUSA, and other happenings in the world of perennial grass energy, including the industrial sector. BLADES was sent to 774 individuals this quarter. Of the 774 individuals who received the September newsletter, 300 (40.1%) of the recipients opened the newsletter, and 65 (21.7%) clicked on a story.

a. Explanation of Variance

None

b. Plans for Next Quarter.

- ✓ Finish the Master Gardener biochar video.
- ✓ Finish Biochar Overview video featuring Dr. David Laird.
- ✓ Post archived Biochar 101 and 102 presentations from the CenUSA annual meeting.
- ✓ Produce first draft of new Fact Sheet "Reducing Hypoxia: How Perennial Grasses Can Improve Water Quality" (working title).
- ✓ Produce November edition of BLADES, CenUSA's bimonthly newsletter.
- ✓ Develop one case study, do upkeep on CenUSA Index, social media promotion of CenUSA.

c. Publications, Presentations, Proposals Submitted

- ✓ E3 Conference Presentation: "CenUSA: Spreading the Word About Bioenergy Through Video and Webinars."
- ✓ Submitted the paper "Reducing Hypoxia: An Alternative Approach" by Pam Porter, Robert Mitchell and Ken Moore) to the Journal for Soil and Water Conservation.
- ✓ New publication in Module 5: "Biochar: Prospects of Commercialization" by David Laird and Pam Porter.

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

a. Planned Activities

- ✓ **Indiana (Purdue University)**
  - Sharing of CenUSA exhibit at CenUSA E3 conference.

- Lafayette area Purdue Agriculture Club presentation on CenUSA by Martin.
- Presentation to the Energy Managers of the Indiana Statewide Rural Electric Cooperative Association by Martin.
- Presentation to Indiana Planning Association group by Martin.
- Update on CenUSA to the Indiana SARE Advisory Board by Martin.
- Presentation on CenUSA at the Ohio Farm Science Review at the OSU "Question the Authorities" stage by Martin.
- Participation in the E3 Conference by Martin.
- August, September and October samplings at Peru and Trafalgar CenUSA plots by Martin and Johnson.
- Grinding of samples collected by Johnson.
- Mowing of weeds in plots at Oakland City by Johnson.
- Plan and host field day in Wabash/Roann with the workshop titled "Second Generation Bioenergy Harvest and Marketing" meeting with presentations by Martin and Johnson (Exhibit 3).
- Plan and host field day with CenUSA Bioenergy plot tour at Trafalgar with Johnson and Martin presentations.
- Place frontage signs at Wabash/Roann and Trafalgar sites.
- Continued effort on the exhibit at Trafalgar.

✓ **Iowa**.

Harvest biomass from CenUSA test plots; present awareness of new switchgrass varieties being developed as well as data from CenUSA switchgrass at Farmland Lease meetings in August and September.

✓ **Minnesota**

Manage and collect data on CenUSA plots; plan and host field day.

✓ **Nebraska**

Host field days at the CenUSA Beaver Crossing and Dawson demonstration sites.

b. Actual Accomplishments

✓ **Indiana**

Indiana (Purdue): The Purdue CenUSA Extension team reached 415 people this quarter – 311 male, 104 female, 4 Hispanic, 356 white, 15 African American, 16 Asian, 24 other.

- Shared CenUSA exhibit at CenUSA E3 conference (Martin).
- Presentation on CenUSA at Lafayette area Purdue Agriculture Club presentation (Martin).
- Presentated to the Energy Managers of the Indiana Statewide Rural Electric Cooperative Association (Martin).
- Presented to Indiana Planning Association group (Martin).
- Provided update on CenUSA to the Indiana SARE Advisory Board (Martin).
- Presentated on CenUSA at the Ohio Farm Science Review at the OSU "Question the Authorities" stage (Martin).
- Participated in the E3 Conference (Martin).
- Sampled Peru and Trafalgar CenUSA plots in August, September and October (Martin and Johnson).
- Grinding of samples collected (Johnson).
- Mowed weeds in plots at Oakland City (Johnson).
- Planned and hosted field day in Wabash/Roann with the workshop titled "Second Generation Bioenergy Harvest and Market" meeting with presentations by Martin and Johnson.
- Planned and hosted field day with CenUSA Bioenergy plot tour at Trafalgar with Johnson and Martin presentations.
- Placed frontage signs at Wabash/Roann and Trafalgar sites.
- Continued effort on the exhibit at Trafalgar.

✓ **Iowa**

The Iowa CenUSA Extension Economics team reached 389 people (land owners, farm operators, bankers and other ag professionals) at 13 different meeting with information about CenUSA and perennial grasses for bioenergy.

- ✓ **Minnesota**

We continued with management and data collection of the CenUSA plots. Hosted field day to share information about perennial grasses for bioenergy production. Twenty-four of the participants (42% producers, 19% entrepreneurs, 15% researchers, 8% extension educators, 8% graduate students, 4% crop consultants, 4% government agency, 4% food manufacturers) completed surveys following the field day indicating the following:

- Participants showed significant increased knowledge regarding establishing perennial grasses, herbicide use in perennial grasses, and energy value of perennial grasses.
- Because of their newly acquired awareness about producing perennial grasses for bioenergy, interest in learning more increased significantly.
- Respondents intentions to take action indicated:
  - 58% will consider planting a bioenergy crop, such as perennial grass, if a market develops 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.

- ✓ **Nebraska**

We prepared and taught session at E3 conference (Hay). We hosted field days at the CenUSA Beaver Crossing and demonstration sites. Topics discussed included establishment and management of bioenergy grasses; energy values of the perennial grasses and environmental impacts of the grasses. The 37 participants who attended the field days were asked to indicate how their knowledge regarding several aspects of perennial grass production and marketing increased. Knowledge gain was significant for:

- Establishing perennial grasses.
- Stand measurement of perennial grasses.

- Herbicide use in perennial grasses.
- Positive environmental effects of perennial grasses.
- Energy created from perennial grasses.
- Insects and diseases in perennial grasses.

Participants were also asked to share their intentions in a follow-up survey:

70% of respondents who indicated they are producers said they would consider planting a perennial grass if a market develops in their area. Fifty-nine percent (59%) of respondents who indicated they are producers will consider using perennial grasses for nutrient management, erosion, or livestock production.

c. Explanation of Variance

No variance was experienced.

d. Plans for Next Year

✓ Indiana

We will concentrate on the following activities:

- Analyze participant surveys from October 2014 CenUSA field days.
- Provide training for ANR Educators and continuous engagement on CenUSA activities.
- Continue development of CenUSA FFA Center Exhibit.
- Provide training for FFA Ag Science teachers at the FFA Center.

✓ Iowa

We will send plot data to Rob Mitchell and plan for 2015.

✓ Minnesota

We will concentrate on the following activities:

- Host calls of soils students and their professor (from Carlton College – small liberal arts college in Northfield, Minnesota) to the demonstration site at Elko in November.

- Do lab work on soil erosion and discuss marginal lands, switchgrass for biofuel, and the CenUSA project. Complete the pre-harvest grassland assessment and sample collection on the demo plots in November.
- Cut and bale the grass at Elko. We will burn the Lamberton plot in the spring of 2015.

✓ Nebraska

"High on Liberty" October 2014 Nebraska Farmer article (Exhibit 4).

e. Publications, Presentations, Proposals Submitted

✓ **Indiana.** Working on field day handbooks to be given out at October field days/tours.

✓ **Minnesota:** Working on a summary of CenUSA research activities for distribution to parties who requested data at the Lamberton Crops Field Day and for future use.

2. Economics and Decision Tools

a. Planned Activities

✓ Develop a web-based integrated crop enterprise budget calculator with crop record database and environmental models, for use with perennial crops.

✓ Submit abstracts to Iowa ICM conference planners to present CenUSA sessions at 2014 Integrated Crop Management (ICM) conference.

b. Actual Accomplishments

✓ The nitrogen spreadsheet has been updated and should be made available for downloading in October 2014.

✓ Made presentation on "Cost-Effectiveness of Perennial Crops for Reducing Nitrogen Losses to Surface Waters in Minnesota" at the annual meeting of the American Association of Cereal Chemists.

✓ Submitted two abstracts to Iowa ICM conference planners to present CenUSA sessions at 2014 ICM conference.

c. Explanation of Variance

None.

d. Plans for Next Quarter

- ✓ Continue development of the budget calculator.
- ✓ Present two sessions at Iowa ICM conference.

e. Publications, Presentations, Proposals Submitted

None.

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**
    - o Finish and install demonstration plots signage at Trafalgar.
    - o Pilot test supplemental electronic modules for demonstration plots.
    - o Send completed curriculum (x4) to editor and graphic designer.
    - o Complete electronic modules for beginner 4-H curriculum.
    - o Begin pilot of high school with FFA instructors.
    - o Identify participants to pilot 4-H materials.
  - ➢ **Iowa**
    - o Host training sessions at the Iowa State Fair and at the "Road Less Traveled" conference for girls that focuses on STEM education.
    - o Present breakout session at E3 conference in September.
    - o Host "hackathon" for Iowa State University computer science students to build games based on the algorithms from the C6 portfolio (See Exhibit 5).
- ✓ **Actual Accomplishments**
  - ➢ **Indiana**

115 adult leaders (60 male and 55 female) participated in CenUSA youth training and 100 youth participated in CenUSA programs this quarter.

- Installed preliminary signage at Trafalgar and Peru demonstration plots.
- Completed edits to Beginner 4-H curriculum in order to start electronic modules.
- Recruited teachers for and launched pilot High School FFA curriculum.
- Began process of identifying 4-H Pilot pilot participants.
- Prepared and delivered presentation for E3 conference.
- Assisted in Purdue Demonstration Plot Field Days.

➢ **Iowa**

- 58 adults (13 male and 45 female; 3 Hispanic, 54 white and 1 African American) participated in C6 activities this quarter; 184 youth participated in C6 program this quarter (63 male, 121 female; 12 Hispanic, 130 white, 16 African American and 21 Asian) participated in CenUSA programs this quarter.
- C6 was featured at the Iowa State Fair in the 4-H building as a hands-on STEM day exhibit. Of those that participated in the C6 activities, 133 youth experienced C6 curriculum and then completed a survey instrument. 96% indicated that they learned more about carbon and 60% indicated that they are more interested in a STEM career after participating in the C6 activities
- Hosted C6 sessions at the "Road Less Travelled" STEM conference for girls. 51 females attended and 19 completed surveys. The data is not yet analyzed.
- The C6 team also hosted a hackathon that invited Iowa State University students to build games based on the algorithms from the C6 game portfolio. Four of these programmers have been hired to develop a C6 game for portable devices using the Android and iOS systems. Curriculum from Purdue and University of Nebraska is being adapted for use in the Iowa C6 curriculum.
- Jay Staker presented a session on C6 at the E3 conference.

✓ **Explanation of Variance**

Indiana (Purdue University) had challenges in obtaining with graphic design services for Demonstration Plot signage that significantly delayed sign production. An internal

(Purdue) design team has been hired to complete the work. Preliminary signage was produced for the fall field days with the new team.

- ✓ **Plans for Next Quarter**
  - ➢ **Indiana**
    - Present CenUSA youth activities at the 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 electronic modules for 4-H Beginner Curriculum.
    - Continue work on final edits and layout for all curriculum.
  - ➢ **Iowa**
    - Continue development of the C6 learning portfolio.
    - Conduct training for use of C6 curriculum for Iowa 4-H staff on November 18, 2014.
    - Share the C6 game and curriculum. Participants will play the game and explore the curriculum.
    - Share background information from the C6 iBook and posters.
- ✓ **Publications, Presentations, Proposals Submitted**
  - ➢ **Indiana**

    Submitted one group and one individual abstract to present at the Annual Hoosier Association of Science Teachers (HASTI) conference in February 2015 and identified additional dissemination and presentation venues: AERA (due July 2015) and NSTA National (January 2015) and school Academic Advisors Conference (tbd).
  - ➢ **Iowa**

    Gave a presentation at the E3 conference on CenUSA C6 materials.

b. Broader Public Education/Master Gardener Program

- ✓ **Planned Activities**
  - ➢ **Iowa**
    - Present at Muscatine Home Garden Demonstration Field Day (Aug. 5, 2014).
    - Finish garden data collection.
    - Collect of completed data sheets from Master Gardener volunteers.
    - Input data.
  - ➢ **Minnesota**
    - Continue data collection at the CenUSA Master Gardener demonstration sites.
    - Provide public display about the Extension Master Gardener role on the biochar project at the Minnesota State Fair on August 31, 2014 in the University of Minnesota building as a special one-day project.
    - Professional writer and Extension Master Gardener, Meleah Maynard, will write and post a blog about the biochar project in late August from the volunteer perspective.
    - Julie Weisenhorn will present "How to Engage Volunteers in Research" – sharing learning from the CenUSA Master Gardener Biochar experience at the E3 Conference at ISU in September.
    - Maintain gardens until hard frost.
    - Clean up gardens for winter.
- ✓ **Actual Accomplishments**
  - ➢ **Iowa**
    - Presented at the Muscatine Home Garden Demonstration Field Day on August 5, 2014. 38 people attended (12 male and 26 female; 27 white and 1 Asian).
    - Presented to the Master Gardener group in Humboldt, Iowa on biochar use as soil amendment, 18 people attended.
    - Finished garden data collection.
    - Collected completed data sheets from Extension Master Gardeners.

- Input data.

➢ **Minnesota**

Over 2500 people participated in CenUSA Minnesota Extension Master Gardener outreach activities this quarter.

- The public display at the Minnesota State Fair was a huge success. Over the course of ten days, 2410 people viewed the CenUSA Master Gardener exhibit in the agriculture/horticulture building. An evaluation system was designed to capture the opinion of people who visited the display to determine, based on what they learned about biochar at the exhibit and in their discussions with Master Gardeners. 1405 participants indicated they would use biochar in their home garden if it were readily available on the market; 634 said "maybe," and 371 said they would not use biochar.
- An additional biochar display was set up in the University of Minnesota building for a special one-day only exhibit. The same evaluation system was displayed that was also located in the agriculture/horticulture building. For this one-day exhibit, 106 people stopped long enough to view the display, discuss biochar with Master Gardeners, and offer their opinions. From that group, 83 indicated they would use biochar if it were available, 16 said "maybe" they would use it, and seven said they would not use it.
- Meleah Maynard wrote and published a blog post for the national Extension Master Gardener blog http://blogs.extension.org/mastergardener/tag/2014-cenusa-bioenergy-biochar-demonstration-garden-research/. The blog was based on the volunteer perspective of working on this research project.
- Julie Weisenhorn presented "how to Engage Volunteers in Research" at the E3 Conference at ISU in September 2014.
- We collected soil from St. Paul Campus' silty loam site and Andover's sandy site for soil moisture tests that Kurt Spokas had agreed to do for the project.
- Gardens in all sites were maintained throughout the season.
- The gardens have all been cleaned up and equipment stored for winter.

✓ **Explanation of Variance**

None

✓ **Plans for Next Quarter**

- **Iowa**
  - Organize and summarize data. Complete the garden data comparison report.
  - Post brief information on findings to Biochar Facebook page.
- **Minnesota**
  - Publish an eXtension blog post on Extension Master Gardener Volunteers from the Fond du Lac site and their work on how this garden has grown to include nutrition education for the 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 CenUSA Minnesota Extension Biochar Demonstration Garden Report based on the data that was submitted by Extension Master Gardener volunteer.

✓ **Publications, Presentations, Proposals Submitted**

"Three years on, Master Gardeners talk about the rewards and challenges of volunteering at Minnesota's three CenUSA biochar test sites." http://blogs.extension.org/mastergardener/tag/2014-cenusa-bioenergy-biochar-demonstration-garden-research/

5. Evaluation and Administration

a. Planned Activities

✓ Collect information from CenUSA Extension teams and prepare reports.

✓ Finalize plans for E3 conference and host the conference.

✓ Continue support for development of CenUSA C6 Youth app, videos, and iBook presence.

✓ Meet with CenUSA Extension teams to plan and conduct Y4 activities.

b. Actual Accomplishments

✓ Met with and provided input for CenUSA Extension teams.

✓ Collected information from CenUSA Extension teams and prepared reports.

- ✓ Prepared and hosted a CenUSA exhibit at Vermeer Equipment Dealer Exposition to showcase CenUSA perennial grass production.
- ✓ Represented CenUSA at October AFRI CAP Extension teleconference.
- ✓ Supported continued development of CenUSA C6 youth app, videos and iBook material.
- ✓ Hosted the *Extension Energy and Environment Conference* (see: http://www.2014e3.org/agenda/). Seventy-nine Extension Educators from 19 states attended the conference. Analysis of pre-post survey results reveal:
  - ➢ Attendees significantly increased their knowledge of resources available from the AFRI Bioenergy CAPS.
  - ➢ Attendees significantly increased their knowledge of resources available from Extension colleagues.
  - ➢ Over 90% of attendees reported that the E3 conference encouraged them to provide renewable energy content to their constituents.
  - ➢ More than 70% indicated they plan to offer new programs using resources available from the AFRI bioenergy CAPS.
- ✓ Worked with Vermeer and editor of Biofuels Journal to develop article on CenUSA and biomass logistics.
- ✓ Conducted analyses on evaluations for two perennial grass field days in Nebraska.
- ✓ Conducted analyses on evaluations for two field days for Minnesota Master Gardeners.
- ✓ Developed evaluation for CenUSA annual meeting and the E3 conference.
- ✓ Submitted an abstract to the 2015 National Extension Energy Summit.

c. Explanation of Variance

None

d. Plans for Next Quarter

- ✓ 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.

- **Publications, Presentations, Proposals Submitted**

  None this quarter.

Objective 10. Commercialization

Sub-Objective 1. Archer, Daniels, Midland.

1. Planned Activities

- **Production of Vanillin**

  Plans for this quarter included an investigation of vanillin production from ADM's integrated soluble fraction (Fraction E)

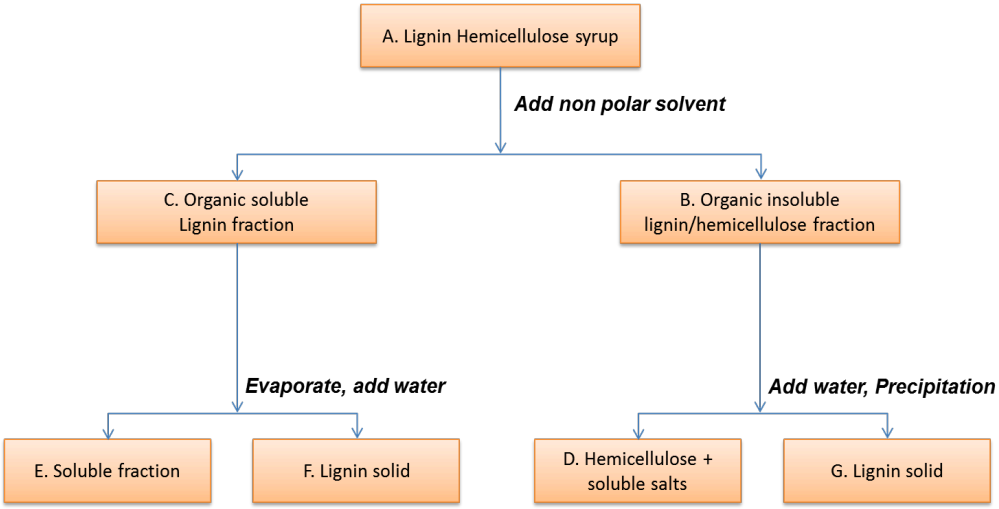

Fig. 30 ADM's integrated biorefinery products

- **Continuous Flow Pyrolysis of Lignin**

Lignin is one of the three major components in lignocellulosic biomass. It can be produced as byproducts from the pulping industry and cellulosic ethanol processes. Thermochemical conversion of lignin based on fast pyrolysis could be a promising method to produce fuels and chemicals from this low-cost feedstock. However, lignin has proven to be extremely difficult to pyrolyze in continuous reactors. Lignin is a form of fine powder that melts at relatively low temperature. During fast pyrolysis in continuous reactors, melted lignin creates a barrier for heat and mass transfer inside the lignin particles and it also acts as a binder to newly introduced lignin feedstock. This would cause char agglomeration and eventually lead to the clogging of the reactors. Therefore, lignin pyrolysis is mostly conducted in batch reactors. This mode of pyrolysis is difficult to scale up for industrial applications. The research goal of this project is to develop a method to pyrolyze lignin in continuous reactors. In this task, we address this goal by pretreating lignin feedstock prior to pyrolysis at a fluidized bed.

2. Actual Accomplishments

- **Production of vanillin from ADM's integrated soluble fraction (organic and water soluble)**. This work demonstrated that ADM's integrated soluble fraction (Fraction E) can produce vanillin via oxidative cleavage reactions. As a preliminary experiment, this fraction was reacted with hydrogen peroxide in water and methanol mixture at 100 ˚C, and the gas chromatogram of the final products is shown in Figure 31. As shown, vanillin was newly formed and detected by gas chromatography. Although the detained reaction mechanism is not confirmed yet, hydrogen peroxide, an efficient oxidant, could provide oxygen and form aldehyde at terminal carbon (Figure 32).

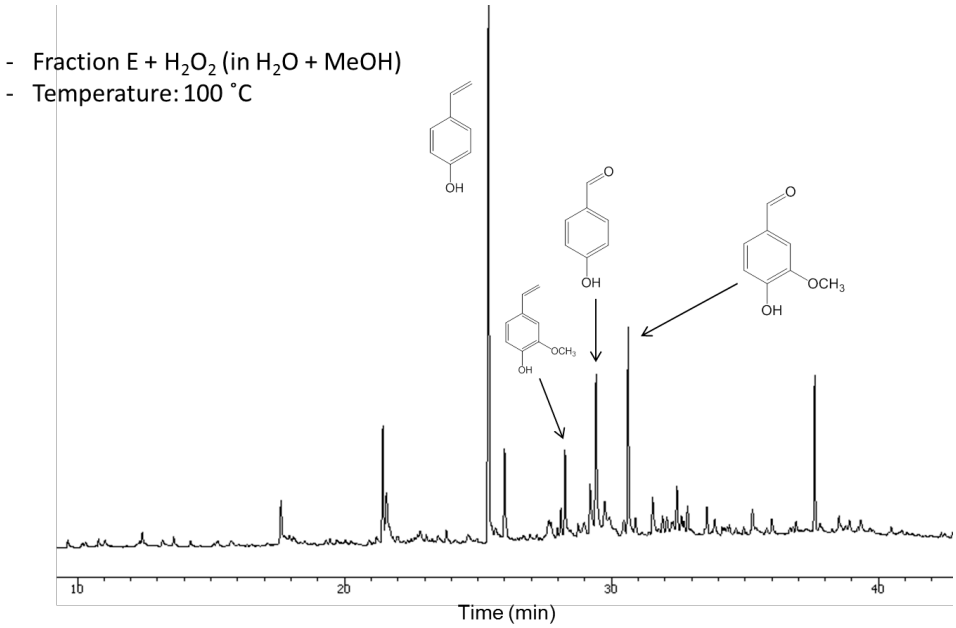

Fig. 31. Gas chromatogram of the reaction products

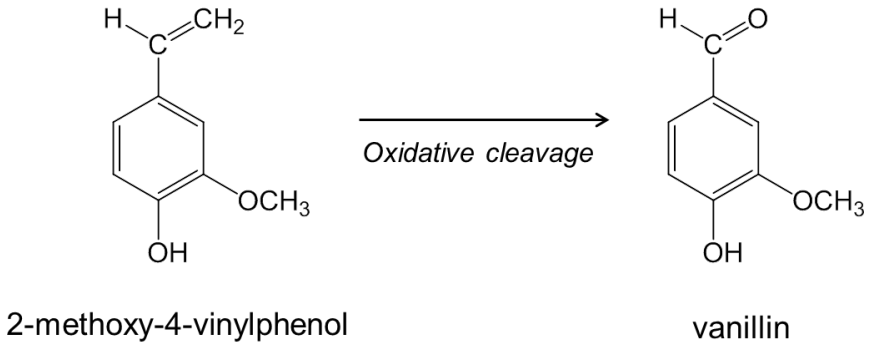

Fig. 32. A possible reaction pathway from 2-methoxy-4-vinylphenol to vanillin via oxidative cleavage reaction

- **Continuous flow pyrolysis of lignin**. Lignin has been pretreated with several methods and the pretreated lignin feedstocks were screened using a furnace that maintained at 425°C. The materials were heated for 1 minute and the pretreatment method, which can reduce lignin agglomeration, was further tested in a lab-scale fluidized bed reactor.

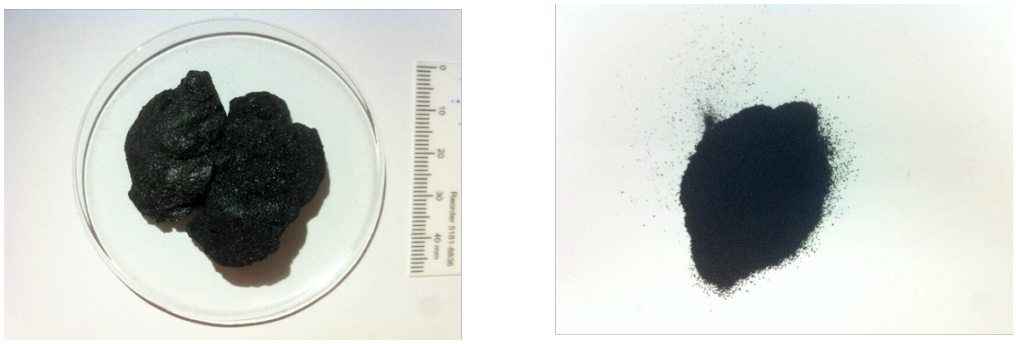

Fig. 33. Char from lignin pyrolysis in a fluidized bed reactor
(Left: non-treated lignin material; Right: pretreated lignin material).

Pretreated lignin was pyrolyzed in a fluidized bed at different temperatures (450, 500, and 550°C) to investigate the effect of temperature on lignin pyrolysis. The mass balance was calculated.

Figure 34 shows the yield of liquid, char and gases. The liquid and char yields were calculated by weight difference of the reactor parts before and after pyrolysis runs. The gases were detected by micro-GC. The overall mass balance is slightly over 100%, possibly overestimating the gas yields based on our current calibrations. New calibration will be performed for future pyrolysis runs.

From Figure 34, the highest liquid yield of 38.7% was obtained, and char yield was as low as 30.3%. The GPC analysis of the liquid fraction (stage fraction 1 and 2, labeled as SF1 and SF2 in the Figure 35) showed the pyrolysis liquid contains mostly lower molecular compounds. The molecular weights of the major peaks are within the range of phenolic monomers and dimers. The composition of gases is shown in Figure 36a and 36b. As expected, the total gas yield increased as the pyrolysis temperature increases. Although it requires further confirmation, initial results indicated that light gas produced from pyrolysis of pretreated lignin contains a significant amount of C3 hydrocarbons.

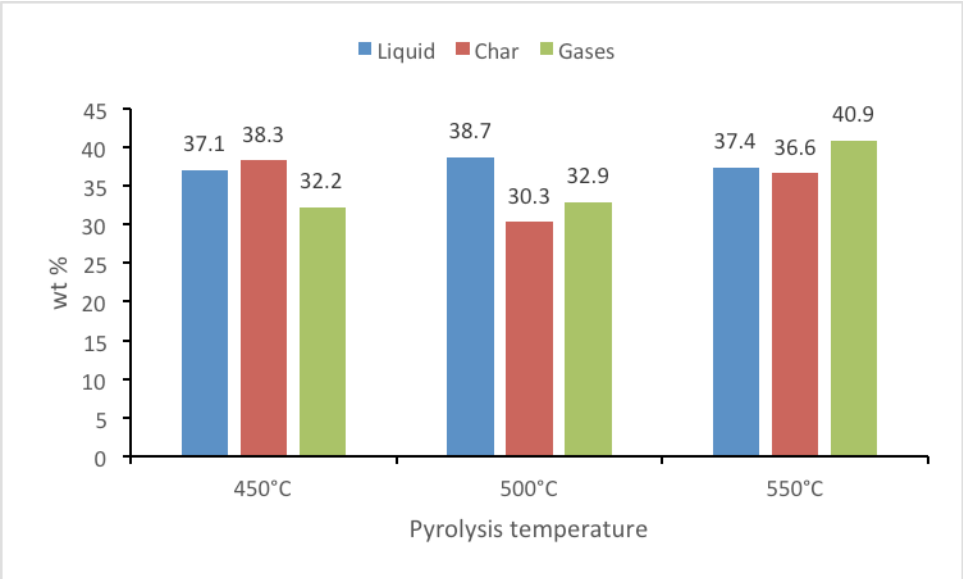

Fig. 34. Yield of liquid, char, and gases of pretreated lignin pyrolysis in fluidized bed reactor at different temperatures.

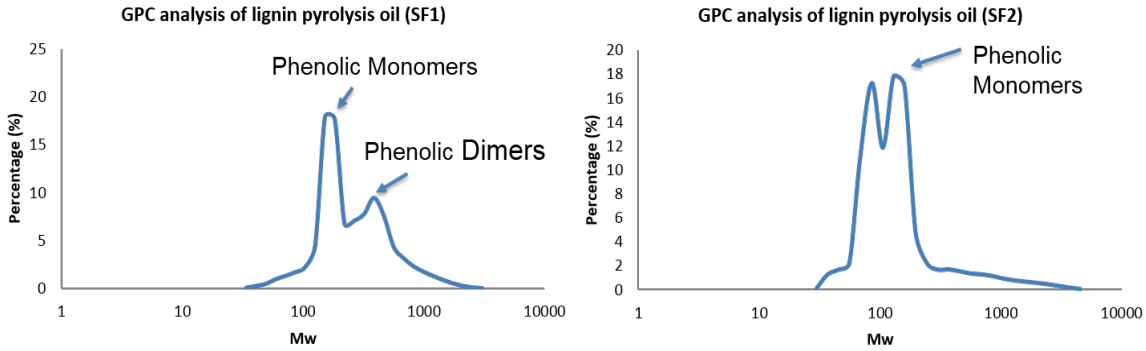

Fig. 35. GPC analysis of the liquid fraction from pyrolysis of pretreated lignin.

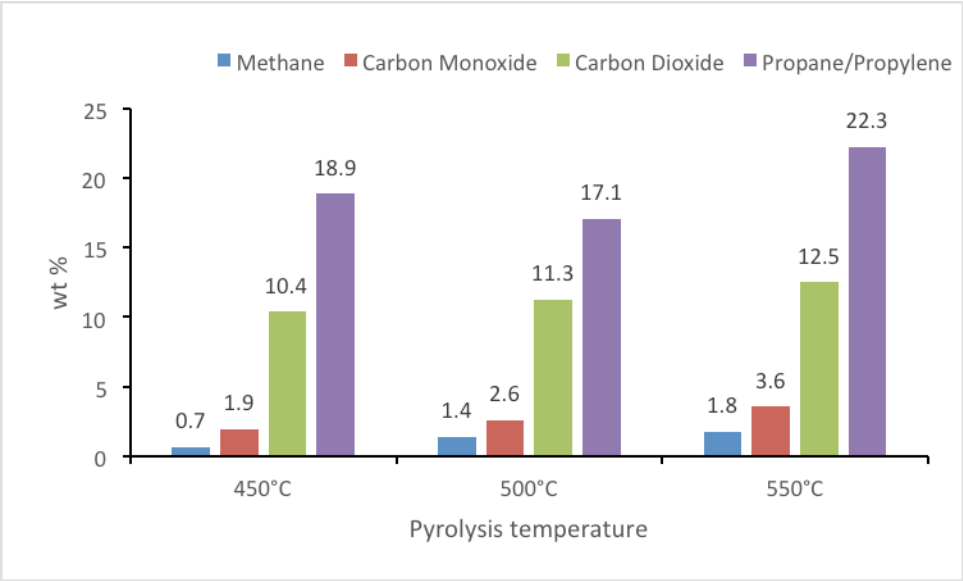

Fig. 36a. Composition of gases: methane, carbon monoxide, carbon dioxide, and propane/propylene.

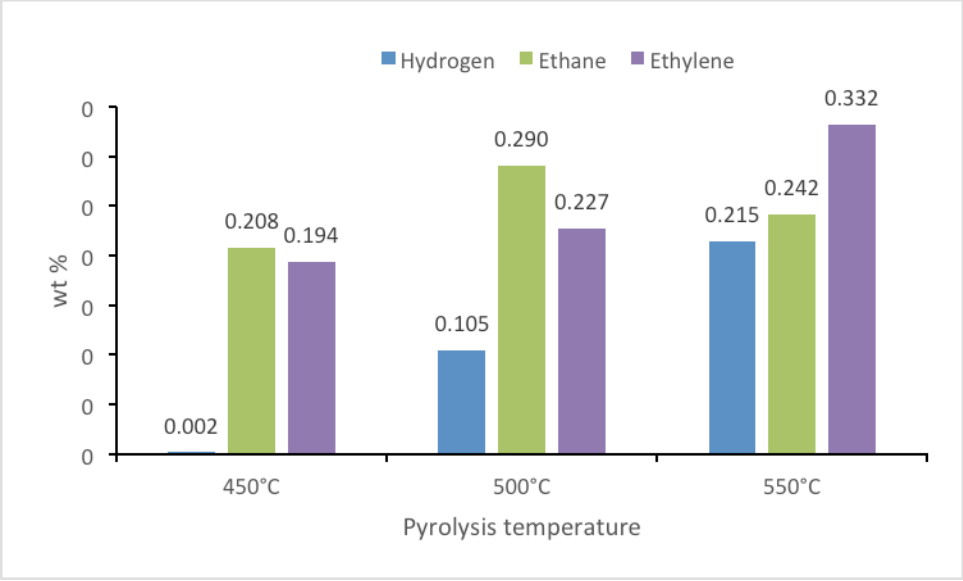

Fig. 36b. Composition of gases: hydrogen, ethane, and ethylene.

In summary, a proprietary pretreatment method was developed that allows for pyrolysis of lignin in a continuous reactor. The liquid yield of 38% was obtained from pyrolysis of pretreated lignin. The liquid consisted primarily of phenolic monomers and dimers. The non-condensable gases include a high content of C3 hydrocarbons.

3. **Explanation of Variance**

None noted.

4. **Plans for Next Quarter**

- **Vanillin production from ADM's integrated soluble fraction (Fraction E, continued)**. Tests will be conducted to maximize the yield of vanillin from ADM's integrated water-soluble fraction. We have confirmed that vanillin can be produced from this fraction using an oxidant. We will test some variables such as reaction temperature, reaction time, catalysts, and solvents to find the optimal reaction conditions for vanillin production. For example, osmium catalysts will be tested to facilitate the oxidative cleavage reaction.

- **Production and recovery of furfural from ADM's integrated soluble fractions (Fraction D & E)**. We have shown that two water-soluble fractions contain a substantial amount of pentoses, which can be converted into furfural. We will continue to investigate to maximize the furfural yield from two fractions using a biphasic solvent system.

- **Fast Pyrolysis of ADM's integrated soluble fractions (Fraction D & E) using a free-fall reactor**. Fast pyrolysis of ADM's integrated two water-soluble fractions (Fraction D & E) using a continuous free-fall reactor will be conducted. This work is designed to assess the potential of fast pyrolysis as a method to recover value-added chemicals, such as acetic acid, sugars and furfural from ADM's soluble fractions. Some modifications of feeder require because these two fractions will be fed as a liquid phase.

- **Continuous flow pyrolysis of lignin**. Pyrolysis experiments with pretreated lignin will be duplicated. The resulting products will undergo a complete characterization. An invention disclosure and manuscript will be prepared on the pretreatment and pyrolysis of lignin in a continuous flow pyrolyzer.

Sub-Objective 2. Renmatix

1. **Planned Activities**

- **Task 10c-0**. Finalize subcontract

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

- **Task 10c-1.1**. Procure budgeted equipment

- **Task 10c-1.2**. Conduct safety review for characterization work.

- **Task 10c-1.3**. Biomass characterization: Conduct full chemical and physical characterization of biomass samples

2. **Actual Accomplishments**

- **Task 10c-0**. Work in August was limited to working on the subcontract with Iowa State University, and that was finalized at the end of August.

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

- **Task 10c-1.1**. Procurement of budgeted equipment began.

Table 4. Biomass Delivery Schedule

No.	Biomass (Notes)	Harvest		Delivery to Renmatix		Screened Particle Size (microns)	Quantity Needed (kg)	Ship to Renmatix/ISU	Received	
		Month	Year	Requested	Confirmed	Confirmed 9/11/14			Y/N	Date
1	Switchgrass	Aug.	2014	10/1/14	9/15/14	<2mm	1	Renmatix	Y	9/22/14
2	Switchgrass 'Liberty'	Nov.	2013	10/1/14	9/30/14	<2mm	1	Renmatix	Y	10/8/14
3	Switchgrass (1,5)	Nov.	2013	6/1/15	9/30/14	chopped	10	Renmatix	Y	10/8/14
4	Switchgrass (1,6)	Nov.	2013	6/1/15	9/30/14	<100	75	ISU		
5	Low diversity mix	Aug.	2014	10/1/14	9/15/14	<2mm	1	Renmatix	Y	9/22/14
6	Low diversity mix	Nov.	2013	10/1/14	9/30/14	<2mm	1	Renmatix	Y	10/8/14
7	Big blue stem	Aug.	2014	10/1/14	9/15/14	<2mm	1	Renmatix	Y	9/22/14
8	Big blue stem	Nov.	2013	10/1/14	9/30/14	<2mm	1	Renmatix	Y	10/8/14
9	Corn stover	Oct.	2014	10/1/14	11/3/14	<2mm	1	Renmatix		
10	Corn stover (1,5)	Nov.	2013	6/1/15	9/15/14	chopped	10	Renmatix	Y	9/22/14
11	Corn stover (1,7)	Nov.7	2013	6/1/15	On hold	<100	75	ISU	Y	
12	Pelletized switchgrass (2)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13	Indiangrass	Nov.	2014	10/1/14	12/15/14	<2mm	1	Renmatix		

	(3,4)							
14	Bio-energy big blue stem (3,4)	Nov.	2014	10/1/14	12/15/14	<2mm	1	Renmatix

Notes:
1. The Nov. 2013 material will be used for Tasks 10-c and 10-d
2. Renmatix will not be receiving pelletized biomasses
3. Indiangrass and Bio-energy big blue stem samples will be received after the frost
4. For characterization only
5. Material will be chopped using a wood chipper
6. About 1/3 of Sample 4 has been ground through a 6mm screen
7. Sample 11 has been shipped from ARS Lincoln to ISU

- **Task 10c-1.2.** The safety of handling the herbaceous perennials and corn stover were reviewed. No major safety issues surfaced. Safety glasses and gloves must be used while handling the biomasses.

- **Task 10c-1.3**. Early in September 2014, discussions were held with Rob Mitchell (USDA) and Ryan Smith (ISU) to set the specific biomass samples, their quantities, and sizes that Renmatix would receive. Table 1 shows the biomass sample schedule. Samples began arriving at the end of September and into October with 8 out of 13 on hand at Renmatix by the end of October.

Sample preparation has been completed for all received biomasses. Extractives determination has started. Chemical characterization has started.

Technical discussions around corn stover milling and particle size analysis have been conducted with ISU. During particle size reduction of corn stover at ISU a fraction of corn cob particles cannot be further size reduced with the existing equipment. It has been decided that these particles will be isolated at ISU and shipped separately. Renmatix will process them separately in a batch type reactor (M/K Digester) to simulate the hemicellulose hydrolysis process. The softened, reacted solids will be then milled using a blender and subsequently combined with milled reacted solids for pilot scale studies. Also, it was discussed that the cutoff for pilot scale feed in Renmatix pilot testing equipment will be 140 mesh. It was confirmed that there is no need for ISU (who will be grinding the corn stover) to adjust the particle size distribution below this size.

3. **Explanation of Variance**

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

- **Task 10c-1.1**. Receipt of equipment is determined by suppliers.

- **Task 10c-1.2**. No variance.
- **Task 10c-1.3**. 10 biomass samples were planned to be at Renmatix this quarter. Instead two of the biomass samples (indiangrass and bio-energy big blue stem) will be received from the 2014 harvest after the frost, and later than planned. This was agreed after discussion with Rob Mitchell and should not adversely impact the plan. However, full chemical characterization for these two biomass species may not be completed by the end of 2014 as planned.

4. Plans for Next Quarter

- **Task 10c-1**. Initial physical and chemical characterization of feedstocks provided by CenUSA
- **Task 10c-1.1**. Continue with equipment procurement.
- **Task 10c-1.3**. Chemical characterization of biomasses will continue. Samples will be prepared for lignin structure characterization by NMR analysis.

5. Publications, Presentations, Proposals Submitted

None submitted.

Exhibit 1

2014 EXTENSION ENERGY AND ENVIRONMENT SUMMIT

Conference Agenda

Click on presentation title to view PDF of slides. Click on presenters name to view biosketch.

Tuesday, Sept. 23, 2014

TIME	ACTIVITY	SPEAKER/LOCATION
4:00 – 7:00 pm	Hotel check-in (dinner on your own)	*Gateway Hotel and Conference Center*
7:00 – 8:00 pm	Registration	*Outside North Prairie Room*
8:00 – 9:30 pm	Kick-off Plenary Session Drinks and light snacks	*North Prairie Room* **Sustainable Intensification: What Is It and How is Ireland Approaching Implementation** *John Gilliland, OBE, Director of Agriculture of Devenish Nutrition, Londonderry, Ireland*

Wednesday, Sept. 24, 2014

TIME	ACTIVITY	SPEAKER/LOCATION
7:00 – 8:00 am	BREAKFAST	*Central Prairie Room*
7:30 – 8:00 am	Registration	*Outside North Prairie Room*
8:00 – 8:40 am	Plenary Session	*North Prairie Room* **Agricultural Producer Attitudes re: Climate Change** *Linda Prokopy, Purdue University*
		North Prairie Room

8:40 – 9:20 am	Plenary Session	**U2U Extension Programming: What Have We Learned** *Chad Hart, Associate Professor and Extension Economist, Iowa State University*
9:20 – 10:00 am	Plenary Session	*North Prairie Room* USDA Climate Hubs *Tom Sauer, Research Soil Scientist, National Laboratory for Agriculture and the Environment*
10:00 – 10:15 am	BREAK	*Lobby*
10:15 – 11:45 am	Speed Sharing Session	*South Prairie Room* Selected Extension Programs
12:00 – 1:00 pm	LUNCH	*Central Prairie Room*
1:00 – 3:00 pm	Tour/Demo Presentations	*North Prairie Room*
3:15 pm	Load Bus	*Underpass near hotel front desk* Discussion time with morning speakers Facilitated discussions
3:45 pm	Tour 1 (1/2 group)	*BioCentury Research Farm (BCRF)* Biochar Research Plots Miscanthus x Giganteus: Experiences in Iowa
3:45 pm	Demonstration (1/2 group)	*BioCentury Research Farm (BCRF)* Taking Biofuel Processing Education to the Field: Biomass Densification Outreach using a Self-Contained Mobile Pelletization Unit *James DeDecker, Michigan State University Extension*
6:00 pm	DINNER	*BioCentury Research Farm (BCRF)*
7:30 pm	Evening Reception	*Gateway Hotel, Central Prairie Room*

Thursday, Sept. 25, 2014

TIME	ACTIVITY	SPEAKER/LOCATION
7:00 – 8:00 am	BREAKFAST	*Central Prairie Room*

8:00 – 8:30 am	Plenary Session	*North Prairie Room* **Thermochemical Processing of Biomass 101** *Mark Mba Wright, Assistant Professor, Iowa State University*
8:30 – 9:00 am	Plenary Session	*North Prairie Room* **Extension Components of CenUSA Bioenergy CAP** *Jill Euken, Deputy Director, Bioeconomy Institute, Iowa State University*
9:15 – 10:30 am	Session 1 Breakouts	*Harvest Room* *Meadow Room* *North Prairie Room* Selected Extension Programs
10:30 – 10:45 am	BREAK	*Lobby*
10:45 – 12:00 pm	Session 2 Breakouts	*Harvest Room* *Meadow Room* *North Prairie Room* Selected Extension Programs
12:00 pm	LUNCH	*Central Prairie Room*
1:00 pm	Load Bus	*Underpass near hotel front desk*
1:15 pm	Tour 2	*ISU COBS Plots, Thompson* *ISU FEEL Demonstrations (PDF)* *Gustafson Farm Visit*
6:00 pm	DINNER	*Garden Room, Reiman Gardens*
	Evening Session: STRIPS–The Movie	*Reimans Gardens* Tim Youngquist Matt Helmers (invited) Matt Liebman Lisa Schulte-Moore Matt O'Neal J. Gordon Arbuckle Mary Harris

Friday, Sept. 26, 2014

TIME	ACTIVITY	SPEAKER/LOCATION
7:30 am	Load Bus	Depart for CNH Ag Information Center
7:45 – 8:15 am	BREAKFAST BUFFET	*CNH Ag Information Center*
8:15 – 9:00 am	Plenary Session	*CNH Ag Information Center* DuPont Corn Stover Soil Health Program *Andy Heggenstaller, Director of Sustainability, DuPont*
9:00 am	Load Bus	
9:30 am	Tour 3	*DuPont Cellulosic Ethanol Plant* *Couser Farm*
12:00 pm	LUNCH	Box lunches
1:00 pm	Return/Adjorn	*Bus returns to Gateway* Adjorn

2014 Extension Energy and Environment Summit

Sept. 23-26, 2014

Gateway Hotel and Conference Center

Maps and Directions

Ames, IA

For More Information

Jill Euken

Iowa State University

515-294-6286

jeuken@iastate.edu

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Exhibit 2

CONNECT WITH US!

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CENUSA BIOENERGY IS SUPPORTED BY AGRICULTURE AND FOOD RESEARCH INITIATIVE COMPETITIVE GRANT NO. 2011-68005-30411 FROM THE USDA NATIONAL INSTITUTE OF FOOD AND AGRICULTURE.

Exhibit 3

Thank you to our sponsors for supporting both field days

PURDUE AGRICULTURE

EXTENSION

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cenusa bioenergy

Indiana Biomass Energy Working Group

CLAAS

Special thanks for providing lunch

PURDUE AGRICULTURE

EXTENSION

Keith Johnson
915 W. State St.
West Lafayette, IN 47907-2054

"Second Generation" Bioenergy Harvest and Marketing Meeting

October 28 • Wabash, IN

Indiana Forage Field Day

October 30 • Trafalgar, IN

cenusa bioenergy

PURDUE AGRICULTURE

EXTENSION

About the Meeting

The "Second Generation" Bioenergy Harvest and Marketing Meeting will be held in Wabash, IN at the Wabash County REMC on October 28 from 9 a.m. to 3:30 p.m. The day will include several discussion topics from experts in the field of bioenergy. Presentations in the afternoon will be field demonstrations; bus transportation will be provided.

Registration

Registration will start at 9 a.m. the day of the event. The cost of the program is $25 per person and is due at registration. Pre-registration is required. Please RSVP to Curt Campbell at ***cecampbe@purdue.edu*** or **260-563-0661** by October 23, 2014. In your RSVP please indicate any specific food or transportation needs. Please make checks payable to Purdue University-Wabash County Education Fund.

About the Field Day

The Indiana Forage Field Day will be held near Trafalgar, IN at the Indiana FFA Leadership Center on October 30 from 9 a.m. to 3 p.m. The day will include several discussion topics from forage experts in the Johnson County area. The field day presentations will be held at various locations; transportation will be provided.

Registration

Registration will start at 9 a.m. the day of the event. The cost of the program is $25 per person and is due at registration. Pre-registration is required. Please RSVP to Sarah Hanson at ***sspeedy@purdue.edu*** or **317-736-3724** by October 25, 2014. In your RSVP please indicate any specific food or transportation needs. Please make checks payable to Purdue University-Johnson County Education Fund. Bus transportation to the farms will be provided.

"Second Generation" Bioenergy Harvest & Marketing Meeting

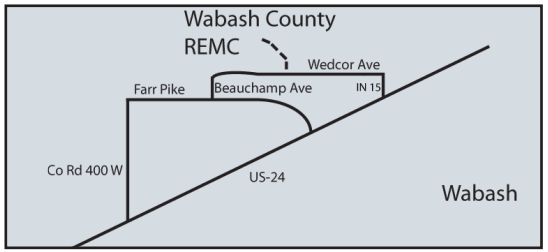
October 28 • Wabash, IN

Topics and Presenters

- **Welcome**
  Chad Martin, Purdue Agricultural and Biological Engineering
- **Policy Update for Bioenergy Production**
  Dr. Wally Tyner, Purdue Agricultural Economics
- **"Cornrower" Stover Recovery Equipment**
  Jim Straeter, New Holland Rochester, Inc.
- **Precision Ag Technology for Biomass Recovery**
  David Muth, AgSolver, Inc.
- **Conversion Technology Update**
  Dr. Nate Mosier, Purdue Agricultural and Biological Engineering
- **Watershed Benefits Growing "Second Generation" Bioenergy Crops**
  Dr. Cibin Raj, Purdue Agricultural and Biological Engineering
- **Warm-Season Grass Production Observations & Results**
  Dr. Keith Johnson, Purdue Agronomy

9 :30 a.m. - 3:30 p.m.

Registration at 9 a.m.



From the intersection of US 24 and IN 15 – go north on IN 15 (.2mi) turn left at Big R (Wedcor Drive) go (.6mi.) and the Wabash County REMC Building will be on right.

Indiana Forage Field Day

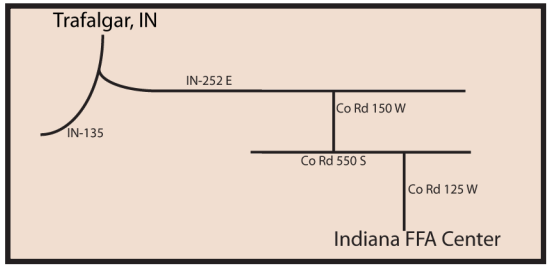
October 30 • Trafalgar, IN

Topics and Presenters

- **Welcome**
  Dr. Keith Johnson, Purdue Agronomy
- **Wagler's Dairy Farm**
  Sarah Wagler, Interviewed by Sarah Hanson- Johnson County Extension
- **Zupancic Farm**
  John and Matthew Zupancic, Interviewed by Chris Parker-Morgan County Extension
- **Warm-Season Grass Production Observations & Results**
  Dr. Keith Johnson, Purdue Agronomy

9 :30 a.m. - 3 p.m.

Registration at 9 a.m.



From Trafalgar turn left onto IN-252 E, turn right onto Co Rd 150 W, turn left onto Co Rd 550 S, take the first right onto Co Rd 125 W. Destination will be approximately one mile on left.

www.FarmProgress.com

October 2014

Exhibit 4

Nebraska® FARMER

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The Magazine of Nebraska Agriculture

Growing hops for craft beer makers Page 32

Vegetative index tested on soybeans Page 36

Young crop scouts test their skills Page 46

BIOFUEL FEEDSTOCK: ARS scientist Rob Mitchell stands in a plot of Liberty switchgrass, newly released by USDA and University of Nebraska-Lincoln.

High on Liberty

By **DON McCABE**

CORN-BASED ethanol is the king of the biofuels market, for now, while cellulosic ethanol produced from corn residue is about ready to hit the start button for commercial production. But perennial biomass crops like switchgrass have a bright future in producing drop-in motor fuels.

At least that's what USDA, seven Midwest universities, including University of Nebraska-Lincoln, and their partners are attempting to prove in a five-year project called CenUSA Bioenergy.

Liberty, a newly released switchgrass variety developed by USDA Agricultural Research Service and UNL scientists in Lincoln, is the primary feedstock being evaluated in this multi-state project.

At a glance

- Liberty is first perennial grass bred for biofuel production.
- It was grown in 35 research and demo sites this year.
- It could alternate with corn residue as biofuels feedstock.

"Liberty is the first perennial grass variety bred specifically for biofuel production in the Midwest," says Rob Mitchell, an ARS research agronomist based in Lincoln who, along with the now retired Ken Vogel, developed the variety. Nebraska switchgrass breeding programs go back to 1936.

Liberty was grown in 35 research and demo sites in the Midwest this year as part of the CenUSA project.

"In its seeding year, Liberty can reach 50% of full production and then reach full production in its first full year," says Mitchell, who also is co-project director.

Liberty has a yield potential of 8 tons per acre of biomass with no irrigation on marginal lands — nearly 40% higher than traditional grazing varieties like Shawnee, says Mitchell. It has a high rate of winter survival and is widely adapted throughout the Midwest.

Other selling points are its benefits to the environment and soil, including lower soil erosion, lower ag runoff and increased carbon capture. Creation of wildlife habitat is another benefit.

Mitchell envisions Liberty as a feedstock for cellulosic ethanol and as a "green gasoline" when run through another promising conversion process called pyrolysis, which involves the heating of organic materials to temperatures of more than 400 degrees C in the absence of oxygen.

Two cellulosic ethanol plants in Iowa and one in Kansas are gearing up for commercial production this fall, and all three use corn residue as the feedstock.

Mitchell says those plants could alternate between corn residue and switchgrass because the "cellulosic conversion technology is similar for both."

The catch is that corn residue is more readily available, while acres of switchgrass will be slow in building without some type of market incentives, Mitchell says.

The logistics of harvesting, storing and transporting perennial grass feedstocks like Liberty pose a considerable challenge due to the volume of material required. A 50 million-gallon-per-year cellulosic biorefinery would need about a half-section of switchgrass to be harvested and delivered to the plant each day.

Read more about CenUSA on Page 26.

Crop Production

CenUSA studies grasses as biofuel crops

By **DON McCABE**

THE multi-state CenUSA Bioenergy project (see this issue's cover feature) began in 2011 and will continue through 2015, with Nebraska as a key player in evaluating perennial grass varieties like Liberty switchgrass. Big bluestem and indiangrass also are under review as biomass feedstocks in this project.

At a glance

- CenUSA is a multi-state project that began in 2011 and ends in 2015.
- Perennial grass feedstocks would help reduce dependence on foreign oil.
- Project evaluating fast pyrolysis as a conversion process.

"The major goal [of CenUSA] is to instigate commercial production of biofuels using biomass feedstocks like perennial grasses," says John Hay, University of Nebraska-Lincoln Extension educator, who focuses on ag-related energy production. "If a market is developed, it is hoped producers can grow a perennial grass feedstock which can be made into 'advanced transportation fuels.'"

CenUSA's intent is to develop a "Midwestern system for producing advanced transportation fuels using perennial grasses grown on land unsuitable or marginal for row crops."

USDA's National Institute of Food and Agriculture funds the $25 million project, which is based at Iowa State University and is part of a major effort to reduce dependence on foreign oil through conversion of energy crops that are sustainable, reduce soil erosion and water runoff, and improve soil quality.

Other components of CenUSA research involve examining the logistics, sustainability and economics of harvesting, transporting and storing perennial grass biomass crops and examining potential farmer incentives to grow them.

The project scientists are evaluating the grasses for yield and feedstock quality, including carbon, nitrogen, sugars, fiber and lignin.

Iowa-based Vermeer, as part of the project, is harvesting and processing the grasses with its forage harvesting equipment.

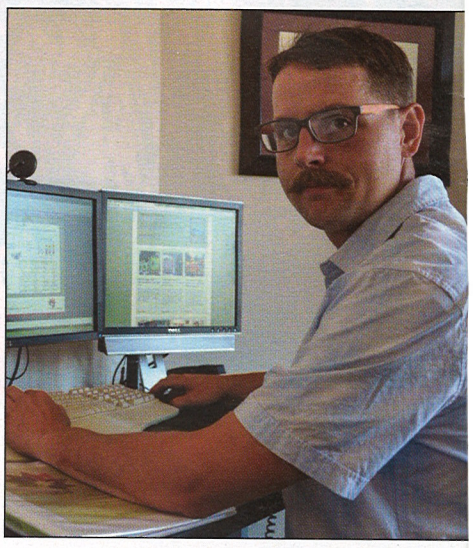
Mixtures of the perennial grasses also will be evaluated for yield and feedstock quality.

While switchgrass and the other native perennial grasses may have a future in cellulosic ethanol production, the potential feedstock conversion process the CenUSA project is studying is called fast pyrolysis. It's not a new technology, but it's not been used on a commercial scale, and it may even be years before that happens.

In the pyrolysis process, perennial grasses like switchgrass are converted to an energy-rich liquid, called bio-oil, and then refined into gasoline. Pyrolysis involves the heating of organic materials to temperatures of more than 400 degrees Celsius in the absence of oxygen.

The pyrolysis process can also produce a solid product called biochar, which can be used as soil amendment, Hay says. Iowa State University is the lead research institution in the pyrolysis process.

Producing transportation fuels in this manner would eliminate issues like the blend wall and the volatile Renewable Fuel Standard that corn-based ethanol faces, Hay says.



BIO-OIL POTENTIAL: John Hay is a UNL collaborator on the CenUSA project.

Exhibit 5

C6 Hackathon

Place: 434 College of Design

Time: October 4th, 9AM - 6PM

Registration deadline is October 1st: c6biofarm.weebly.com

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

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