cenusa bioenergy

Quarterly Progress Report

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

October 2015

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

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Exhibit 1. The Advisory Board continued its practice of providing written feedback on project activities

Exhibit 2. The Extension Objective completed the Guidelines to Growing Perennial Grasses brochure

Exhibit 3. National Bioenergy Day at Iowa State

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").

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

First Quarter Report: August 1, 2015 – October 31, 2015

Project Administration, Project Organization and Governance

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

- **CenUSA Bioenergy Advisory Board**

  Our Advisory Board continues its strong performance. The Advisory Board attended our September 2015 Co-Project Director monthly meeting. This allowed the Advisory Board and the Co-Project Directors to discuss the Board's feedback and written comments from the Year 4 annual meeting (August 2015) The Advisory Board continued its practice of providing written feedback on project activities. (Exhibit 1).

- **Executive Team Meetings**

  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 documents to be viewed by all participants, enhancing communications and dialogue among participants. Tom Binder, the Advisory Board chair also attends these meetings on behalf of the Advisory Board.

- **Extension and Outreach**.

  The Extension Objective completed the Guidelines to Growing Perennial Grasses brochure (Exhibit 2).

- **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 request a No-cost Extension as provided for by the project sponsor USDA-NIFA and are exploring the availability of supplemental funding to continue the pursuit of the CenUSA vision.

  We will submit our No-cost Extension year package in March 2016.

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 was on the establishment of new breeding and evaluation trials.

1. Significant Accomplishments Summary

- We developed genomic predictive equations to predict biomass yield of 'Liberty' switchgrass with accuracy as high as 0.62, roughly equivalent to heritability. This will allow us to begin applying genomic selection models to 'Liberty' in an effort to increase the rate of progress in generating further increases in biomass yield. If we can continue to fund this research for a 12-year period, we expect to reach the 10-T/A goal.
- This research provides important information on the arthropods associated with bioenergy grasses and valuable information on the host suitability of switchgrass and other bioenergy grasses to four aphids within a system that has been largely overlooked. Results indicate that there are genetic differences among switchgrass populations for resistance. The ultimate goal of this project is to develop effective and sustainable management strategies for the key arthropod pests affecting switchgrass.

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 2015 biomass harvesting, sample collection, and data collection.
- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria and Akwasi Boateng – ARS Wyndmoor)**
  - ✓ Repeat analysis of outliers from 88 sample set for this year (Year 5).
  - ✓ Complete analysis of cinnamic acid ester/ether linkages for this year's sample set.
  - ✓ Complete enzymatic sugar release analysis of 132 big bluestem biomass samples.
- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Complete sampling for Year 4.
  - ✓ 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 ~12,000 biomass samples for grinding and scanning during winter.

  ✓ Harvested seed on two new big bluestem populations and two new switchgrass populations.

  ✓ Germinated seedlings to begin first cycle of genomic selection within Liberty-C2.

  ✓ Compiled and proofed 2014 data from all locations of the 13-location variety trials.

- **Feedback Quality Analysis (Bruce Dien and Akwasi Boateng)**

  ✓ Repeated analysis of outliers from 88 sample set for this year.

  ✓ Completed analysis of cinnamic acid ester/ether linkages for this year's sample set.

  ✓ Completed enzymatic sugar release analysis of 132 big bluestem biomass samples.

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

  ✓ A total of 160 pitfall and sticky board traps were collected every two weeks from May to September 2015 in Nebraska and Wisconsin.

  ✓ Processing of the samples for the 2015 season is 90% complete.

  ✓ Completed the electronic feeding monitoring study for the greenbug.

4. **Explanation of Variances**

   None to report.

5. **Plans for Next Quarter**

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**

  ✓ Begin grinding and scanning 2015 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)**
  - ✓ Process 88 samples for enzymatic sugar release following hot-water pretreatment.
  - ✓ Repeat any outliers for the cinnamic acid ester/ether linkages.
- **Pathology and Entomology (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Compile 2015 data.
  - ✓ Complete analysis of the electronic feeding monitoring.

6. Publications / Presentations/Proposals Submitted

- Dien, B.S., Anderson, W.F., O'Bryan, P.J. & P.J. Slininger. Field productivities of Napier grass for production of sugars and ethanol. 38th Symposium on Biotechnology for Fuels and Chemicals (SBFC), Society of Industrial Microbiology, April 25-28, 2016, Baltimore, MD
- Ramstein, G.P., Evans, J., Kaeppler, S.M., Mitchell, R.B., Vogel, K.P., Buell, C.R. & M.D. Casler. (2015). Accuracy of genomic prediction in switchgrass improved by accounting for linkage disequilibrium. *Genes, Genomes, Genetics* (in review).

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**
  - **Planned Activities**

At this writing, corn harvest is complete, fall soil samples have been collected for fertility analysis, bulk soil samples have been collected for future incubation studies, and soil moisture, temperature and EC data have been retrieved from the data loggers. We are still waiting for a killing freeze before harvesting and collecting end-of-season biomass samples from the switchgrass, low diversity, and high diversity plots. Once harvested the biomass samples will be dried, weighed and processed. Other activities include data analysis and manuscript preparation.

Fig. 1. Biomass production on the switchgrass and low diversity plots; pictures taken at the time of the August 2015 peak biomass sampling. Left: Picture of switchgrass plot. Middle: Undergraduate student worker holding cut biomass from one of the switchgrass plots. Right: Cathi Hunt holding biomass cut from one of the low diversity plots

Peak biomass data was collected in August 2015. Peak sown plant biomass in 2015 has increased by 1.5-2 times over 2014 yields, and averaged nearly 6 t ac^{-1} in the switchgrass plots, 3.5 t ac^{-1} in low diversity plots and 1.5 t ac^{-1} in high diversity plots (see Fig. 2). Weed competition continues to be problematic in the high diversity plots, is minimal in the low diversity plots, and virtually non-existent in the switchgrass plots. Biochar application had no effect on biomass yields for the August 2015 sampling.

A 28-day aerobic laboratory incubation for soil collected from the Armstrong bioenergy system plots was conducted to determine potentially mineralizable nitrogen and NO_3 to NH_4 ratios. Statistical analysis is on going to determine whether cropping system by biochar interactions are significant.

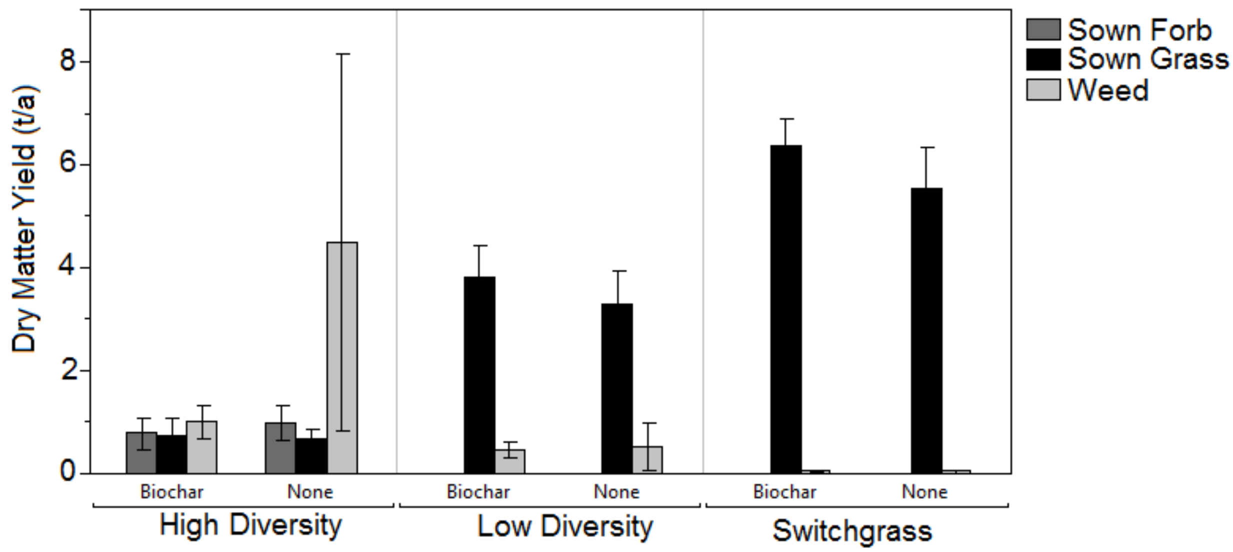

Fig. 2 Peak Biomass Data, August 2015.

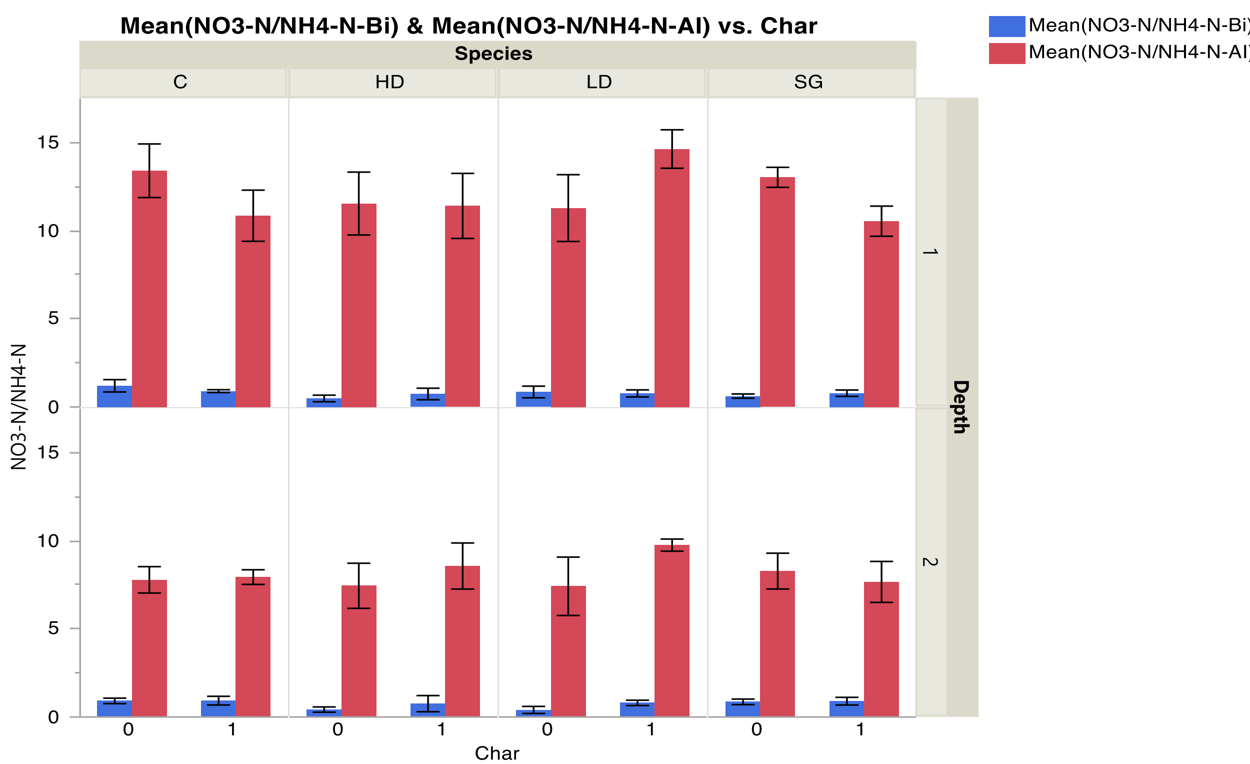

Fig. 3 Effect of biochar application on average NO_3^--N /NH_4^+-N for soils before incubation (Blue, -Bi) and after incubation (Red, -Ai) taken from two soil depths (depth 1= 0-5 cm and depth 2 = 5-15 cm). Error bars show standard errors.

- **Update of Activities on the Long Term Rotation Plots (Sorenson Farm)**

  Harvest is complete, yield data, plant biomass samples and soil samples have been collected. Eight deep (1.2m) soil cores were collected post-harvest from paired biochar and control plots. These cores will be sectioned and analyzed for soil organic matter, particle size analysis, bulk density, and the determination of water retention curve parameters.

  A new study, initiated in spring 2015 on the long term rotation plots, is investigating the effect of biochar and biochar age on soil nitrogen dynamics. Soil samples were collected monthly from April to October from the continuous corn plots and analyzed for KCl extractable nitrate and ammonium concentrations. April samples were collected as baseline samples before planting and fertilization. In addition to soil sampling, chlorophyll meter readings were taken monthly on the newest fully expanded leaf of six plants from each plot using a SPAD 502 Plus Chlorophyll Meter. This provides us with a measure of the nitrogen status of the corn throughout the growing season and allows us to relate soil and leaf N measurements. Finally, samples from all continuous corn plots were collected for fall stalk nitrate analysis. Analysis is ongoing but preliminary data on soil nitrate and ammonium levels are given below.

- **Plans for Next Quarter (Sorenson Farm)**

  Fall soil and plant tissue samples will be processed and analyzed. The viability of pedotransfer functions developed by Saxton and Rawls (2006) for estimating soil water relations from soil organic matter and texture is being tested for biochar amended soils. This information is needed to further development of the new biochar module which has been developed for the APSIM Cropping system model. Statistical analysis and manuscript writing are ongoing for a new paper entitled *Influence of biochar and diversified cropping systems on soil physical and chemical properties*.

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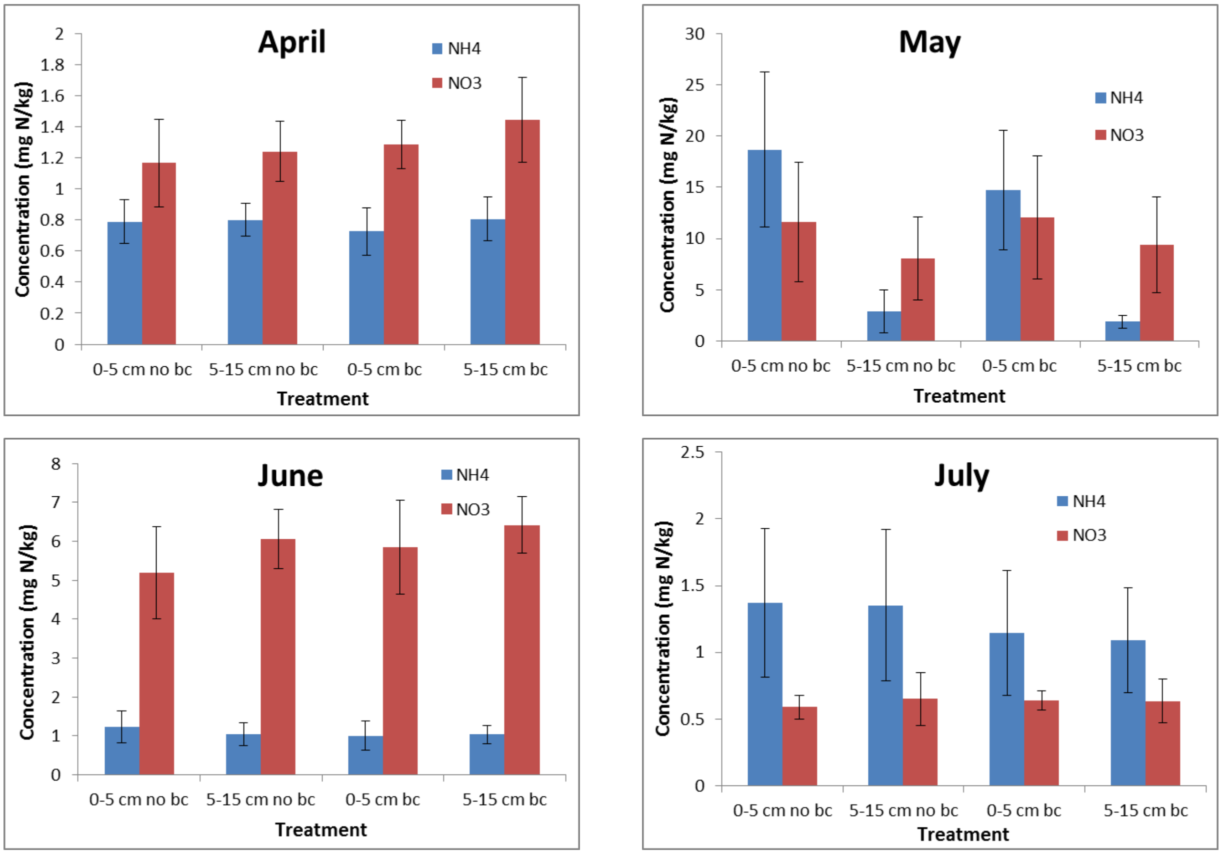

Fig. 4 The effect of biochar and biochar age on soil nitrogen dynamics.

- **Update of Activities on the Biochar Rate Trials (Boyd Farm)**

  Harvest is complete, biomass samples fall stalk nitrate sample, soil samples and deep (1.2 m) soil cores have been collected from all plots. These samples are being processed and analyzed.

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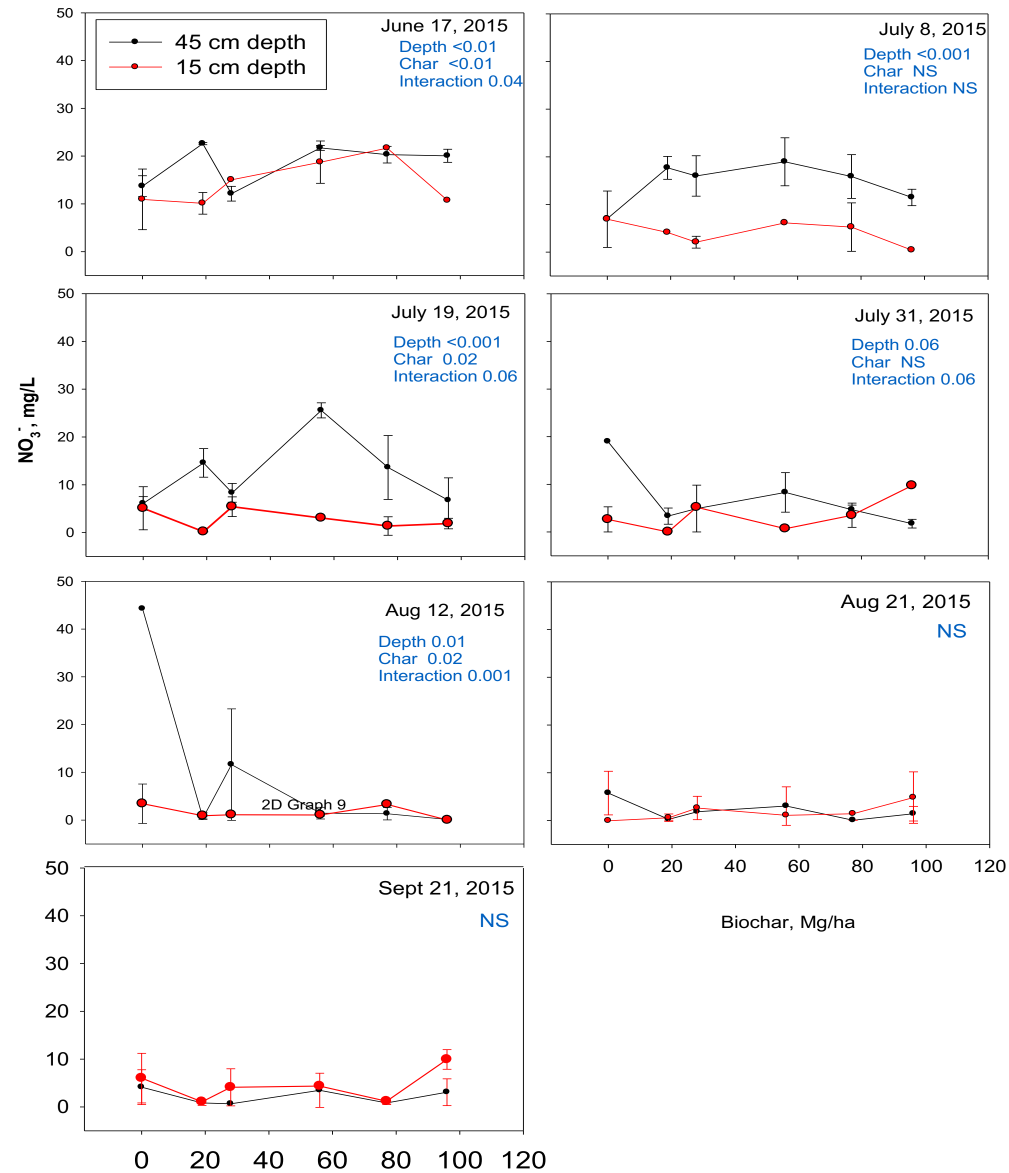

Fig. 5. Relation between biochar application rate and soil solution nitrate concentrations at two soil depths for soil solution samples collected after major rain events during the 2015 growing season.

Suction lysimeters were installed in the biochar plots on the Boyd farm at two depths, 15 and 45 cm in Spring 2014. Ground water samples were collection from these lysimeter began in Spring 2015 after every major rainfall event to monitor nitrate, ammonium, P and other nutrient concentrations in the soil solution. Figure 6 below shows nitrate concentrations as a function of depth and biochar application rates. Significant effects of biochar and depth on nitrate concentrations were observed during growing season, however, by the end of the season no effect was observed.

An incubation study with soils taken from the biochar rate trials on the Boyd farm was conducted. Data analysis is still on going however shown below (Fig. 6) are NO_3^--N /NH_4^+-N ratios for three soil depths. Depth 1, 2, 3 corresponds to 0-5, 5-15 and 15-30 cm respectively. Error bars indicating standard error.

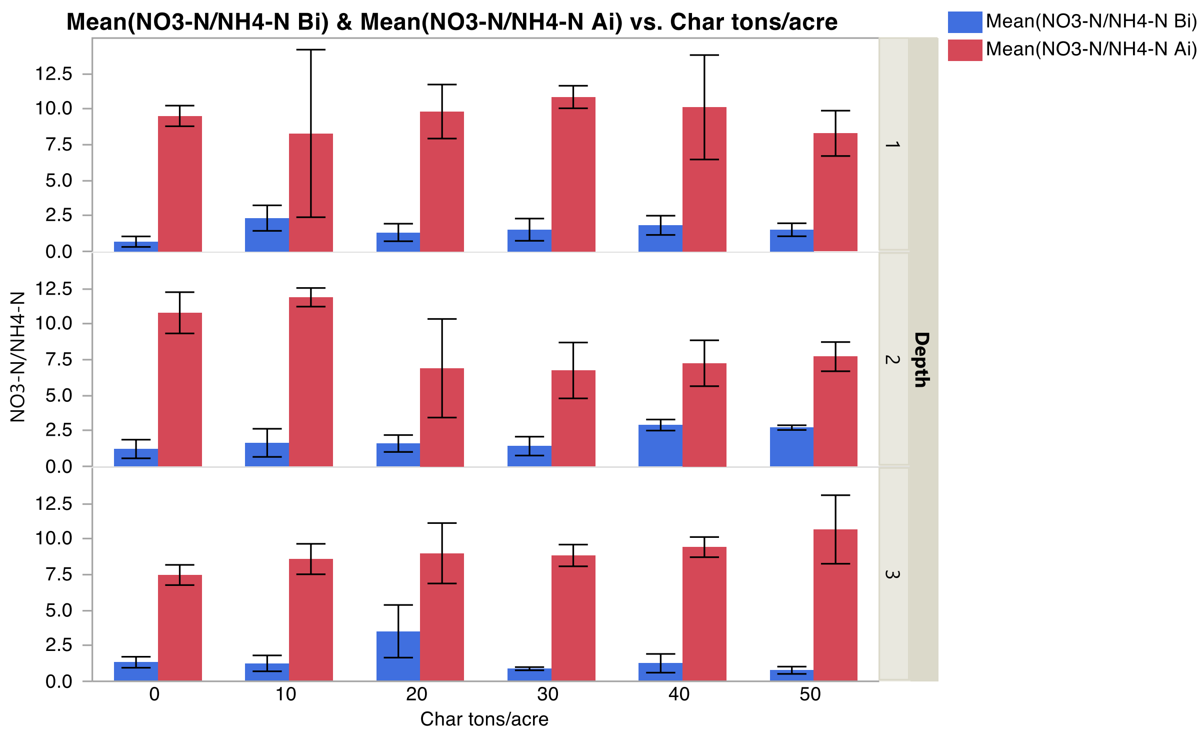

Fig. 6 Relation between biochar application rate to average NO_3^--N /NH_4^+-N for soils before incubation (Bi) and after incubation (Ai) taken from three different depths.

- **Purdue University**

The first quarter of Year 5 has focused on analysis of biomass and soil samples from the 2014 harvest season. This includes nutrient concentrations for studies where soil fertility/plant nutrition is an important variable. Other analyses include specific C pools whose concentrations might impact the rate and extent of conversion of biomass to biofuels/bioproducts. Preparations are also underway to harvest biomass from the 2015 growing season that begins in earnest in November 2015. The following tables contain data representative of recent analytical results. In some cases, previously reported biomass yields are provided again in order to provide context for the analytical results (e.g., did soil test P level impact biomass yield?).

Table 1. Soil test phosphorus (P) and potassium (K) concentrations at two depths and biomass yield of Shawnee switchgrass at Throckmorton Purdue Ag Center. The P fertilizer was applied annually at the rates shown from 1997 to 2004 while this field was an alfalfa P and K fertility study. The alfalfa was killed in 2006 and switchgrass seeded in 2007 in order to determine the impact of variation in soil test P and K on switchgrass growth and composition. Results shown are averaged over the five K fertilizer application rates shown in Table 2. Despite large differences in soil test P, including very low levels below 5 mg/kg, switchgrass yields remained high. This suggests that switchgrass will be well suited to marginal lands where P fertility is the main limitation.

Table 1. Soil test phosphorus (P) and potassium (K) concentrations at two depths and biomass yield of Shawnee switchgrass at Throckmorton Purdue Ag Center.

P Applied 1997-04	Soil P 0-10 cm	Soil P 10-20 cm	Soil K 0-10 cm	Soil K 10-20 cm	2014 Biomass
kg/ha/yr	- - - - - - - -	- - - - - -mg/kg	- - - - - - -	- - - - - - -	kg/ha
0	4.8	3.3	153	96	10115
25	6.0	3.7	130	92	9968
50	12.9	4.8	128	89	9860
75	27.9	6.2	120	87	9649
LSD	3.0	1.3	12	6 (P<0.10)	NS

Table 2. Soil test phosphorus (P) and potassium (K) concentrations at two depths and biomass yield of Shawnee switchgrass at Throckmorton Purdue Ag Center. The K fertilizer was applied annually at the rates shown from 1997 to 2004 while this field was an alfalfa P and K fertility study. The alfalfa was killed in 2006 and switchgrass seeded in 2007 in order to determine the impact of variation in soil test P and K on switchgrass growth and composition. Results shown are averaged over the four P fertilizer application rates shown in Table 1. Despite differences in soil test K, including moderately low levels approaching 100 mg/kg, switchgrass yields remained high. This suggests that switchgrass will be well suited to marginal lands where K fertility is the main limitation.

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Table 2. Soil test phosphorus (P) and potassium (K) concentrations at two depths and biomass yield of Shawnee switchgrass at Throckmorton Purdue Ag Center.

K Applied 1997-04	Soil P 0-10 cm	Soil P 10-20 cm	Soil K 0-10 cm	Soil K 10-20 cm	2014 Biomass
kg/ha/yr	- - - - - - - - - - - - - - mg/kg - - - - - - - - - - - - - -				kg/ha
0	14.9	5.1	108	83	9985
100	14.2	5.2	118	85	9480
200	12.1	4.2	123	88	10038
300	13.6	4.2	148	95	10173
400	9.7	3.9	167	104	9814
LSD	3.4	NS	13	8	NS

Table 3. Soil test phosphorus (P) concentrations at two depths and biomass yield of Shawnee switchgrass at Throckmorton Purdue Ag Center. The P and K fertilizers were applied annually at the rates shown from 2000 to 2004 ('00-04) while this field was an alfalfa P and K fertility study. The alfalfa was killed in 2006 and switchgrass seeded in 2007 in order to determine the impact of variation in soil test P and K on switchgrass growth and composition. The P-K plots were large enough to divide into four sub-plots where four N rates were randomly applied beginning in 2011 at the annual application rates shown. Like the data in Table 1 above, soil P levels did not alter biomass yield even though soil test P concentrations without P fertilizer application were below 5 mg/kg. Biomass yield is tending towards being higher (P=0.12) with 50 kg N/ha applied. Agreeing with results in Table 1, this study suggests that switchgrass will be well suited to marginal lands where P fertility is the main limitation.

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Table 3. Soil test phosphorus (P) concentrations at two depths and biomass yield of Shawnee switchgrass at Throckmorton Purdue Ag Center.

			N Fertilizer Applied in 2015, kg/ha				P/K Means
Trait	P Applied '00-04	K Applied '00-04	0	50	100	150	Averaged Over N
Yield, kg/ha	0	0	9845	10935	10474	10725	10495
	0	400	10091	11338	10953	9863	10561
	75	0	9541	10713	10521	10861	10409
	75	400	9984	10047	10084	9506	9906
Soil P 0-10 cm, mg/kg	0	0	4.8	5.0	4.5	4.7	4.8
	0	400	4.6	3.7	3.8	4.3	4.1
	75	0	13.4	11.1	15.4	14.6	13.6
	75	400	10.6	11.9	9.1	9.8	10.3
Soil P 10-20 cm, mg/kg	0	0	3.4	3.4	3.8	4.0	3.6
	0	400	3.6	3.9	3.0	2.9	3.4
	75	0	6.0	4.7	4.9	4.8	5.1
	75	400	4.4	4.4	4.1	3.4	4.1
N Main Effect Means*			9865	10758	10508	10239	

*N main effect means significant at *P*=0.12

Table 4. Yield and phosphorus (P) concentrations of *Miscanthus x giganteus* biomass, and soil test P levels in the upper (0-10 cm) and lower (10-20 cm) depths of the soil profile as influenced by application of N, P, and K fertilizer. As expected, soil test P levels and biomass P concentrations are higher where P fertilizer is applied. Tissue P concentrations are highest (*P*=0.10) in the 0 N plots. Biomass yield increased with N fertilizer, and tended to be higher where P and K also were applied.

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Table 4. Yield and phosphorus (P) concentrations of *Miscanthus x giganteus* biomass, and soil test P levels in the upper (0-10 cm) and lower (10-20 cm) depths of the soil profile as influenced by application of N, P, and K fertilizer.

	0 kg N/ha		50 kg N/ha		100 kg N/ha		150 kg N/ha		
Trait	0P 0K	30P/30 0K	0P 0K	30P/30 0K	0P 0K	30P/30 0K	0P 0K	30P/30 0K	LSD
Yield, kg/ha	25808	22999	28445	29150	27611	30345	29147	31534	2898
Tissue P mg/g	0.36	0.70	0.21	0.44	0.16	0.24	0.11	0.23	*P*=0.10
P removal kg/ha	9.4	16.0	6.1	12.8	4.3	7.4	3.3	7.2	PK, N trts at *P*<0.01
Soil P 0-10 cm, mg/kg	7.0	46.7	8.5	31.4	13.8	49.4	12.1	45.4	PK trt at *P*<0.01
Soil P 10-20 cm, mg/kg	4.5	6.9	6.7	7.5	7.0	10.7	6.7	10.3	PK trt at *P*<0.03

Table 5. Biomass yield and sugar concentrations of three sorghum lines and maize (control) grown at five rates of N fertilizer on three marginal sites. The sorghums included a dual-purpose line for both biomass and grain, a sweet sorghum and a photoperiod-sensitive line. Maize generally had the lowest biomass yields at all three locations irrespective of N rate confirming that these sites are marginal for maize production. Biomass yield of the photoperiod-sensitive sorghum was generally greater than the other sorghums. Biomass sugar concentrations were highest in the sweet sorghum, low in maize and the dual-purpose sorghum, and intermediate in the photoperiod-sensitive sorghum. Yield of biomass sugars per ha (biomass yield x sugar concentration) often exceeded 3000 kg/ha for sweet sorghum, and were occasionally over 2000 kg/ha for the photoperiod-sensitive sorghum. By comparison, sugar yield of maize biomass was 226 kg/ha or less.

Table 5. Biomass yield and sugar concentrations of three sorghum lines and maize (control) grown at five rates of N fertilizer on three marginal sites.

Location	Species	N Rate, kg/ha	Biomass, kg/ha	Biomass sugar, g/kg	Biomass sugar, kg/ha
Throckmorton Purdue Ag Center	Maize	0	4337	22	86
		50	4942	24	115
		100	8519	24	186
		150	7621	21	147

		200	9794	17	173
	Sorghum-Dual Purpose	0	6661	13	91
		50	7539	17	132
		100	11007	15	166
		150	10186	20	208
		200	10211	19	191
	Sorghum-Sweet	0	12074	255	3089
		50	10723	190	2242
		100	14665	245	3585
		150	12674	192	2543
		200	13553	211	2889
	Sorghum-Photoperiod Sensitive	0	12111	152	1861
		50	12688	152	2061
		100	17220	143	2463
		150	17063	170	2890
		200	17353	181	3178
Northeast Purdue Ag Center	Maize	0	2544	17	39
		50	4437	11	61
		100	4469	16	68
		150	12569	15	192
		200	9434	14	115
	Sorghum-Sweet	0	487	62	114
		50	2265	62	277
		100	7032	114	805
		150	9441	196	1819
		200	8307	186	1585
	Sorghum-Photoperiod Sensitive	0	1221	91	444
		50	7595	67	602
		100	11567	65	742
		150	12712	70	892
		200	14424	107	1556
Southeast Purdue Ag Center	Maize	0	2027	69	145
		50	2776	62	167
		100	3317	54	178
		150	3120	64	182
		200	4079	56	226

Sorghum-Dual Purpose	0	4889	32	138
	50	6910	26	174
	100	8698	28	216
	150	9714	31	292
	200	8295	32	244
Sorghum-Sweet	0	7440	242	1799
	50	12443	230	2895
	100	11187	244	2724
	150	13956	206	2864
	200	13237	231	3060
Sorghum-Photoperiod Sensitive	0	6415	162	1061
	50	11241	158	1777
	100	11602	170	1956
	150	14647	169	2482
	200	16416	170	2723
Statistical significance	Location (L)	*P*<0.001	*P*<0.001	*P*<0.001
	Species (S)	*P*<0.001	*P*<0.001	*P*<0.001
	N rate (N)	*P*<0.001	*P*=0.002	*P*<0.001
	L x S	*P*<0.001	*P*<0.001	*P*<0.001
	L x N	*P*=0.04	*P*<0.001	*P*=0.22
	S x N	*P*<0.001	*P*=0.01	*P*=0.003
	L x S x N	*P*=0.83	*P*<0.001	*P*=0.21

- **Soil Water Assessment Tool Modeling (led by Indrajeet Chaubey)**

  ✓ Completion of Upper Mississippi River Basin (UMBR) modeling with SWAT including Crop yield (soybean and corn) calibration and validation.

  ✓ Improving the UMRB water quality simulations in the SWAT model.

  ✓ Studying on the effect of drought on UMRB water quality, crop yield and hydrology.

  ✓ Collecting data (crop yield by county and state, drought index data).

  ✓ Completing multi-site multi-variable calibration and validation of the Wabash and White River Basins water quality.

  ✓ Evaluating hydrologic/water quality impacts of perennial bioenergy crop production in Upper Mississippi River basin.

- **University of Illinois Urbana-Champaign**

  - **Factor Analysis Plots**

    - ✓ Biomass was harvested in September 15-16, 2015. The plots for "H1" (post anthesis stage) and "H3" (Alternate H1 and H2 plots) treatments were harvested at this time.
    - ✓ Biomass yield for each plot was calculated, and tissue samples were saved for future chemical analyses.
    - ✓ The H2 treatment plots will be harvested within two weeks after the killing frost.

Fig. 7. Factor analysis plots (H1, H2, and H3) showing different growth stages in September 13, 2015).

Fig. 8. Factor analysis plots (H1, H2, and H3) (Left: September 16, 2015; Right: November 9, 2015).

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Fig. 9 H1 and H3 treatment plots from both 2012 and 2013 planting were harvested on September 15-16, 2015

- **University of Minnesota**

  - **Overview**

The H1/H3 harvest at Becker was completed on August 4, 2015 and the H1 harvest at Lamberton on August 5. The H2 harvest at Becker was completed on October 23 and the H2/H3 harvest at Lamberton is planned for early November.

✓ **Becker**. Overall, the Becker plots looked great in 2015 Rainfall was adequate and growth was robust. The H1 (near anthesis) harvest is showing less biomass than the H3 (alternating near anthesis and post-frost) harvest, indicating that repeated peak-season cuttings are decreasing stand productivity (Figs. 10 and 11). Both harvest regimes have similar production patterns (e.g. Liberty < Sunburst), but the magnitude is greater in the H3 harvest.

The grass plots were sprayed for weeds both in late fall, 2013, and during the early-to-mid growing season of 2014. Heavy weed pressure and low grass biomass in Liberty, in particular, is a result of 2013-2014 winter stand loss following a very dry growing season.

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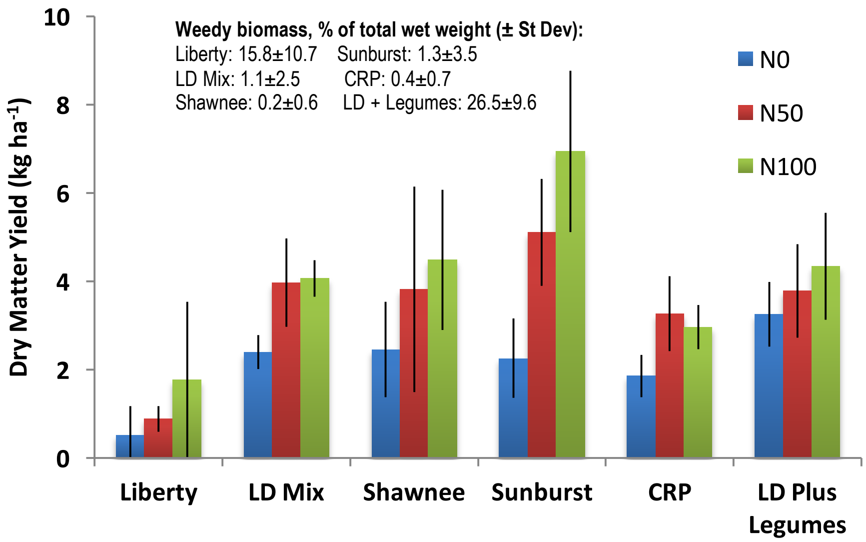

Fig. 10. August 4, 2015, dry matter yield on H1 (near-anthesis harvest) plots at Becker. N = nitrogen application in lbs ac^{-1}. Error bars denote one standard deviation.

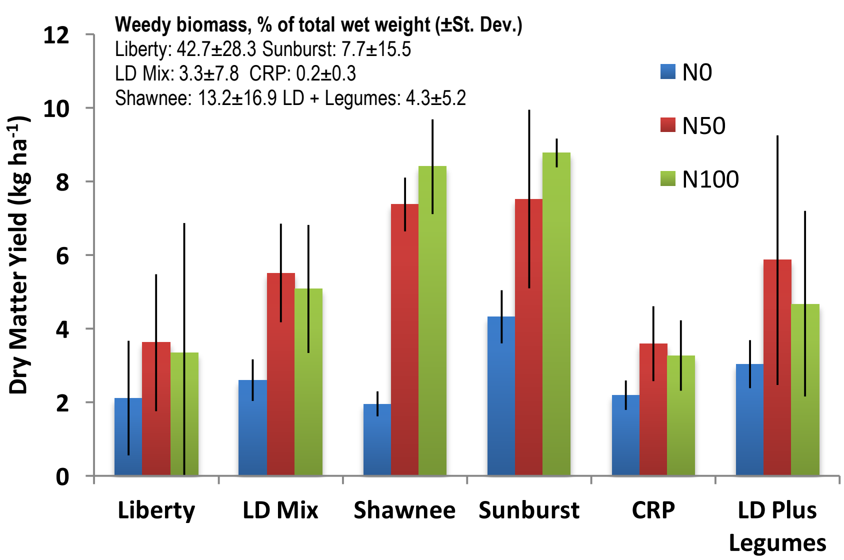

Fig. 11. August 4, 2015, dry matter yield on H3 (alternating harvest) plots at Becker. N = nitrogen application in lbs ac^{-1}. Error bars denote one standard deviation.

✓ **Lamberton**. The plots at Lamberton looked great in 2014 as well. The grass plots were sprayed early in the growing season, but weed pressure is still evident in ‘Liberty’, likely as a result of winter stand loss.

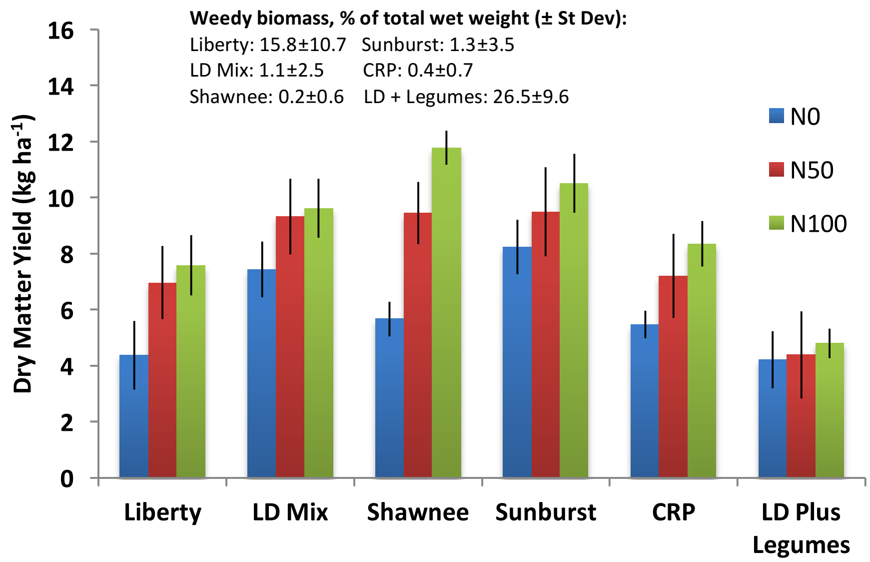

Fig. 12. August 5, 2015, dry matter yield on H1 (near-anthesis harvest) plots at Lamberton. N = nitrogen application in lbs ac^{-1}. Error bars denote one standard deviation.

- **USDA-ARS, Lincoln**

  - **Undergraduate Student Hourly Employees Trained in all Aspects of the Scientific Process**

    David Walla, University of Nebraska Student

  - **Graduate Students Trained**

    Jordan Leach, University of Nebraska Student, Agronomy, in process.

  - **Factor Analysis Plots**

    ✓ Yield data for 2012-2014 is being summarized.

    ✓ Feedstock samples collected in 2012, 2013, and 2014 have been processed and are being scanned and biomass composition predicted using NIRS.

    ✓ Plots have been maintained, anthesis harvests completed, and prepared for post-frost harvest.

  - **System Analysis Plots**

    ✓ Samples collected in 2012, 2013, & 2014 are processed and are being scanned and biomass composition predicted using NIRS.

- ✓ Corn plots were harvested on 9/30/15 with a yield of 125.6 bu/acre and triticale cover crop planted. Triticale stands are very good.
- ✓ GHG samples from 2013 and 2014 are being summarized and 2015 sampling is in process.
- ✓ VOM & elongated leaf height data are being summarized and 2015 sampling is in process.
- ✓ Fields have been maintained, anthesis harvests completed in the harvest height study, and prepared for post-frost harvest in the fertilizer treatment fields.

- Factor analysis plots in two wetland sites in eastern North Dakota are doing well. Establishment was variable.
- The Ryzup study evaluating its effects on switchgrass managed for bioenergy have been maintained & prepared for post-frost harvest.
- The Crop/Livestock/Bioenergy Production System Demonstration site in eastern Nebraska is established. Ten-acre fields of corn and soybean have been harvested and cover crops seeded. Liberty switchgrass, Shawnee switchgrass and Newell smooth brome are being prepared for harvest. Corn was harvested on 9/28/15 with a yield of 131.4 bu/acre. Soybean was harvested on 10/1/15 with a yield of 47.2 bu/acre. Cover crop stand is excellent.
- The field-scale herbaceous perennial feedstock research and demonstration site in cooperation with Vermeer Manufacturing near Pella, IA is being prepared for post-frost harvest.
- Continued managing the annual and perennial feedstocks to supply CHP to an advanced ethanol fermentation plant. Teff and sorghum were harvested, and winter wheat was planted.
- The warm-season grass grazing for 2015 was completed, but the only valid data will be grazing days due to wild steers that could not be kept in the proper pastures.
- A draft decision support tool that compares the returns from row crop production to the returns for perennial grasses for bioenergy developed in collaboration with Dr. Chad Hart and Dr. Keri Jacobs is nearly ready for release.
- Completed the following research updates:

- ✓ Updated the Nebraska Plant Materials Committee on new perennial grass research on 20 August.
- ✓ Presented information to the Two Rivers Coop Field Day in Pella, IA on 24 August.
- ✓ Attended Husker Harvest Days and present CenUSA information on 15 September, 2015.
- ✓ Attended the University of Nebraska Biofuels and Bioproducts Symposium on 18 September, 2015.
- ✓ Attended the Switchgrass III: Prairie and Native Grass International Conference in Knoxville, TN on 29 September – 2 October 2015.

- **Plans for Next Quarter**
  - ✓ Continue scanning and predicting 2012, 2013, & 2014 biomass samples.
  - ✓ Collect post-frost harvest data in multiple studies in 2015.
  - ✓ Analyze and summarize field data.
  - ✓ Begin processing 2015 biomass samples.

- **USDA-ARS, Madison**

1. Planned Activities

- Complete first two harvests of 2015 at two locations.
- Finish grinding 2014 and 2015 samples.
- Begin scanning 2014 and 2015 samples on NIRS.

2. Actual Accomplishments

- Completed first two harvests of 2015 at two locations.

3. Plans for Next Quarter

- Finish 2015 samples.
- Finish scanning 2015 samples on NIRS.

4. Publications, Presentations, and Proposals Submitted

- Aller, D., Laird, D.A., Mazur, R., Moore, K., Hintz, R. (2015). Influence of biochar and diversified cropping systems on soil physical and chemical properties. Soil and Water Conservation Society Annual Conference. Greensboro, NC. July 2015. (oral presentation)
- Archontoulis, S.V., Huber, I., Miguez, F.E., Thorburn, P.J. & D.A. Laird. (2015). A model for mechanistic and system assessments of biochar effects on soils and crops and trade-offs. GCB Bioenergy. http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12314/full (in press).
- Bakshi, S., Aller, D.M., Laird, D.A. & Chintala, R. (2015). Comparison of the physical and chemical properties of laboratory- and field-aged biochars. GCB Bioenergy. (Submitted).
- Feng, Q., Chaubey, I., Cibin, R., Engel, B., Sudheer, K.P. & J. Volenec. (2015). Bioenergy grass production on marginal lands and hydrologic and water quality impacts in the Upper Mississippi River Basin (UMRB). International Soil & Water Assessment Tool Conference, October 12-14. Purdue University, West Lafayette, IN.
- Feng, Q., Chaubey, I., Cibin, R., Engel, B., Sudheer, K.P. & J. Volenec. (2015). Marginal land suitability for biomass crop production in the Upper Mississippi River Basin. The Third International Symposium on Sustainable Agriculture for Subtropical Regions, Oct. 18-20. Changsha, Hunan Province, China.
- Feng, Q., Chaubey, I., Cibin, R., Engel, B., Sudheer, K.P. & J. Volenec. (2015). Simulating establishment period of perennial bioenergy grasses in the SWAT model. International Soil & Water Assessment Tool Conference, October 12-14. Purdue University, West Lafayette, IN.
- Fidel, R.B. (2015). Biochar properties and impact on soil CO_2 and N_2O emissions. Iowa State University.
- Laird, D.A., C. Anderson, D. Hayes. (2015). Carbon Farming as a Carbon Negative Technology. AGU Fall Meeting. San Francisco, CA. Dec. 14-15, 2015. https://agu.confex.com/agu/fm15/meetingapp.cgi/ Paper/83017
- Omani, N., Chaubey I., Li P., Panagopolous Y., & M. White. (2015). Assessing sensitivity of UMRB agriculture and water resources to past and current drought. International Soil & Water Assessment Tool Conference, October 12-14. Purdue University, West Lafayette, IN.

- Rogovska, N., Laird, D.A., & D.L. Karlen. (2015). Corn and Soil Response to Biochar Application and Stover Harvest. Field Crops Research. (Submitted).
- Serapiglia, M.J., Boateng, A.A., Lee, D.K. & M.D. Casler. (2015). Switchgrass crop management can impact biomass yield and nutrient content. Crop Sci. (in review).

Objective 3. Feedstock Logistics

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

Iowa State University

1. Planned Activities

- In the fall of 2015, four field drying experiments in Mead, Nebraska will be conducted to study the influence of swath density and weather conditions on drying potential of switchgrass. The model developed in the lab drying study will be compared to the results with the field drying studies to further recalibrate or validate the empirical models. In addition, field drying experiments will be conducted on corn stover to compare the model developed in laboratory study with the field drying behavior of corn stover.
- We will develop and evaluate a prototype real-time biomass moisture sensor for switchgrass and corn stover.

2. Actual Accomplishments

In the past quarter, empirical drying rate models were developed for switchgrass in the seed development stage of maturity. A series of 27 drying experiments and separate validation experiments were performed in the environmental chamber developed for the study. In addition, a different nighttime drying model was also developed to account for rewetting of switchgrass due to dew formation at night. For the seed shattering and seed shattered stage of maturity, 14 experiments out of 27 have been completed in the environmental chamber. A different set of experiments for validation of the model will also be performed after completion of the model development experiments. An empirical model for night time conditions in seed shattering and seed shattered stage of maturity have already been developed.

We also performed four field drying experiments on switchgrass in Mead, Nebraska in which we studied the effect of weather conditions and swath density on drying behavior of switchgrass. Two corn stover field drying rate experiments were also completed in Boone, Iowa to evaluate the effect of swath density and crop conditioning on stover drying rate. A change in corn stover conditioning level was achieved by using a conventional and biomass harvesting combine. In the field drying study of corn stover and switchgrass the effect of environmental conditions, swath density and conditioning level was related to the drying potential of both crops.

Research on the development of sensors capable of predicting moisture content and bulk density of biomass feedstocks based on the dielectric measurements continued during this quarter. Results from the last showed that dielectric measurements have good potential for predicting moisture content and bulk density although further investigation is required for a wider range of frequencies, moisture content, and bulk density levels. In this quarter, the emphasis has been on the design of the electronics for real-time biomass moisture sensor.

3. Explanation of Variance

No variance in planned activities has been experienced.

4. Plans for Next Quarter

Research activities planned during next quarter include:

- Analysis of data collected during fall (2015) field drying experiments and comparison of results with empirical drying prediction models developed from controlled laboratory experiments.
- Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover.

5. Publications, Presentations, and Proposals Submitted

No publications submitted this quarter.

University of Wisconsin

1. Planned Activities

Our efforts in this quarter were to include:

- Continue work on the system to compact and re-shape both round and square bales;
- Investigate means to achieve weight limited transport using modified large-square baler; and

- Continue to assess the economic viability of the various grass harvest and processing options by improving the economic model and begin integration of model results into the Integrated Biomass Supply Analysis and Logistics Model (IBSAL).

2. Actual Accomplishments

- Work continued on reshaping round bales into a parallelepiped or cuboid shape to enhance transport characteristics. Bale compaction experiments to quantify compression forces, bale density, and bale re-expansion rate were conducted using switchgrass, wheat straw and corn stover. To achieve a similar density, recompressing bales of switchgrass required greater force and energy than corn stover but less than force and energy required for straw bales. Round bales were reshaped to a cuboid shape, but because of non-uniform re-expansion of the bales, stacking these bales in the typical orientation did not produce a stable stack. However, stacking by placing the bales on their face was successful and appears to be the appropriate approach if the processed is scaled.

- A new bale press was designed and fabricated that can compress large square bales to double density. The press has been instrumented and data will be collected using the same crops described above. Comparisons of force, energy and density differences for recompressing round and square bales will then be made.

- Extensive field evaluation of high-density large square baling using a modified baler was conducted using switchgrass, native grass mixes, reed canarygrass, corn stover and wheat straw. It was possible to achieve slightly greater than 13 lbs/ft^3 (dry basis) with all the grasses. Assuming 15% moisture, the target goal of greater than 15 lbs/ft^3 could be achieved. It is possible that densities greater than these could be achieved using twine with greater tensile strength than was used for these tests. Corn stover density was slightly less than grasses while wheat straw was considerably less. In all crops, small incremental increases in density required large expenditures in fuel and power.

- A model which features modules for harvest, roadsiding, storage, transport and primary grinding has been developed to conduct techno-economic analysis of grass feedstock logistics. The combined model was used to estimate the economic impact of some of the harvest and storage options considered in this research, including bale size, bale density, bale accumulation, pre-cutting at baling, and storage options. One of the CenUSA interns from 2015 was hired and she continues to develop and expand the model.

3. Explanation of Variance

None

4. Plans for Next Quarter

Our efforts in the next year will include:

- Complete work on the system to compact and re-shape both round and square bales and collect data on compressing large square bales;
- Continue to assess the economic viability of the various grass harvest and processing options by improving the economic model and further integration of model results into the Integrated Biomass Supply Analysis and Logistics Model (IBSAL), and
- Submit two manuscripts for publication review.

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 the System Performance 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 switchgrass and corn/soybean rotations as possible land use options. As a starting point on an extensive scenario testing for biofuels in the area with this large-scale hydrologic model, three cellulosic biofuel scenarios are tested: a) 50% corn stover removal from all the corn-soybean and continuous corn land with slopes <2%, b) the 'Shawnee' switchgrass growth on all cropland with slopes >2% and to all pastureland and c) the cultivation of Miscanthus to all cropland with slopes >2% and to all pastureland as well. The model is executed for a recent 20-year period and the results are evaluated based on SWAT outputs on an annual basis. Hydrology is not practically influenced compared to the baseline, however, sediments from HRUs entering streams have been significantly reduced under the growth of both perennial crops but not under the stover removal scenario, which caused an expected slight sediment increase. A similar output is produced for P, which is strongly connected with sediments in SWAT. On the other hand, all scenarios resulted in reduced N losses to streams and rivers which are reflected to a considerably reduced N load in the Mississippi river downstream. Crop and biomass yields were also estimated across the landscape and based on the updated SWAT growth routines for perennials they are very promising for biofuel production. These papers were presented at the SWAT Conference in Purdue on October 14-16, 2015.

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

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

A paper has been submitted to the NAREA association journal concerning tradeoffs between food, fuel and water quality in a watershed with limited availability of land. We assess empirically how agricultural lands should be used to produce the highest valued outputs, including food, energy, and environmental goods and services. We explore the efficiency trade-offs associated with allocating land between food and bioenergy. We use a set of market prices and non-market environmental values to value the outputs produced by these crops. We explore the degree to which using marginal land for energy crops is an approximately optimal rule. Our empirical findings for an agricultural watershed in Iowa show that placing energy crops on marginal land is not likely to yield the highest valued output.

5. Publications, Presentations, and Proposals Submitted

Valcu, A., Kling, C.L. & P. Gassman. (2015) The Optimality of Using Marginal Land for Bioenergy Crops: Tradeoffs between Food, Fuel, and Environmental Services" at the *Northeast Agricultural and Resource Economics Association Journal*. Under review, December 2015.

Panagopoulos, Y., Gassman, P.W., Kling, C. L., Raj, C., & I. Chaubey. (2015). "SWAT Bioenergy Applications for the U.S. Corn Belt Region Part 4: Assessment of large-scale scenarios for the UMRB and OTRB," presented at the SWAT Conference. Purdue University, September 2015.

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**

   Our focus this quarter was on developing spatially-explicit switchgrass life cycle air pollutant inventories. We also reexamined our assessment of the fuel market effects of advanced biofuel production for the Renewable Fuel Standard.

3. **Explanation of Variance**

   No variance has been experienced.

4. **Plans for Next Quarter**

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

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

   - Hill, J. (2015). Promoting renewable energy options that are truly sustainable using a life cycle approach. Renewable Energy Convergence Colloquium, Minneapolis, MN, October 2015.
   - Hill, J. (2015). The emerging role of biofuels: Effects on air quality. Energy Summit, University of Wisconsin–Madison, October 2015.
   - Tessum, C. (2015). Economic input-output life cycle assessment of PM2.5 health impacts and environmental injustice. American Association for Aerosol Research, Minneapolis, MN, October 2015.
   - Tessum, C., Hill, J. & J. Marshall. (2015) InMAP: a new model for air pollution interventions. Submitted to *Geosci. Model Dev.* (In review).

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.

1. **Planned Activities**

Planned activities for the previous quarter were to obtain the missing Dissolver organic carbon (DOC) data and complete work on the biochar aging and AEC stability during oxidation manuscripts. The peak temperature used to separate biochar volatile matter from fixed C during proximate analysis will be evaluated and compared with H:C ratios to better distinguish labile and recalcitrant biochar fractions.

2. **Actual Accomplishments**

Dissolver organic carbon (DOC) data was acquired for acid extracts of 22 fresh and aged biochars. The DOC data allowed completion of a manuscript documenting changes in physical and chemical properties of 22 biochars and a comparison of the effects of field ageing (biochar in agricultural soils for 3 years) and laboratory ageing (biochars subjected to acidification, oxidation, leaching, and equilibration with DOC).

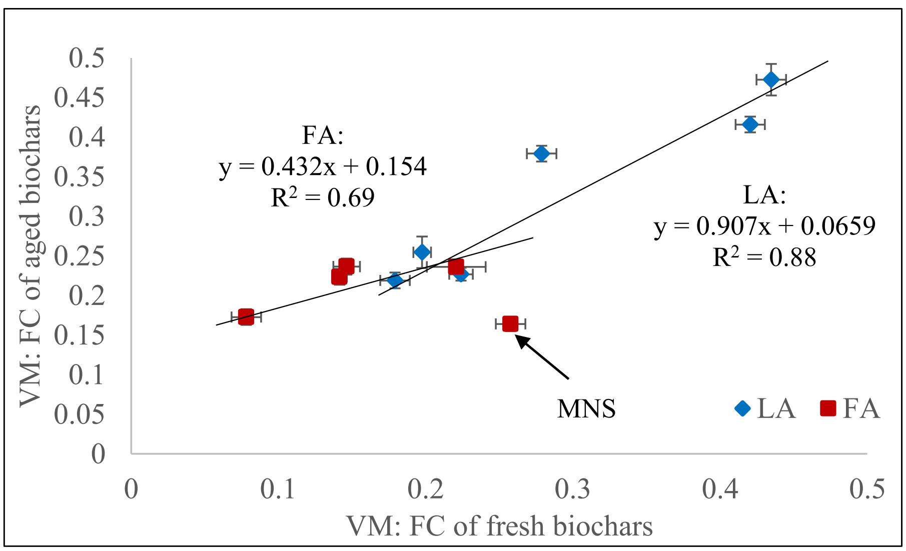

Fig. 13. Comparison of volatile matter (VM) to fixed carbon (FC) ratios for fresh and aged biochars. Biochars were either lab aged (LA) or field aged (FA).

Proximate analysis is a procedure used for characterization of biochars. Specifically, proximate analysis allows quantification of fixed carbon, volatile matter, ash, and moisture content of biochars. Volatile matter is equated with labile organic carbon in biochars while fixed carbon is assumed to represent the recalcitrant fraction of biochars. The proximate analysis method was originally developed for characterization of coal and charcoal but has never been fully tested for use with biochars. During this period, we completed work on a study evaluating a modified proximate analysis method designed for biochars. Specifically, we assessed the use an N_2 purge during heat treatments and evaluated 9 different temperatures ranging from 350°C to 950°C to determine the appropriate temperature to use when quantifying volatile matter and fixed carbon. Total C, H, and N and H:C ratios were determined for 22 biochars. Below (Fig. 14) are the relationships between the ratios of volatile matter to fixed carbon (VM/FC) and hydrogen to organic carbon ($H:C_{org}$) content for the 22 slow pyrolysis, fast pyrolysis, and gasification biochars.

Shown in Figure 15 are the ratios of VM/FC determined at various temperatures ranging from 350°C to 900°C relative to VM/FC ratio determined at 950°C for 22 biochars. The results show that a minimum separation temperature of 800°C is sufficient to obtain consistent proximate analysis results.

The results show that fast pyrolysis biochars generally have higher levels of VM than slow pyrolysis or gasification biochars. Furthermore, higher ash content was found in biochars produced from herbaceous feedstocks (corn stover and switchgrass) and lower ash content was found in biochars produced from hardwood feedstocks. Aging caused changes in ash content for both the LA and FA biochars, however, opposite trends were observed. Laboratory aging consistently caused a decrease in ash content (ranging between 22.2-74%; $P<0.05$), whereas ash content of the FA biochars (HG, HS2, and MNS) increased by 18-195% ($P<0.05$) and gasification herbaceous biochars (SG and CG) decreased by 12-21%. We found a better linear VM:FC-fresh vs VM:FC-aged relationship for LA biochars than FA biochars ($R^2 = 0.88$ and 0.69 for LA and FA samples, respectively, $P<0.05$ for slope test) with the exception of one outlier, MNS (with inclusion of MNS, R^2 dramatically changes from 0.69 to 0.09 for FA biochars). Assuming that FC is constant (unchanged on aging), the results show that on aging VM increases to a similar extent for both LA and FA biochars due to the adsorption of DOC. The $H:C_{org}$ ratio is commonly used as an index of biochar C stability as proposed by the International Biochar Initiative (IBI). Similar relationships between $H:C_{org}$ and VM/FC ratios were obtained for the LA and FA biochars (though a better relationship for LA biochars, $R^2 = 0.71$, compared with $R^2 = 0.59$ for FA biochars). This suggests that the laboratory aging procedure mimicked the field aging procedure in terms of biochar stability but was more aggressive in terms of leaching ash.

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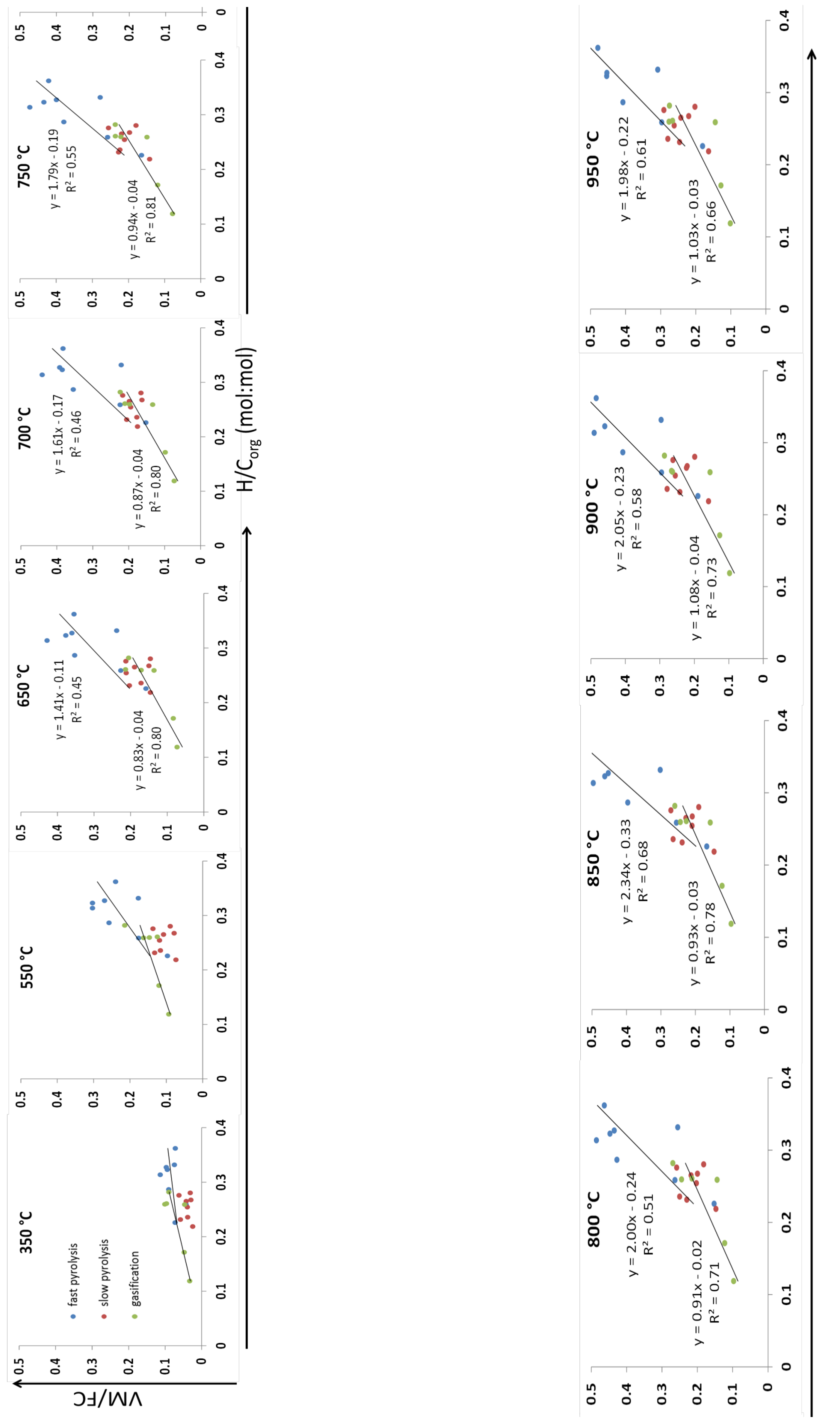

Fig. 14. VM/FC vs. H/Corg (mol:mol) ratios determined using temperatures ranging from 350 - 950 °C to separate VM from FC under a N_2 purge. The biochars are grouped by production technique; slow pyrolysis, fast pyrolysis, and gasification biochars.

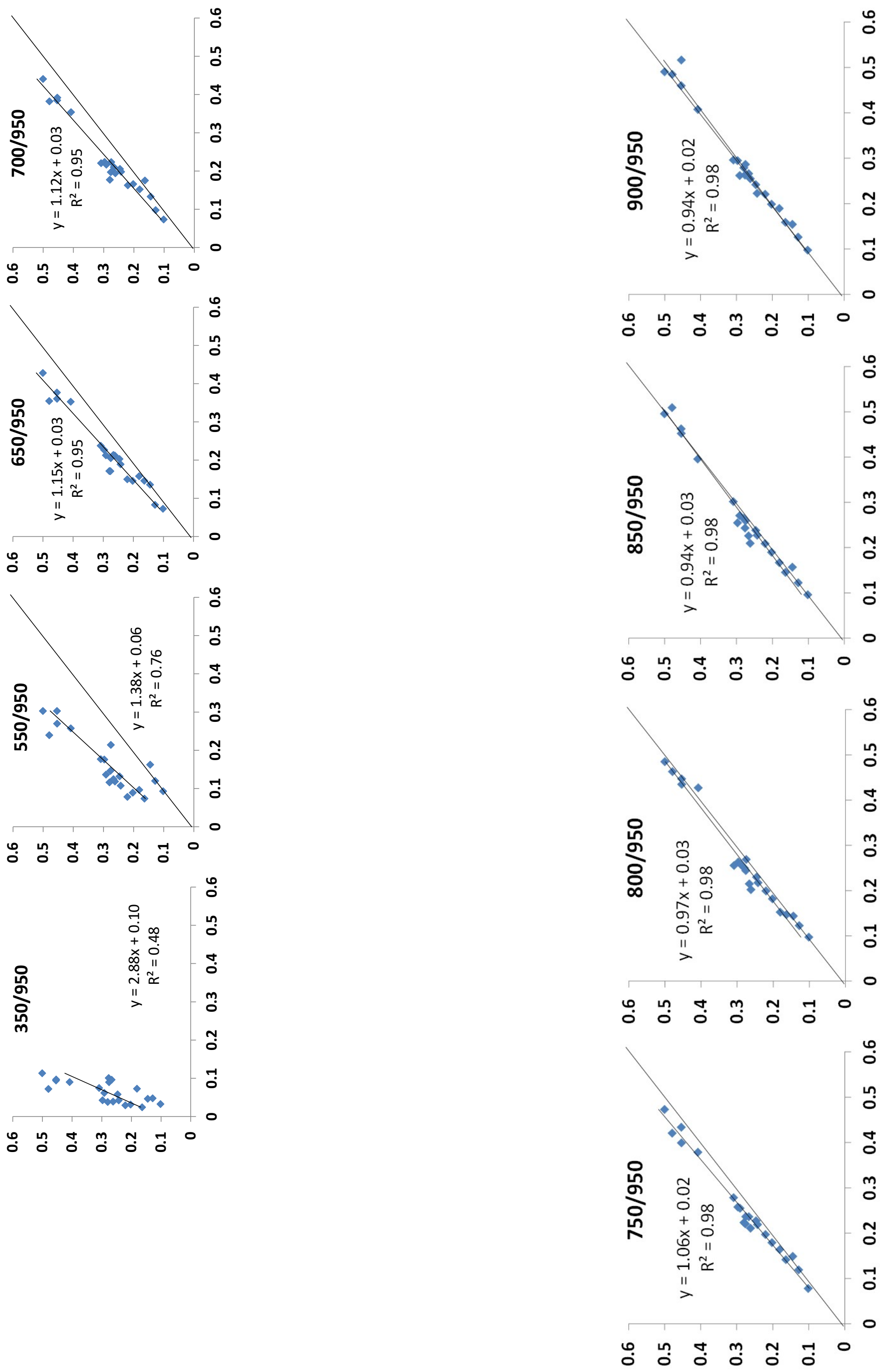

Fig. 15. Ratios of VM/FC determined at temperatures ranging from 350ºC to 900ºC relative to VM/FC ratio determined at 950ºC for 22 biochars.

A manuscript documenting the comparison of field aged and lab aged biochars has been submitted to GCB Bioenergy. The first draft of a manuscript documenting development of the modified proximate analysis method has been prepared and is currently being revised. (See publication list below for details).

The focus of Michael Lawrinenko's dissertation research is the development of biochars with zero valent iron (BC-ZVI), which have potential high value environmental application for the decontamination of trichloroethylene (TCE) and other halogenated compounds found in contaminated soil and ground water. BC-ZVI has potential to be deployed in reactive barriers that intercept plumes of contaminated ground water. Currently, ZVI is employed without biochar in reactive barriers. The hypothesis underlying the research is that TCE degradation can be enhanced relative to ZVI alone through combined adsorption on biochar and electron transfer from ZVI with the biochar facilitating the electron transfer. The literature shows that BC-ZVI composites exhibit faster TCE degradation kinetics, but the mechanisms are not clearly understood. Thus, initial work is focused on understanding transformations of iron in pyrolysis, the relationships between feedstock and pyrolysis temperature, and identification of feedstocks and pyrolysis conditions and treatments that yield BC-ZVI composites.

In this quarter, biochars were prepared from select biomasses pre-treated with ferric chloride, in addition to controls, and the resulting biochar products were characterized to assess the mineralogies of iron that formed during pyrolysis. Figure 16 presents x-ray diffraction (XRD) patterns of these biochars. Evidence shows that ZVI formation was achieved at 700 °C, the highest treatment temperature (HTT) in biochar derived from corn stover and red oak, with significantly increased ZVI achieved for pyrolysis at 900 °C. Biochars produced from red oak, corn stover, cellulose, and switchgrass all exhibited evidence of ZVI. Biochar produced from dry distiller grain (DDG) exhibited no evidence of ZVI formation. Iron in the DDG biochars associated with phosphate resulting in schreiberite and barringerite; ferric and ferrous phosphides, at the HTT of 900 °C. Similar association of iron with silicon was observed in biochars derived from corn stover and switchgrass resulting in fayalite, (Fe)2SiO4. The results show that iron associates with other elements in biomass feedstocks, forming myriad iron mineralogies. Hence, more efficient use of iron would be achieved through use of cleaner feedstocks. Additionally, we learned that the HTT of 900 °C yields more ZVI in biochar than biochar produced at 700°C. Crystallite size of ZVI in these biochars was consistent among these 900 °C HTT biochars as manifested by the full width at half maximum of the primary 110 ZVI reflection (Fig. 17).

To be of value for use in a reactive barrier it is necessary that zero valent iron (ZVI) be relatively stable (not immediately oxidized on exposure to air). Thus, a study was undertaken to assess the stability of ZVI in biochars. Shown in Figures 18-22 are XRD patterns of biochars as they aged in a laboratory environment at ambient temperature and humidity. The

ZVI phases in biochars derived from cellulose and red oak were stable over this period, while ZVI in biochars made from corn stover and switchgrass rapidly oxidized to magnetite and maghemite; oxides of iron. These results reveal relative differences in stability of ZVI phases in biochars derived from different feedstocks.

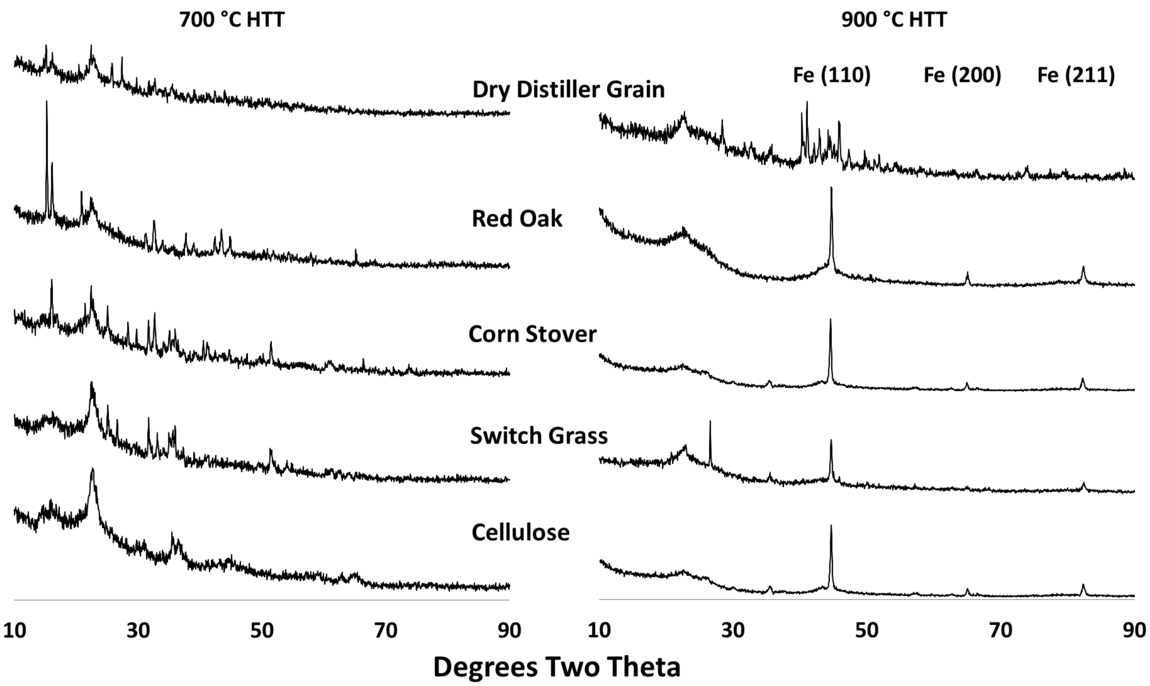

Fig. 16. XRD patterns of biochar-iron composites

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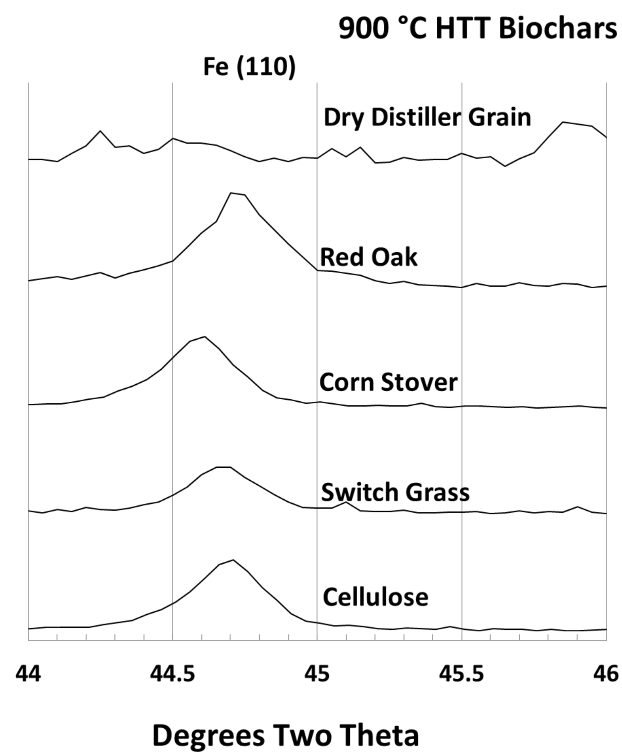

Fig. 17. XRD patterns showing the 110 reflection of ZVI in biochars.

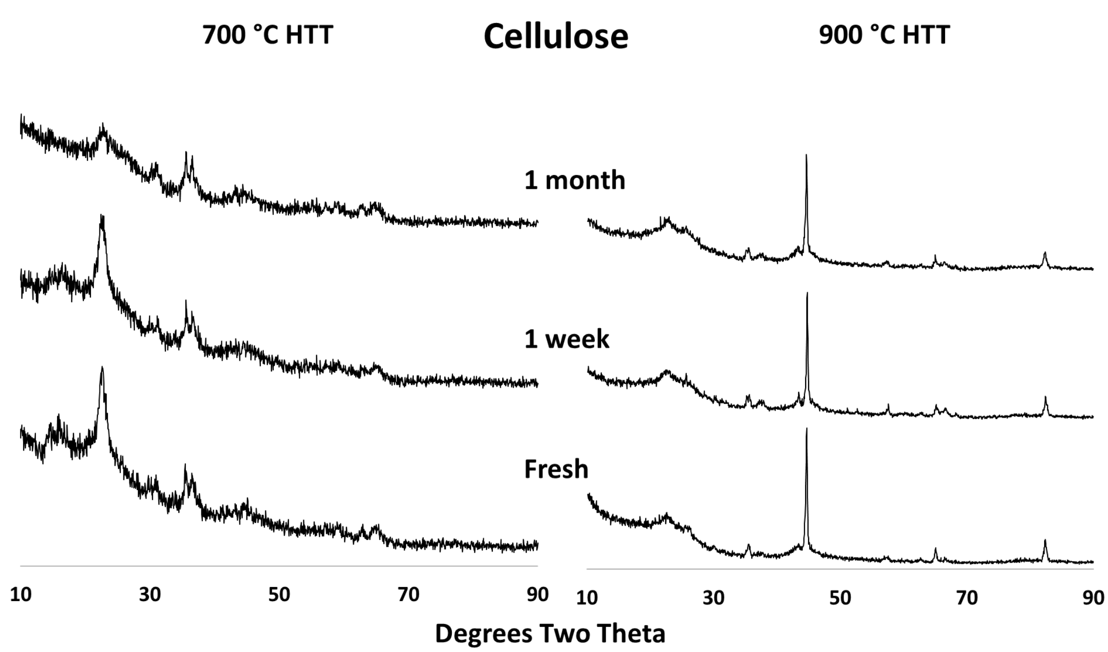

Fig. 18. XRD patterns of biochars derived from cellulose.

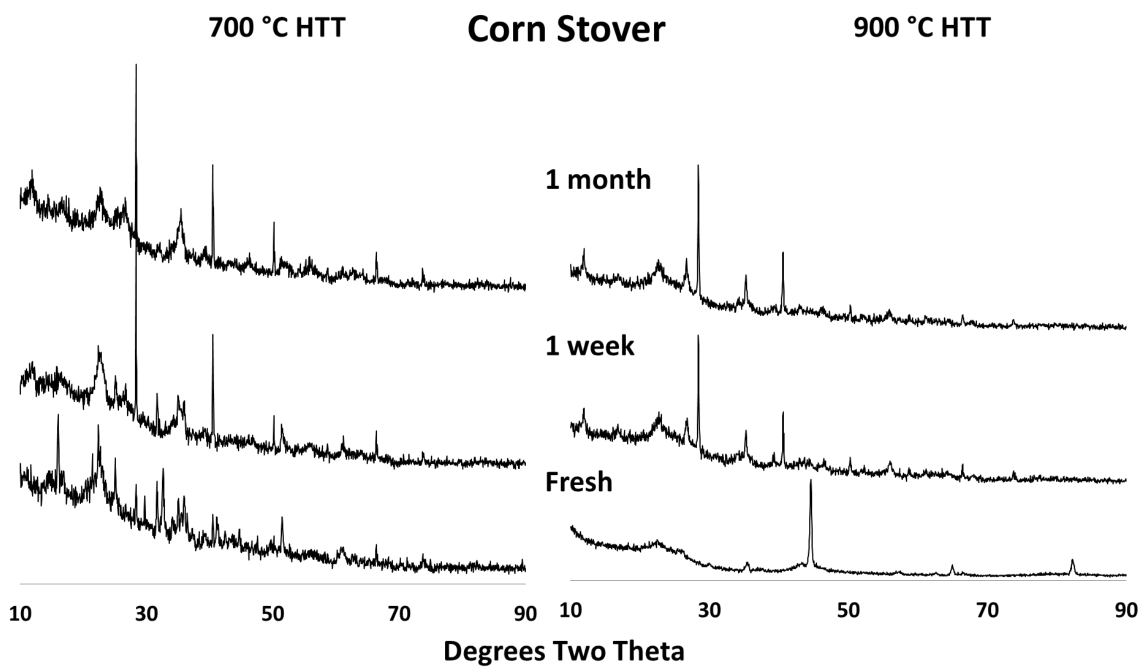

Fig. 19. XRD patterns of biochars derived from corn stover.

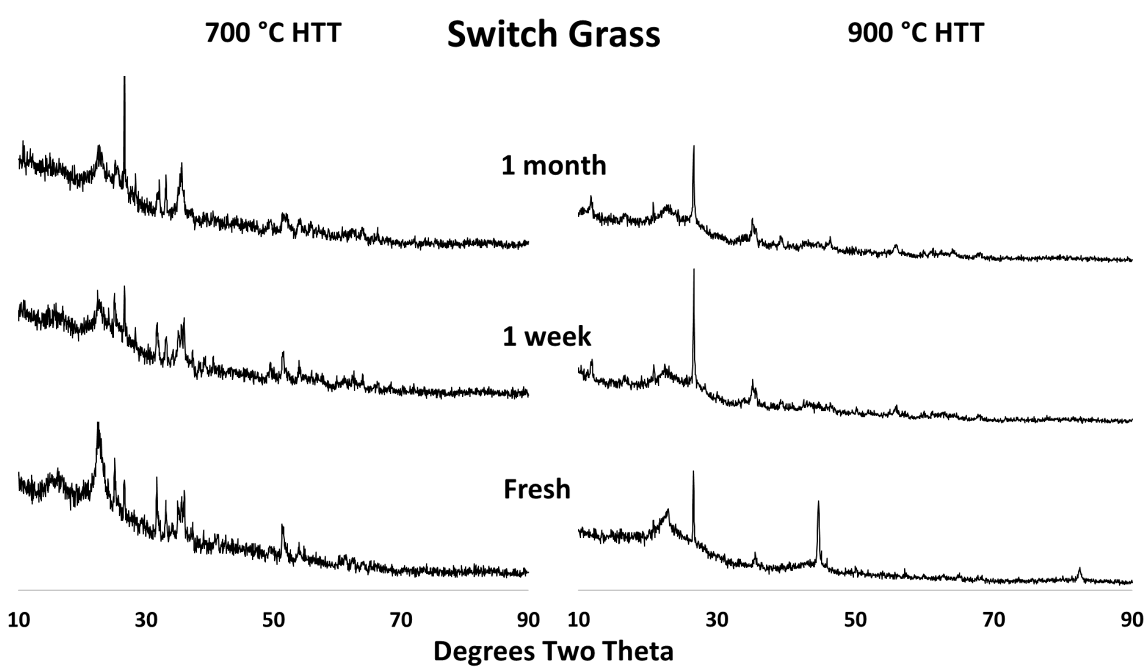

Fig. 20. XRD patterns of biochars derived from switchgrass.

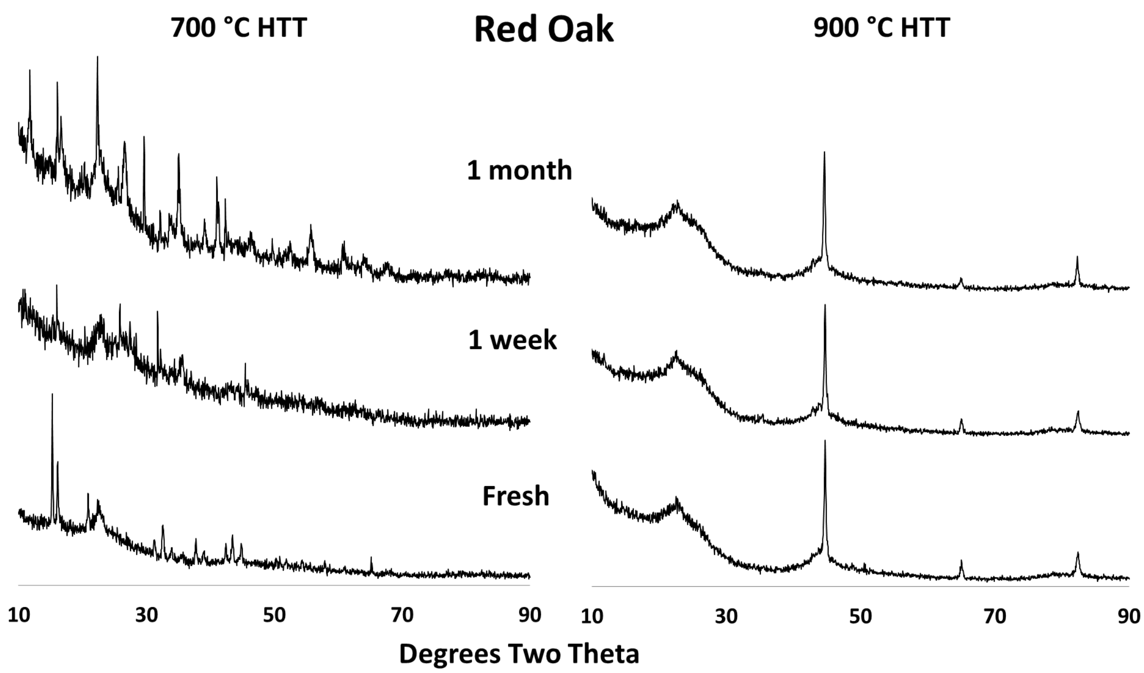

Fig. 21. XRD patterns of biochars derived from red oak.

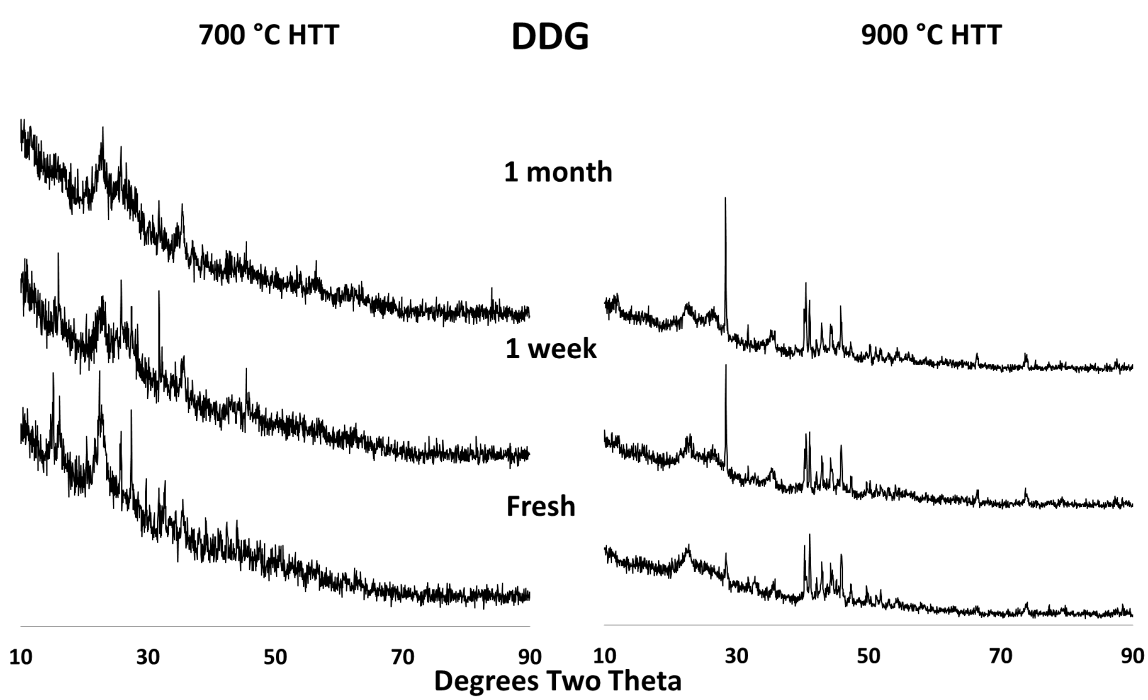

Fig. 22. XRD patterns of biochars derived from DDG.

A manuscript entitled "Accelerated ageing of biochars; impact on anion exchange capacity" was prepared and submitted to Carbon for publication. The first draft of a second manuscript entitled "Improved anion exchange capacity in biochar by aluminum and iron surface enhancement" has been prepared and is currently undergoing revisions. (See publication list below for details).

3. **Explanation of Variance**

No variance.

4. **Plans for Next Quarter**

We will obtain the missing DOC data and complete work on the biochar aging and AEC stability during oxidation manuscripts. The peak temperature used to separate biochar volatile matter from fixed C during proximate analysis will be evaluated and compared with H:C ratios to better distinguish labile and recalcitrant biochar fractions.

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

None

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**

- **Planned Activity A.** CenUSA collaborators and leaders Keri Jacobs, Rob Mitchell and Chad Hart are working on a producer decision tool based on the project's parameters for perennial grass production. The expected output is a publicly available decision aid on the CenUSA website and Ag Decision Maker. The tool will be demonstrated to extension personnel. The components of the tool have been decided.

- **Planned Activity B.** Continue work on a spatial model of biomass supply.
- **Planned Activity C.** Continue work on the economic feasibility of grasses by modelling the cost optimization problem of a unique plant under different market structures. Initial findings suggest that residues from agriculture will not be available in sufficient quantities to meet the mandate at relatively low prices, and this will provide an opportunity for perennial grasses.

2. **Actual Accomplishments**

- **Planned Activity A.** Ongoing but nearing completion. This tool will be rolled out and presented at extension meetings during December 2015 and beyond, including ISU's Integrated Crop Management Conference.
- **Planned Activity B.** Ongoing. Hayes and Jacobs are working with industry partner DuPont to identify optimal market segmentations for biomass collection systems and contracting. This work is expected to be complete during summer, 2016.
- **Planned Activity C.** Ongoing.

3. **Explanation of Variance**

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

4. **Plans for Next Quarter**

During the second quarter of year 5 (Q2 Y5) our team will continue work as outlined in the planned activities. All of the above ongoing projects will continue, largely conditional on the no-cost extension for this project.

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**

Multiple runs of the probabilistic risk assessment model (approximately 500,000 iterations) will be performed for testing the reliability of the results and observing the variation between modifications of inputs. Additional data refinement and adjustments for the probabilistic risk assessment model might be added. Data collection of results will begin for the development of a future paper on the outcomes of using the probabilistic risk assessment model for predicting the risk of the two farming systems.

- **Actual Accomplishments**

Several runs of the probabilistic risk assessment model (approximately 500,000 iterations for each run) were performed for testing the reliability of the results. One procedural error was discovered with the reliability testing. The linkage between input data to frequency distribution used by the probabilistic risk assessment model was not being refreshed correctly. Now the procedure is for each change of input data requires the construction of a new frequency distribution. The new frequency distribution must then be resampled by the model to reflect input data changes.

Minimum data refinement and adjustments for the probabilistic risk assessment model was performed. Gerberich (1998) transformation data was simplified to include only those values currently being used by the model.

A draft for a technical paper for the *2016 International Society for Agriculture Safety and Health* conference in June was started. The content for the technical paper will be the preliminary outcomes of using probabilistic risk assessment model for predicting the risk of the two farming systems – corn and switchgrass.

- **Explanation of Variance**

None to report.

- **Plans for Next Quarter**

Preform a series of runs to predict the risk difference between corn and switchgrass farming systems. Start a sensitivity analysis to determine greatest factors contributing to output variance. A technical paper proposal will be submitted to the *International Society of Agricultural Safety and Health* conference in June 2016.

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

  ✓ Ryan, S.J., Schwab, C.V. & G.A. Mosher. (2015). Agricultural Risk: Development of a probabilistic risk assessment model for measurement of the difference in risk of corn and biofuel switchgrass farming systems. International Society for Agriculture Safety and Health. International Meeting Normal, Illinois. ISASH Paper No. 15-01. ISASH Urbana, IL 61801.

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

- **Planned Activities**

  Receive approval for modifications to the human subjects study to include the transportation location and potential subjects.

- **Actual Accomplishments**

  The modifications to the human subjects study to include the transportation location and potential subjects needed to be adjusted prior to approval. The approval process is still ongoing.

- **Explanation of Variance**

  None to report.

- **Plans for Next Quarter**

  Receive approval for modifications to the human subjects study and authorization to start selection of subjects.

- **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 follows:

- 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 a 10-week summer internship program modeled on the highly successful NSF REU (research experience for undergraduates) program. Subtask 2B is **training graduate students** via a two-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

- **Conversion Modules 12 thru 15**

  Continue refining draft content and converting to on-line format.

2. Actual Accomplishments

- **Conversion Modules 12 - 15**

  Refinement of draft content continues.

- **Module 16 Biomass Quality (**John Guretzky)

  Began drafting module content.

- Gwen Nugent gave invited presentation at E-Learn 2015 (see citation)

- **Bioenergy MOOC**

  Prepare the list of modules from CenUSA program selected for the MOOC.

3. Explanation of Variance

No variance was experienced.

4. Plans for Next Quarter

- **Module 3. Harvesting.** Edit pre-existing module on UNL PaSSeL and bring on-line in new OSU module site.

- **Module 9. Enterprise Budgeting.** Add case study content with new cost estimation tool by Jacobs and Mitchell to draft module.

- **Conversion Modules 12 – 15.** Continue content refinement and on-line conversion.
- **Module 16.** Complete initial draft of content.

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

None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. **Planned Activities**

- On August 1, 2015 all student interns depart Iowa State University.
- Finalize and process all payments related to the internship program.
- Create a calendar and content outline for the summer 2016 program.
- Begin solicitation of research projects for the summer 2016 program.

2. **Actual Accomplishments**

- All 19 interns departed Iowa State University for home on Saturday, August 1, 2015.
- All internship-relevant payments processed.
- Created tentative calendar and program content outline for the 2016 program.
- Begin soliciting faculty hosts for the summer 2016 program.
- Each year, Iowa State University's Research Institute for Studies in Education (RISE) administers a pre-program survey to assess students. This provides a baseline for program evaluation. RISE also conducts a post-survey and focus groups at the close of the program, as well as a post program six-month survey. RISE conducted the post-program evaluation and focus groups on Friday, July 31. RISE is currently assessing and compiling these results.
- Through email and social media (including LinkedIn) we finalized contact with all 55 alumni of the CenUSA summer research internship program. Of those who have completed their undergraduate studies, 40% have matriculated to graduate school.

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 2016 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 in this period.

Subtask 2B – Training Graduate Students via Intensive Program

1. **Actual Accomplishments**:

   None as this was strictly a PY2 and a PY4 program activity. No forward planning is required.

2. **Explanation of Variance**
   None.

3. **Plans for Next Quarter**:

   None as this was strictly a PY2 and a PY4 program activity. No forward planning is required.

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

   None.

Subtask 2C –Subtask 2C – Training Graduate Students via Monthly Research Webinar

1. **Planned Activities**

   This series will no longer be offered, however graduate students will be invited to participate in critical project meetings as objectives disseminate findings in this final year.

2. **Actual Accomplishments**

None as this was strictly a PY1 - PY4 program activity. No forward planning is required.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   None as this was strictly a PY1 - PY4 program activity. No forward planning is required.

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

   Nugent, G., Kohmetscher, A., Namuth-Covert, D., Guretzky, J. Murphy, P. & DK Lee. (2015). Learning from online modules in diversity instructional contexts. E-Learn 2015 Conference. Kona, HI, Oct 19-22.

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.

- **Extension Staff Training/eXtension Team**

1. Planned Activities

- Video shoot of CenUSA booth at Nebraska's Husker Harvest Days.
- September 2015 issue of BLADES Newsletter.
- Continue maintenance of eXtension's CenUSA index.
- Continue production and planning of the CenUSA legacy video.
- Continue production and planning of a plant breeding video.

2. Actual Accomplishments

- Completed the video shoot of the CenUSA booth at Husker Harvest Days.

- Released October issue of BLADES Newsletter (http://blades-newsletter.blogspot.com/p/october-2015.html).
- Plant breeding video field and greenhouse shoot in Wisconsin.
- Continued production and planning of the legacy video.
- Continued maintenance of eXtension CenUSA index (http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa)
- **Website.** The CenUSA web site had 1,049 visitors this quarter. These visitors logged a total of 2,853 pageviews during 1,401 sessions. Pageviews are the total number of pages that visitors looked at during their time on the site. A session qualifies as the entire time a user is actively engaging with the site. If activity ceases for an extended period of time, and the user returns, a new session is started.
- **Vimeo**. During this quarter, the 47 CenUSA videos archived on Vimeo have had 223 plays or views of the videos on our Vimeo site, or on a web site that embedded a CenUSA video. The 47 videos also had 4,594 loads; 4,360 of those loads came from our videos embedded on other sites. When a video is loaded, people see the video but they do not click "play". The embedded videos were played 132 times. Vimeo videos were downloaded 8 times. This means the video was saved to their hard drive (users usually do this because they have limited Internet connectivity that does not allow for live streaming of a video). Once the video is downloaded, it is available on their computer to watch at their convenience.
- **YouTube**. The 47 CenUSA videos have been viewed 912 times between August 1, 2015 and October 31, 2015. Of these, 540 views were from the United States. Demographic analytics report an audience that is 85% male and 15% female. Our viewers ranged in age from 13-65+. The top three represented age groups were 55-64 (27%), 25-34 (23%), and 35-44 (17%). YouTube also provides data related to how users access the videos. Videos were viewed on their associated watch page, the YouTube Channel page, or on web pages where the videos were embedded. Nearly 95% of the videos were viewed on their associated YouTube watch page (each video has a unique "watch page"). Embedded videos on another site accounted for 4.5% of the views, and 0.4% of video views came from the YouTube Channel page. Users find our videos through various avenues, which are referred to as "traffic sources". Our top four traffic sources for this quarter include: YouTube search, YouTube suggested videos, referrals from other web sites, and other YouTube features. Some 47% of our views came from users accessing videos through YouTube Search.

YouTube suggested videos accounted for 26% of our views. Referrals from outside YouTube (Google search or access through external web sites) account for 17% of video views. Views from other YouTube features account t for 5.6% of video views.

- **Twitter**. Twitter traffic consists of followers who subscribe to our account and "follow" our tweets (announcements). Followers can "favorite" a tweet, or retweet it to share with their own followers. They can also "mention" us by tagging CenUSA bioenergy's Twitter account in their own tweets. During this quarter our tweets were retweeted a total of 113 times. Followers tagged CenUSA tweets as a favorite 139 times, and mentioned us 85 times. CenUSA Bioenergy also has 677 followers currently, up from 649 followers last quarter.

- **Facebook**. By the end of October 2015, CenUSA's Facebook page had 225 likes, up from 216 the previous quarter. Our most liked post from this quarter received 8 likes. The highest weekly reach of the quarter had a total reach of 205 individuals.

- **BLADES Newsletter**. **The** BLADES newsletter was sent to 851 people this quarter; the newsletter had 298 unique opens (36%). We published one newsletter (October 2015) during this quarter featuring 5 e-stories available at http://blades-newsletter.blogspot.com/p/october-2015.html:

  ✓ Switchgrass: Two Decades of Progress.

  ✓ Listening in with USDA's Bill Goldner.

  ✓ Could Bioenergy Perennial Grasses Help Pollinators?

  ✓ C6 BioFarm iPad Game Launched.

  ✓ Ken Vogel – Leading Progress on Switchgrass.

  ✓ Commercial Corner: AgSolver – Return on Investment Farming.

3. Explanation of Variance

None noted.

4. Plans for Next Quarter

- Implement the November Harvest Social Media Plan.

- Produce six stories for the December BLADES newsletter.

- Continue working on the production of the plant breeding and legacy videos.

- Continue maintenance of the eXtension CenUSA index.

5. Publications, Presentations, Proposals Submitted

- October 2015 BLADES Newsletter (http://blades-newsletter.blogspot.com/p/october-2015.html).
- Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts (https://cenusa.iastate.edu/files/guidelines_to_growing_perennial_grasses_copy.pdf).

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

1. Planned Activities

- **Indiana**

  Participate in:

  ✓ Indiana FFA Ag Science Biofuels Training.

  ✓ Ohio Farm Science Review.

  ✓ Trafalgar Field Day at the FFA Center.

  ✓ Roann Field Day at the Sweeten Farm.

  ✓ Forage Diagnostics Training.

  ✓ Throckmorton plot tour with Ag Education students.

- **Iowa**

  ✓ Host the CenUSA Perennial Grass Field Day.

  ✓ Harvest CenUSA plots in Washington and Johnson County for yield samples.

- **Minnesota**

  ✓ Complete monthly grassland assessments on demonstration plots.

- **Nebraska**.

  ✓ Continue development of outreach plans for CenUSA presence at the Nebraska State Fair and Husker Harvest Days both located near Grand Island, Nebraska.

  ✓ Work with David and Associates to develop educational/teaching materials for Raising Nebraska Exhibit at the Nebraska State Fair and for Husker Harvest

Days.

- ✓ Develop biochar and switchgrass seed sample giveaways for the Husker Harvest Days.
- ✓ Collect biomass samples and record visual observations at both sites during the months of August, September and October 2015.
- ✓ Make arrangements for final biomass harvest and removal at both field plot locations.

2. Actual Accomplishments

- **Indiana**

A total of 226 people (175 males, 51 females; 4 Hispanic, 205 White, 3 African American, 14 Asian) at the following CenUSA outreach events this quarter:

- ✓ Indiana FFA Ag Science Biofuels Training.
- ✓ Ohio Farm Science Review.
- ✓ Forage diagnostic training.
- ✓ Throckmorton plot tour with Ag Education students.

- **Iowa**

Hosted CenUSA perennial grass field day in Washington County on September 2, 2015. Forty people attended the field day (27 males and 13 females). Thirty people responded to a survey at the end of the field day:

- ✓ Thirty out of thirty participants responded “yes” to the question “After this evening, do you have a better understanding of the benefits of the production of perennial grass for bioenergy?
- ✓ Fifteen out of thirty participants responded “yes” to the question “Would you try planting perennial grass if a market for them develops in your area?”

- **Minnesota**

Completed monthly grassland assessments on demonstration plots.

- **Nebraska**

- ✓ Showcased CenUSA switchgrass biomass/biofuel project at the Nebraska State

Fair "Raising Nebraska outdoor exhibit.

- ✓ Showcased CenUSA switchgrass biomass/biofuel project at the University of Nebraska building located at the Husker Harvest Days Farm Show.
- ✓ The CenUSA Exhibits reached a total 1080 individuals.
- ✓ The CenUSA exhibit at Husker Harvest Days included a backdrop providing details of the CenUSA switchgrass biofuel effort. At the front of the exhibit was a LED panel where the CenUSA Extension team looped video of seeding through harvest of biomass. They discovered that one particular segment showing the compression of a biomass round bale was a show stopper. Therefore, the team adjusted the video to just play the compression clip. This clip seemed to make everyone stop at the CenUSA exhibit. At that point, the team was able to start a discussion about the aspects of switchgrass as a biofuel feedstock and how the CenUSA project has generated new discoveries and accomplishments. Team member Keith Glewen reported, "I have worked many farm shows, but I have never experienced such a positive experience with interest being expressed by show goers!"
- ✓ CenUSA Extension team member also did a video interview (see: http://www.1011now.com/video?videoid=3277866).
- ✓ Collected biomass samples and recorded visual observations at both on-farm research sites during the months of August, September and October, 2015.
- ✓ Made a presentation on the CenUSA project to Wahoo, Nebraska Lion's Club and Kiwanis Club.

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Fig. 23. Signage in switchgrass at Husker Harvest exhibit

Fig. 24. Video illustrating bale compression at Husker Harvest exhibit

Fig. 25. Exhibit at Husker Harvest Days, Nebraska

Fig. 26. Exhibit at Husker Harvest Days, Nebraska

3. Explanation of Variance

- The Purdue field days were cancelled due to lack of registrations.
- The Iowa harvest was delayed until November due to lack of frost.

4. Plans for Next Quarter

- **Indiana**
  - ✓ Plan the Huntington County Extension annual meeting presentation.
  - ✓ Plan the Kentuckiana Forage Expo.

- **Iowa**

  Harvest yield samples of Washington and Johnson County plots.

- **Minnesota**

  Harvest plots, dry and weigh harvest samples and begin grinding.

- **Nebraska**

  Harvest plots, dry and weigh harvest samples and begin grinding; conduct workshops on CenUSA producer decision tool.

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

   None submitted.

Economics and Decision Tools

1. **Planned Activities**

- Work on the University of Minnesota Biomass Crop Economic and Environmental Decision Support Tool (BCEEDST) and complete beta test with U of MN extension educators and stakeholders.
- Provide webinar training session for Extension Educators on the CenUSA Bioenergy Decision Tool on September 25, 2015.
- Continue work on advanced version of the decision tool.

2. **Actual Accomplishments**

- The UMN Biomass Crop Economic and Environmental Decision Support Tool (BCEEDST) is nearly complete.
- Conducted beta test with 10 extension educators and stakeholders interested in perennial bioenergy crops.
- Provided web training session for Extension Educators on the CenUSA Bioenergy Decision Tool on September 25th. (session is archived at https://www.youtube.com/watch?v=f8HZWSLCKQw.) Eleven people attended the meeting: 7 participants were Extension Educators, 2 were academics and 1 was "other." Respondents to the survey at the end of the session indicated:

  ✓ Understanding of the topic changed (6 respondents indicated "to some extent" and

3 to a great extent.

- ✓ In response to the question: "How might you use this information," two respondents indicated "teaching others", four indicated "written communication with clients", two indicted "improve my knowledge" and two indicated "other."
- ✓ Participants came from Illinois, Iowa, Kansas, Nebraska, and Wisconsin.
- ✓ Continued work on advanced decision tool.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- Complete a working version of the UMN Biomass Crop Economic and Environmental Decision Support Tool (BCEEDST).
- Finalize advanced version of the decision tool.
- Teach sessions on using the decision tool.

5. Publications, Presentations, Proposals Submitted

None.

- **Health and Safety**

See Objective 7.

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

- **Youth Development**

1. Planned Activities

- **Indiana**

- ✓ Prepare and submit proposal for HASTI conference 2016.
- ✓ Continue work on electronic companion materials for demonstration plot signage.
- ✓ Continue editing of high school curriculum.
- ✓ Field days will be held in fall.

- ✓ Training for Ag and Science teachers will be conducted in September 2015.

- **Iowa**

  Plan and conduct CenUSA "C6" Youth training programs for the following groups and dates:

  - ✓ Reiman Gardens Discovery Days - Aug. 1
  - ✓ SCI iEarth 3 - Aug. 3
  - ✓ Annette Brown Camp - Aug. 7
  - ✓ Gerald Joseph Camp - Aug. 7
  - ✓ Science Center of Iowa Speaking in Code - Aug. 10
  - ✓ Science Center of Iowa Imaginarium - Aug. 10
  - ✓ C6 BioFarm @ Iowa State Fair - Aug. 13
  - ✓ Robotics Challenge @ Iowa State Fair - Aug. 16
  - ✓ Robotics Challenge @ Iowa State Fair - Aug. 17
  - ✓ C6 BioFarm @ Iowa State Fair - Aug. 18
  - ✓ Varied Industries Building @ Iowa State Fair - Aug. 20
  - ✓ Varied Industries Building @ Iowa State Fair - Aug. 23
  - ✓ Collegiate 4-H Presentation - Sep. 14
  - ✓ Region 5 C6 BioFarm webinar - Sep. 15
  - ✓ Iowa City Farmer's Market - Sep. 19
  - ✓ ICTM Conference - Sep. 21
  - ✓ Environmental Science Presentation - Sep. 23
  - ✓ Green Umbrella Presentation - Sep. 29
  - ✓ ISU BioBus Presentation - Oct. 1
  - ✓ Taking the Road Less Traveled - Oct. 8
  - ✓ STEM Field Day - Muscatine - Oct. 14

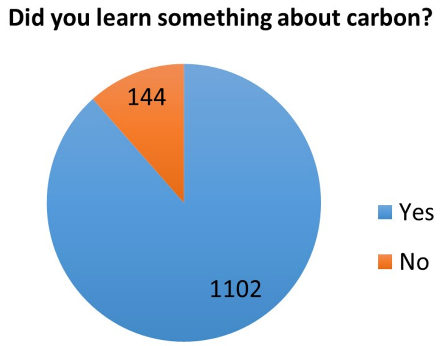
- ✓ National Campus Sustainability Day - Oct. 15
- ✓ Linn County Fairgrounds Recruiting Event - Oct. 17
- ✓ DMACC STEM Festival - Oct. 19
- ✓ National Bioenergy Day - Oct. 21 (Exhibit 3)
- ✓ Taking the Road Less Traveled - Oct. 22
- ✓ Taking the Road Less Traveled - Oct. 29

2. Actual Accomplishments

- **Indiana**
  - ✓ Successfully conducted both 2015 Renewable Energy 4-H Science Workshop and 4-H Round Up Sessions in June 2015.
  - ✓ Fifty (50) adult leaders (15 males, 35 females; 1 Hispanic, 49 White) were trained to use CenUSA Bioenergy teaching materials in this quarter at the Ag and Science teachers training in September 2015.
  - ✓ Twenty-five (25) youth (all females; 10 Hispanic, 5 White, 10 African American) participated in the participated in the Girls in Science program
  - ✓ Proposal was prepared and submitted for HASTI conference 2016.
  - ✓ Work continued on electronic companion materials for demonstration plot signage.
  - ✓ Continued editing the CenUSA Bioenergy high school curriculum.
- **Iowa**
  - ✓ Reached 1684 youth at the events listed below:
    - ➢ Reiman Gardens Discovery Days - Aug. 1
    - ➢ SCI iEarth 3 - Aug. 3
    - ➢ Annette Brown Camp - Aug. 7
    - ➢ Gerald Joseph Camp - Aug. 7
    - ➢ Science Center of Iowa Speaking in Code - Aug. 10

- Science Center of Iowa Imaginarium - Aug. 10
- C6 BioFarm @ Iowa State Fair - Aug. 13
- Robotics Challenge @ Iowa State Fair - Aug. 16
- Robotics Challenge @ Iowa State Fair - Aug. 17
- C6 BioFarm @ Iowa State Fair - Aug. 18
- Varied Industries Building @ Iowa State Fair - Aug. 20
- Varied Industries Building @ Iowa State Fair - Aug. 23
- Collegiate 4-H Presentation - Sep. 14
- Region 5 C6 BioFarm webinar - Sep. 15
- Iowa City Farmer's Market - Sep. 19
- ICTM Conference - Sep. 21
- Environmental Science Presentation - Sep. 23
- Green Umbrella Presentation - Sep. 29
- ISU BioBus Presentation - Oct. 1
- Taking the Road Less Traveled - Oct. 8
- STEM Field Day - Muscatine - Oct. 14
- National Campus Sustainability Day - Oct. 15
- Linn County Fairgrounds Recruiting Event - Oct. 17
- DMACC STEM Festival - Oct. 19
- National Bioenergy Day - Oct. 21
- Taking the Road Less Traveled - Oct. 22
- Taking the Road Less Traveled - Oct. 29

✓ Youth participating in the C6 activities were surveyed regarding what they learned by participating (Fig. 26)



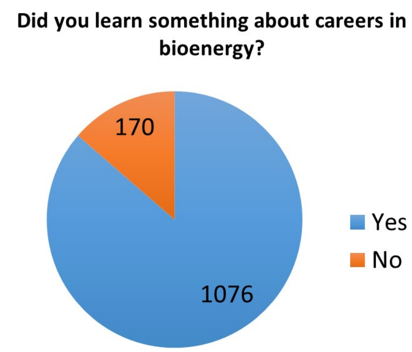


Fig. 27. Youth participating in the C6 activities

- ✓ 6 BioFarm is now available on the app store (see: http://www.extension.iastate.edu/article/c6-biofarm-app-debuts-itunes-0).
- ✓ Curriculum development is continuing.

3. Explanation of Variance

None noted.

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Fig. 28. Playing C6 BioFarm at Iowa State Fair

4. **Plans for Next Quarter**

- **Indiana**

  ✓ Continue to finish edits on curriculum and supporting materials and launch web portal for access to all Purdue developed Extension and education materials.

  ✓ Complete draft of journal article focused on 4-H Renewable Energy Science Workshops.

  ✓ Collaboration with Indiana State 4-H and Indiana Corn Board to create "Teens Teaching" model for Bioenergy. Training for first teams of teens to be held in March, with supporting materials for the teaching teams currently under development.

- **Iowa**

  ✓ Beginning Farmer's Network - Nov. 3

  ✓ Dallas County Clover Kids - Nov. 7

- ✓ Dallas County 4-H - Nov. 7
- ✓ Poweshiek County STEM Festival - Nov. 8
- ✓ 4-H Region 20 Food to Fuel Event - Nov. 11
- ✓ Cedar Valley STEM Festival - Nov. 12
- ✓ Region 1 STEM Festival - Nov. 14
- ✓ YouthFest - Nov. 17
- ✓ FIRST LEGO League - Jan. 16
- ✓ IHCC STEM Festival - Feb. 23
- ✓ Taking the Road Less Traveled - Mar. 31
- ✓ Drake University STEM Festival - Apr. 14
- ➢ Dubuque Family STEM Festival - Apr. 16
- ➢ Southeastern Community College STEM Festival - Apr. 23

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

- **Indiana**

  None.

- **Iowa**

  See list of events above.

Broader Public Education/Master Gardener Program

- **Iowa**

1. **Planned Activities**

   Collect crop data.

2. **Actual Accomplishments**

   Began crop data collection.

3. **Explanation of Variance**

None.

4. **Plans for Next Quarter**

Continue crop data collection and add data to data base.

5. **Publications, Presentations, Proposals**

None.

- **Minnesota**

1. **Planned Activities**

- Collect data measuring: plant growth, color and produce yields in demonstration gardens.
- Provide a public display about the Extension Master Gardener role on the biochar project at the Minnesota State Fair (Horticulture Agriculture Building) from August 27-September 6, 2015.
- Provide a display and short PowerPoint presentation at the International Master Gardener Conference in Council Bluffs, Iowa on September 23, 2015; and receive “Search for Excellence” award on behalf of all the volunteers and CenUSA projects in Iowa and Minnesota.
- Maintain gardens until hard frost.
- Clean up gardens to prepare for winter.

2. **Actual Accomplishments**

- All data has been collected and recorded online.
- Information about the Extension Master Gardener role on the biochar project was on display at the Minnesota State Fair from August 27-September 6, 2015 in Horticulture Agriculture building. An evaluation system was set up for people to cast their preference when asked “based on the information learned about biochar from this display, if biochar were available on the market, would you be interested in using it?” From the state fair display, there were 1,228 votes cost. Of those, 576 voted “yes”, 356 voted “maybe”, and 296 voted “no”.
- The same information was also displayed at the International Master Gardener Conference in Council Bluffs, Iowa on September 23rd, 2015.

- Extension Master Gardeners in Iowa and Minnesota received the 2015 Extension Master Gardener Search for Excellence Award/Research Category for the CenUSA Biochar demonstration gardens.

- A blog was posted on eXtension website about the project and award.

- Gardens were maintained up until mid-October 2015.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- **Minnesota**

  ✓ Analyze biochar demonstration garden data and create the final report for the project.

5. Publications, Presentations, Proposals Submitted

Blog post on eXtension: http://blogs.extension.org/mastergardener/2015/11/04/2015-search-for-excellence-awards-research-1st-place-winner/?utm_source=feedburner&utm_medium=email&campaign=Feed%3A+ExtensionMasterGardener+%28Extension+Master+Gardener+Blog+Posts%29

Evaluation and Administration

1. Planned Activities

- Teach two sessions at National Association of County Association Agents (NACAA) National Conference in Sioux Falls, South Dakota.

- Finalize brochure about CenUSA bioenergy grasses.

- Collect information from CenUSA Extension teams and prepare reports.

- Continue support for development of CenUSA C6 Youth app and videos.

- Meet with CenUSA Extension teams to plan and coordinate activities.

2. Actual Accomplishments

- Taught two sessions at the NACAA National Conference. CenUSA Outreach and Extension educators presented a program on the potential for growing perennial grasses for biomass at the 2015 NACAA annual meeting in Sioux Falls, South Dakota. More than 200 Extension professionals attended the CenUSA breakout sessions, representing Extension agents from all over the country who are responsible for educational programs in their state. Respondents to session surveys (*n*=46) completed a paired sample post-test to determine their increase in knowledge regarding the topics after the presentations. Topics included:

- ✓ The potential for growing perennial grasses as bioenergy feedstocks.
- ✓ Where to find resources on perennial grasses for bioenergy from the CenUSA.
- ✓ Participants' intentions to use CenUSA resources in bioenergy programs.
- ✓ Participants' intentions to plan new bioenergy programs using resources available from CenUSA.

- **Evaluation Results**

  By comparing knowledge levels 'Before' and 'After' the presentation, results show that after attending the program:

  - ✓ Participants' knowledge significantly increased from low-to-moderate to moderate-to-high regarding the potential for growing perennial grasses as bioenergy feedstocks.
  - ✓ Participants' knowledge significantly increased on where to find resources on perennial grasses for bioenergy from none-to-low to moderate-to-high.
  - ✓ Participants' intentions to both use CenUSA resources and plan new bioenergy programs significantly increased from none-to-low to moderate.
  - ✓ Participants were also asked the extent to which the information in the CenUSA presentation would encourage them to provide renewable energy content in educational programs for their clientele.
    - ➢ 8.9% responded the program offered much encouragement.
    - ➢ 42.2% responded the program offered moderate encouragement.
    - ➢ 35.6% responded the program offered slight.
    - ➢ 13.3% responded they did not think the program offered encouragement.

- Finalized brochure about CenUSA bioenergy grasses.

- Collected information from CenUSA Extension teams and prepared reports
- Continued support for development of CenUSA C6 Youth app, videos, and iBook.
- Met with CenUSA Extension teams to plan and coordinate activities.

3. Explanation of Variance

None.

4. 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.

5. Publications, Presentations, Proposals Submitted

None this quarter.

Objective 10. Commercialization

Sub Objective 10A. Archer-Daniels-Midland

The Commercialization Objective was initiated in project year 4 (2015-2015) to evaluate near and long-term commercialization prospects for products produced from perennial grasses grown on marginal land. It involves two commercial partners, ADM and Renmatix, who are evaluating CenUSA feedstocks in their conversion processes.

1. Planned Activities

- **Low temperature, low pressure conversion of industrial lignin sources to stable intermediates**

  The planned research for the previous quarter was to explore pretreatments other than sodium hydroxide to enable low temperature, low pressure-hydrogenation (LTLP-H) of

Renmatix lignin. While sodium hydroxide pretreatment followed by LTLP-H is an effective pathway to convert lignin into a stable, liquid intermediate, sodium is problematic in upgrading with zeolite catalysts. Alternate pretreatments include calcium hydroxide, ammonium hydroxide, trimethylamine, and acetic acid.

- **Conversion of lignin-derived phenolic monomers to vanillin**

As described in earlier updates, thermochemical depolymerization of lignocellulosic biomass and industrial lignin streams produces high concentrations of phenolic monomers. These phenolic monomers, such as 4-vinylguaiacol (4-VG) have the potential to be upgraded to high-value products and chemicals. The plan for this quarter was to begin studies on biological transformation of 4-VG to vanillin, a molecule with a market value of $12/kg and market size of 20,000 metric tons/year.

2. Actual Accomplishments

- **Low temperature, low pressure conversion of industrial lignin sources to stable intermediates**

As discussed previously, initial attempts to perform LTLP-H for the various lignin streams produced mixed results. ADM's organosolv lignin was soluble in methanol and 1,4-dioxane and preliminary efforts suggested LTLP-H would be successful after process optimization. Renmatix supercritical hydrolysis lignin proved to be more difficult to convert due to larger molecular weight species remaining within this lignin stream. Because the Renmatix lignin did not directly dissolve in any solvents, it was evident that it was not as fully fragmented as the organosolv lignin. This was due to differences in the industrial processes of removing the sugars from the original feedstock.

Previous results showed that sodium hydroxide (NaOH) was an effective pretreatment for Renmatix lignin, as it readily liquefied and became water soluble when hydrogenated at atmospheric pressure and room temperature. However, during the process, some of the sodium hydroxide breaks down and contributes to the liquid product. This can be problematic, as sodium deactivates the cracking function of the zeolite catalyst. Therefore, alternate catalyst types may need to be used in upgrading.

Alternate pretreatments were selected for testing. Calcium hydroxide [Ca(OH)2], ammonium hydroxide (NH_4OH), trimethylamine, and acetic acid were applied to Renmatix lignin. The lignin was then hydrogenated at room temperature and atmospheric pressure. As the results in Table 6 show, none of the alternative pretreatments resulted in liquid yields comparable to that from sodium hydroxide. However, trimethylamine resulted in 65.9% liquid yield on a mass balance of only 79.3%. Further investigation is needed to achieve higher mass balance and determine if liquid yield is higher. Another advantage to trimethylamine is that it does not appear to break down during the pretreatment or hydrogenation steps, and has a boiling point of 89.5° C, suggesting distillation should be an effective means for recovering and recycling the trimethylamine. Additionally, trimethylamine does not demonstrate zeolite catalyst deactivation.

Table 6. Comparison of Renmatix lignin product yield after mild pre-treatment utilizing sodium hydroxide, calcium hydroxide, ammonium hydroxide, triethylamine, and acetic acid, followed by LTLP-H.

Pretreatment	Liquid Product Yield (wt%)	Solid Residue Yield (wt%)	Mass balance (wt%)
Sodium hydroxide	98.1	5.03	103.4
Calcium hydroxide	21.7	78.6	100.3
Ammonium hydroxide	9.34	87.5	96.8
Triethylamine	65.9	13.4	79.3
Acetic acid	5.84	116	121.8

- **Conversion of lignin-derived phenolic monomers to vanillin**

A variety of microorganisms have been reported to produce vanillin from phenolic monomers. We have acquired and characterized several of these that were deemed likely to convert 4-VG to vanillin, including *Pseudomonomas putida KT2440, Bacillus coagulans DSM1* and *Lactobacillus coagulans DSM 20174*. However, at this time no production of vanillin from 4-VG has been observed by these organisms, though we have confirmed our ability to detect vanillin in aqueous samples (data not shown). As opposed to using existing, undercharacterized organisms as our microbial catalyst for vanillin production from 4-VG, we are currently pursuing the genetic modification of standard industrial organisms, such as *E. coli* and *S. cerevisiae,* to enable the 4-VG to vanillin reaction. Specifically, we will be using the *Cso2* enzyme. This *Caulobacter segnis* enzyme was previously expressed and characterized in *E. coli* and showed a high Vmax for the production of vanillin from pure 4-VG. We plan to optimize the activity of this enzyme and characterize its activity on lignin-derived 4-VG in both *E. coli, R. opacus*, and *S. cerevisiae*. Institutional Biosafety approval forms have been approved for this recombinant DNA work.

We will use plasmid vectors to shuttle the *cso2* gene into our selected organisms. The commercial vector pET30b was chosen for *E. coli* modification. Vector pET30b has a kanamycin antibiotic resistance marker and the expression is induced by isopropyl-b-d-thiogalactopyranoside (IPTG) which can be used to screen for *E. coli* colonies that harbor the plasmid and express the gene of interest. We inserted the gene *cso2* codon optimized for *E. coli* into pET30b and verified by a polymerase chain reaction (PCR). Primers (short sequences of DNA which specifically bind to *cso2*) were used in the PCR reaction to amplify only *cso2*. Gel electrophoresis of the PCR product verified that three of six replicates (Colonies 2, 3, and 5 in Fig. 29) harbored the correct plasmid. Next, our plasmid (pET30bcso2) will be transformed into selected host strain *E. coli* BL21 by electroporation. The transformed cells will be subject to a 4-VG fermentation broth to test for growth and vanillin production.

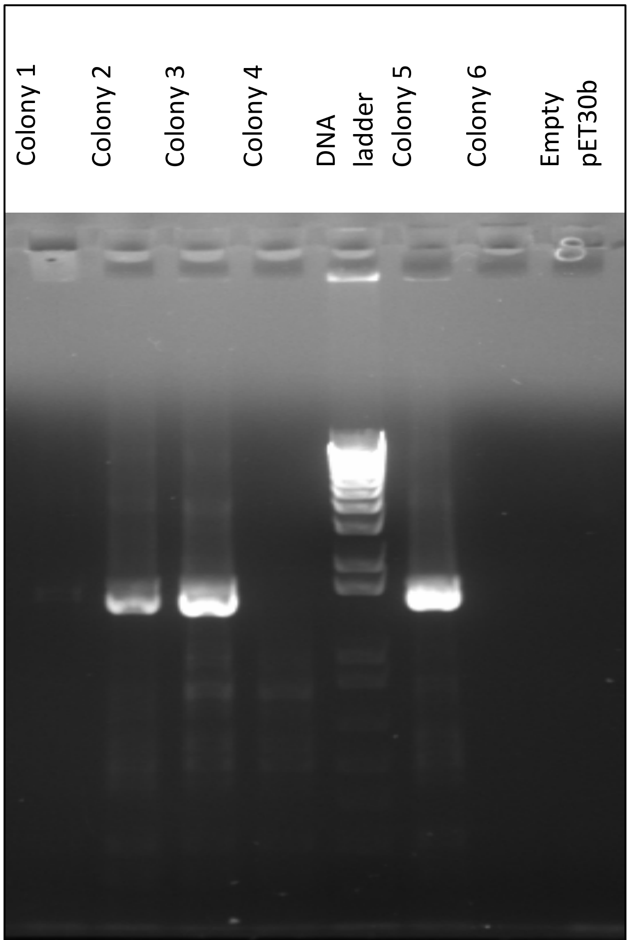


Fig. 29. A gel electrophoresis of the PCR product verifies that colony replicates 2, 3, and 5 harbor a plasmid which contains *cso2*.

3. Explanation of Variance

None noted.

4. Plans for Next Quarter

- Further investigate sodium hydroxide and trimethylamine treatment of lignin followed by LTLP hydrogenation to achieve better mass balances.
- Explore impact of sodium hydroxide and trimethylamine treatments on catalysts and upgrading processes
- Use of plasmid vectors to shuttle *cso2* gene into selected organisms and transform plasmid into selected host strain of E. coli, then subject transformed cells to 4-vinylguaiacol fermentation broth for vanillin production.

Sub-Objective 2. Renmatix

1. Planned Activities

- **Task 10c-2: Bench scale: determine suitability for processing herbaceous biomass with the Plantrose® process.** Bench scale studies of conditions for hemicellulose removal from corn stover and switchgrass using water under subcritical conditions. Bench scale lab tests using a batch Accelerated Solvent Extractor (ASE) system for the screening of conditions and a pilot scale batch reactor (M/K Digester) for testing conditions at a larger process scale. Technical report summarizing results from both lab activities.
- **Task 10c-3.** Pilot-scale testing to determine potential economic feasibility of switchgrass and corn stover conversion into sugars and lignin via Renmatix's Plantrose® technology. The two biomass materials will be processed individually in Renmatix's Bioflex Conversion Unit (BCU) for Hemicellulose and Supercritical Hydrolysis conversion. Xylose and glucose oligomer solutions will be produced and further refined to monomeric sugar solutions. Fermentability testing on xylose solutions to ethanol with common yeast or bacteria will be conducted.

2. Actual Accomplishments

- **Task 10c-1.** A lignin structure study using two-dimensional (2D) NMR spectroscopy was completed. The method allows for relative comparison of different lignin structural subunits between different biomasses. Lignin preparations were isolated from three biomasses, specifically corn stover, switchgrass and big bluestem. Results showed clear structural differences in the lignin preparations among the three biomasses. More quantitative information will be obtained when ^{13}C NMR data are available and can be used for calibration of the 2D NMR numbers.

- **Task 10c-2: Bench scale: determine suitability for processing herbaceous biomass with the Plantrose® process.** A bench-scale, screening study for hemicellulose removal from corn stover and switchgrass by water under sub-critical conditions was completed using a lab batch reactor (ASE). Results showed good hemicellulose conversion and yield to xylose from both biomasses during hot water extractions. Also, a pre-washing step using the same lab batch reactor was tested to remove soluble salts before the hemicellulose hydrolysis (HH) step. This pre-washing process helped increase the sugar yield during the HH process step. A window of temperature and residence time conditions for better yield and conversion was found for the finely ground biomass in the ASE. These ASE results were used as the starting point for work in the pilot batch reactor (M/K Digester). This larger, pilot batch reactor system used biomass of larger size that more closely resembles that which might be used in a commercial scale process; it also included both a pre-washing step and a washing step. The goal of the washing is to simulate the counter-current wash stage in a commercial reactor; during this step soluble sugars trapped within the pores of the solids are further removed. Results from the pilot batch reactor were encouraging showing good xylan yields for both biomasses during water extractions: 60% for switchgrass and 65% for corn stover. These data and gained experience with physical characteristics of the materials will be used for the development of a high level manufacturing process. The high level process will be used to form the basis of preliminary economics in future work.

  Analysis of results from both batch scales, bench and pilot, have been 90% completed. Report drafting has started.

- **Task 10c-3** Both biomasses were run through the Renmatix BCU pilot unit for both hemicellulose and supercritical hydrolysis. Positive results from the pilot plant run on switchgrass were obtained showing both good xylan yield (>65%) and conversion (>75%) during the hemicellulose auto-hydrolysis process. Supercritical hydrolysis of switchgrass cellulose showed also a good conversion level (>85%). Positive results on corn stover have been obtained as well. Xylan yield was >70% and conversion over 80% during the hemicellulose auto-hydrolysis process. Supercritical hydrolysis of corn stover cellulose showed a good conversion level of >75%.

  No technological or operational drawbacks were encountered for either biomass based on the pilot work. Initial, small oligomeric C5 and C6 sugar samples were produced and a lignin crude sample as well.

3. Explanation of Variance

- **Task 10c-1.** The report on structural characterization of lignin by NMR was scheduled to be completed during the project's second quarter. However, as indicated in previous reports, this activity was delayed due to equipment issues in our labs that were eventually resolved. Additionally, lignin ^{13}C-NMR analysis was to be run at an analytical partner but their NMR equipment broke; their equipment was fixed and samples are being analyzed. A 2D NMR study was conducted and completed in order to progress on this activity and the results will be later complemented with results coming from the ^{13}C-NMR study. Final report is expected to be complete in December.

- **Task 10c-2: Bench scale: determine suitability for processing herbaceous biomass with the Plantrose® process.** Lab activities proceeded on schedule. Analysis of data took longer than expected producing a delay in issuing of the second technical report. It is expected to be completed by the end of November.

- **Task 10c-3.** Operation activities on schedule.

4. Plans for Next Quarter

- **Task 10c-1.** Final report on lignin characterization by ^{13}C-NMR will be issued.

- **Task 10c-2: Bench scale: determine suitability for processing herbaceous biomass with the Plantrose® process.** Final report on removal of hemicellulose by water at subcritical conditions on selected biomasses will be issued.

- **Task 10c-3.** Refining of sugar samples and fermentation testing will be completed. Samples of C5 and C6 sugar streams have been requested for testing by Bruce Dien at the USDA ARS. Development of a conceptual manufacturing process and economics for the processing of switchgrass and corn stover will be completed.

5. Publications / Presentations /Proposals Submitted

None.

Objective 10C. USDA-ARS, Lincoln, Nebraska - Alternative Uses for Native Perennial Warm-season Grasses

Nothing of significance to report this quarter.

Exhibit 1

CenUSA Advisory Board Comments
Project Progress: August 2014 - July 2015

Overall this program has been excellent, with advances made in all areas. It has also provided training for a whole new cohort of scientists. It has been a very good and responsive group to work with.

Objective 1. Feedstock Development. This group has achieved a significant advancement, the advisory board learned a lot about crop development. Commercial production of *Liberty* seed is a great step forward. It is good to see continued development of new varieties especially in the areas of disease and insect resistance. The industry will need to multiple varieties to continue to grow. With the realization that fuel may not be the initial path to commercialization it would be good to develop marker assisted breeding techniques that will speed the delivery of industrially interesting traits beyond yield. These would include: high lignin, high cellulose or high hemicellulose for some industrial applications. Forage traits might also be targeted. The board and the stakeholders will be interested in productive plant life – how many years will each variety will produce before replacement should be considered. How difficult is it to replace today's varieties? Are they environmental impacts to reestablishment?

There was some concern from last year report on the availability of *Liberty* seed to growers, this was not discussed this year, has this been resolved. When do you think *Liberty* performance will have been tested in enough locations for field performance assurances?

Objective 2. Sustainable Feedstock Production. Continue the work on test plots so that as many years of data as possible are available on the best practices. Interesting results on biochar plots. Getting more of the information out on the comparisons of different grasses and their traits would be useful. Consider providing links of this to the Extension objective. The flooding results this year will be very interesting. The pictures showing grasses surviving flood conditions bodes well for HEL land and filter strip uses. Jeff mentioned using a portfolio of varieties to overcome weather issue – will need Extension to create tools for good advice plus understanding any cost implication. Initially getting a farm to plant one variety will be good, as these crops become more valuable, then portfolios make sense. In the interest of clarity should Jeff change the name of “native prairie” to native vegetation planting. The plots planted at Purdue aren’t really native prairie.

Objective 3. Feedstock Logistics. Very sobering numbers of $60 a dry ton for ash free biomass logistics and a total cost of ~100 dollars per dry ton without profit will be useful for everyone. It may be necessary to look outside the box for solutions that can take cost out of this system. Good information is being providing on drying and solids losses due to rain events. If only solubles are being lost, this may not be catastrophic and for those industrial plants not interested in the solubles could actually decrease their waste treatment costs. Good conversation and research on the reality of supply chain costs. Over the years we have seen more people becoming aware that residue is not trash, and equipment/operation is not cheap. As Kevin pointed out, there are no profits built into numbers, so make sure this is very clear in any publications. We would like to see a comparison of your internal cost of operation to current custom harvest rates – are custom harvester not profitable?

Objective 4. System Performance. Very interesting and sure to be controversial report. It is probably out of the purview of the industrial advisory board since any comments would automatically be assumed to be biased. This report will probably have the most lasting effect on public opinion of all the different objective reports.

Maps are deceiving with such a small scale and it appears that the scale was used for visual impact. We also believe that in reality, energy grasses will be grown many places outside of the upper Midwest – so all the impact shown by replacing corn acres may not be real. While the results shown were not very positive for any biobased fuel it may bring to light areas where we can do better. As with all modelling papers, the assumptions can create a positive or negative. The board would like to know if there was a consensus on the assumption made in this model.

This group needs to provide some balance in their story, green energy plants like perennial grasses have many environmental benefits for water quality, soil health, soil protection. To focus the model on air quality comparing corn ethanol to gasoline is a narrow focus for a system performance. Surely cellulosic ethanol and pyrolysis oil based products can compare more favorable to all environmental factors than petroleum based products for air quality.

As a whole the board was not provided with enough information about the assumptions made in the model to endorse the findings in the report. We should be careful with the use of this info in a general public forum. The majority don’t understand models, tend to jump to conclusions, and take things out of context. This information is too easily misinterpreted without context from Jason and the other PIs.

Objective 5. Feedstock Conversion. Unfortunately for many people that have invested time and effort into biofuel, the current economic environment is not positive for deploying new biofuels. It is good to see some of the work on catalytic pyrolysis and this needs to continue so that the knowledge is available when conditions change again. The biochar seems to be moving along. It needs a high value co-product to become cost effective for large acreage application.

There are still some feedstock cost alignment issues - $71/ton vs. $100+. Great that you are investigating all sorts of end products and how energy grass can supply all types of renewables. There was a photo of “granola” and pellets – don’t know what state char leaves the system – what are there additional costs to make pellets/granola

Objective 6. Markets and Distribution. This was a useful discussion of how perennial grasses will actually be enabled in a crop residue collection environment. This fits very well with the CenUSA model of displacing crops on fragile landscapes.

The presentation mentions POET and relates that to “farmer supply chain”. One of the board members works with POET extensively and understand the linkage, but in reality, they have a diverse supply chain; farmer, custom and land contracts. Presentation also assumes that the current companies are harvesting in a sustainable manner – a bit risky since many different practices have been seen in the field. Presentation also assumes farmer and contract harvest process yields same tonnage per acre – also false. Current commercial information would indicate some operation yields at least twice as much per acre (1 dry ton avg. vs. 2+ dry ton/acre). ISU has documented that the POET approach to stover harvest is sustainable, has the same been done for other operators’ approaches? It would therefore be good to have this presentation actually state the sustainable harvest method used in the model rather than quote companies’ names.

In this final year this group may want to highlight the opportunities of high value chemicals and high value products that can be developed from perennial grasses versus just focusing on energy. Hopefully such a study might influence policy makers.

Objective 7. Health and Safety. It is good to know that the switchgrass production will be less hazardous than the corn. It would be good in the last year to have some assessment of the unique hazards of the quilt work deployment of perennial crops in corn/soybean production environment that achieves both a harvestable crop and a more sustainable row crop production system. Is bale transport included in safety analysis? Many farms will transport bales also. Loading bales, securing bales, unstrapping and unloading…

Objective 8. Education. Raj has done a great job. We would be interested in whatever exit interview statistics are available on what the students thought were the positives and negatives of the program. The education modules look very interesting.

Who is approving content? How someone words sentences, photos used, statements used out of context – all have consequences. If not already in place we would encourage all documents, web page content, Blades articles, and etc. have a documented sign off by people who are quoted or content experts.

The poster presentations were excellent as usual.

Objective 9. Outreach and Extension. Lots of outreach to farmers, organic gardeners and grade school and high school programs. Informing interested parties as to what the current and future markets might be will be important.

In the current era videos are a great tool to reach land owners. The pluses of energy grasses with tiles sounds great. Are there any known issues with these grasses strong root systems and tiles?

Objective 10. Commercialization. Progress being made. Still no current path directly to building plants although information being produced will hopefully be needed to attract commercial investment.

Great addition to the project. We are really excited that this was added and what has been produced. We think this will end up as one of the biggest achievements of the project since it really is where the tire meets the road.

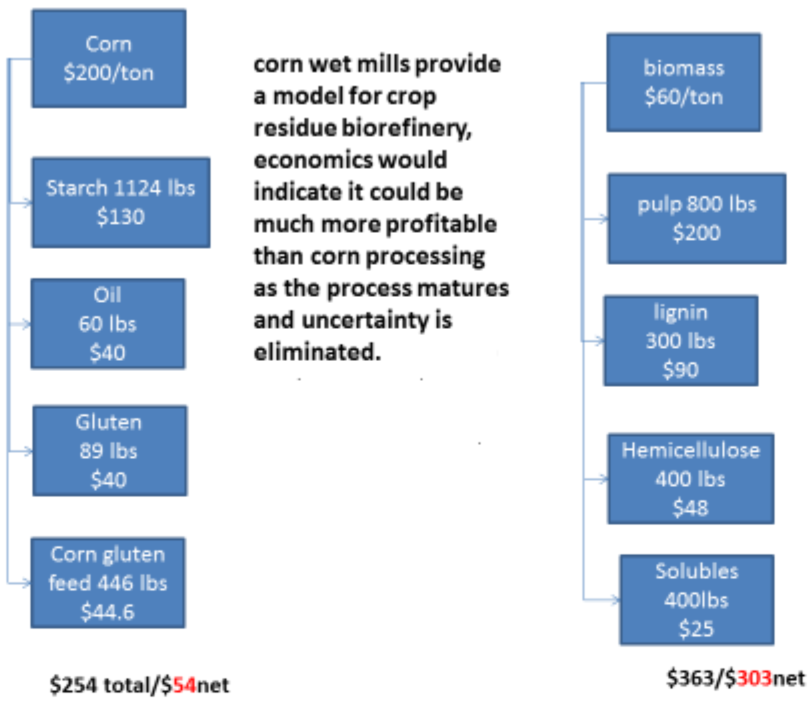
Thanks to those companies/people assisting.

Other Advisory Board Comments

The advisory board wants to re-affirm that in this last year the latest information on yields, inputs, and input costs be used across all objectives for reports and projections. Finally, we all currently feel that forage and chemical production are the most likely paths forward under current economics and not fuel. The diagram below comparing corn wet milling and biomass fractionation might provide some inspiration for future development. May want to assume the biomass will cost $100/ton. The diagram indicates that Corn wet milling has about $54 dollars of margin that has to cover costs of processing and any profit to be made. At $100-dollar biomass a biomass fractionating plant has $260 dollars to cover processing and profit. This should be possible.

To speed the development of energy crop what can currently be done to develop, organize, and implement smaller capitalization projects. Landowners will produce the product (perennial grasses) if economical and marketable to a project for their area. Production of perennial grasses is not an option if the landowners has no need for a forage crop.

Ken Vogel's switchgrass history lesson was great. Should make that available to the public. I hope the USDA and other world ag statistic groups begin tracking energy crop acres/hectares. Thank you for the opportunity to serve on the advisory board. It has been a great experience and have enjoyed meeting many experts in their respective fields. Great job!!



Objective 1, 2, 3, 5 and 6. Efforts to advance perennial yields and the progress demonstrated by Liberty, is very encouraging. It is also very encouraging to see a few pictures that include large, high-yield biomass stands of Miscanthus and energy crops in the presentations made by Mike and Jeff. That said, feedstock costs are still very challenging, especially when considering current SG yield potentials and feedstock harvest/transport systems typically deployed in the upper Midwest.

As someone ultimately interested in developing and deploying biomass conversion technologies, it would be very helpful if a number of potential "transition pathways" can be identified. The primary goal would be to identify likely high-biomass production crops (including annual energy crops) and high volume harvest/transport systems, and incorporate these potential production scenarios into preliminary high-level techno-economic analyses … is it even possible to get to $60/ton when using high volume biomass crops and harvest/transport systems?

Although our ultimate goal is to get native grass perennials and marginal land in to production without competing with food production, if likely and economical transition pathways can be identified they can be utilized to supply and support the development of our first advanced biomass conversion facilities (with no significant impact to the region's overall food production).

Utilizing "transition" biomass production pathways for our first conversion facilities will benefit current breeding programs by allowing more time to develop much higher yielding perennials, and it will give the engineers more time to further adapt and refine high-volume biomass harvest and transport systems. It may also make sense for these first advanced conversion facilities to co-locate (in more southern states such as Missouri and Kansas) at existing agro-industrial facilities, and limit facility size to manageable and realistic scales such as 150 to 300 ton/day.

OBJECTIVE 4 Overview of Issues Surrounding the Assumptions

The model developed as part of Objective 4 (System Performance) is an exciting tool and looks to be an excellent foundation for many more significant and important studies in Life Cycle air quality impacts and assessments. The recently published results presented at this year's annual meeting, clearly highlight the environmental impacts and very significant challenges that are associated with modern US agricultural practices, especially those related to fossil-fuel derived fertilizers, their inefficient applications and nitrification emissions. What is counter intuitive, however, is the primary conclusion that the authors promote and present to the general public, i.e. increasing the use of gasoline has less impact on air quality and less impact on human mortality rates, when compared an equivalent increase use of corn ethanol as a national transportation fuel. In addition to being counter intuitive, it has been very disappointing to see the numerous media outlets claiming similar headlines as "U of M Study Finds Ethanol Worse for Air Quality than Gasoline". These counter intuitive and disappointing conclusions are difficult for me to imagine, largely because I've had the good fortune to be able to work closely with the ethanol industry's fuel and engine performance specialists and see first-hand their recent published research efforts that clearly demonstrate ethanol's significant benefit as a means to reduce vehicular emissions when splash blended with consumer gasoline.

As a direct employee of the ethanol industry, with renewable energy related interests in New Product Development and R&D (including many 1000s of hours building complex process simulations), the following (bias) commentary is based on a detailed review of the recent publication "Life cycle air quality impacts of conventional and alternative light-duty transportation in the United States" and related materials.

It is important to note that the study only looks at an incremental increase in PM2.5 and O3 over continental US for the various light-duty transportation scenarios, and therefore it excludes human health, emissions and general environmental impacts related to the exploitation of international sources of crude oil and petroleum products. Environmental impacts from sources such as Canadian tar sands are excluded. To account for the "only US" scope, GREET model default emissions factors related to conventional oil extraction and supply are adjusted to discount international emissions. The study also excludes the environment, health and GHG impacts from frequent large and small oil spills and pipeline ruptures. Leakage and large spills from deep and shallow ocean wells and their impacts to fisheries and human health are excluded. Conventional oil field volatile hydrocarbon leakage is excluded. Hydrocarbon leakage and water contamination form oil and NG extraction via hydraulic fracturing is excluded. Emissions and health impacts from frequent oil train derailments/explosions/uncontrollable fires within Canada and continental US are excluded. In addition to the above-mentioned, also excluded are the environmental and human health impacts associated with maintaining, both in the US and abroad, the very large infrastructure, human resources, energy use and emissions, needed to address very challenging and complex international geopolitical situations and strategic interests related to the safe, secure and continuous delivery of crude oil from highly volatile regions of the world.

With respect to the model and assumptions, there are a number of important parameters that impact the study's results. These include the assumptions used to estimate vehicle emissions, which are based on GREET 2020 estimates and EPA models. Those assumptions, especially GREET 2020, significantly bias results in favor of a more substantial impact from corn ethanol's agricultural practices. Projected GREET PM2.5 vehicle emissions for the year 2020 are approximately 64% lower than GREET PM2.5 estimates for 2010. The study also relies on questionable EPA estimates for emissions from E10 vehicles, which suggest that E10 vehicles have higher emissions than E0 gasoline blends. Recent studies conclusively show that vehicle emissions are significantly reduced (not increasing as currently predicted by EPA models), when ethanol is splash blended with E0 consumer gasoline – the higher the splash blend percentage of ethanol, the greater the reduction in emissions.

There is also a significant and growing body of recent and ongoing research related to human health and vehicle emissions. Those studies highlight the fact that not all PM2.5 particles have equal impacts to human health. Although I'm not a fan of hanging around dusty corn fields during harvest, in my personal opinion, I'd much rather live next to a Midwest corn field (or for that matter next to a well-managed and properly designed industrial emission control system) then live next to urban highway on-off ramps where highly toxic ultra-fine (UF) particulate matter (< 0.1 micron) are released at very high levels. Ultra-Fine particles can essentially remain airborne for very long periods. UF particulates largely result from the incomplete combustion of aromatic compounds that can comprise up to 30+% of consumer gasoline blends. A typically consumer blend of gasoline can easily contain more than 300+ identifiable compounds, with a very significant fraction that includes aromatic compounds such as benzene, toluene, xylene, and up to large complex multi-ringed aromatic compounds. UF formation is especially significant during rapid vehicle acceleration/deceleration, which is common at urban settings near street intersections and highway on-off ramps. There is a growing body of research suggesting UF particles are having an enormous negative impact to human health.

From a strictly academic point of view, most of the above mentioned exclusions made by the authors make a lot of sense, since their Life Cycle assessment has a very narrow scope of study and only considers impacts to air quality (PM2.5 and O3) within continental US. However, with respect to the true Life Cycle impacts to human health and overall environmental impacts of worldwide extraction and refining of crude oil and fossil fuels in general, it is my personal and biased opinion, that it would have been very valuable to readership and appropriate for the study's authors (including during national television interviews and congressional hearings) to put more effort into explicitly describing exclusions, the model's limitations and its very narrow scope of study, so that the general public and special interest groups cannot briefly review the study's abstract and come away with the misleading and generalized conclusions such as, "U of M Study Finds Ethanol Worse for Air Quality than Gasoline".

Finally, the new tools and modeling approach the authors of Objective 4 have developed are very substantial and exciting. It is my hope that future modeling efforts will be able to broaden scope and take a more substantial, comprehensive and realistic Life Cycle look at the environment impacts of corn ethanol at various splash blend rates and compared them with petroleum derived fuels (and other alternatives). Including an emphasis at building on the GREET model's conventional petroleum related default pathways and adding in Life Cycle impact and estimates that better represent the many indirect and direct environment impacts associated with a more inclusive Life Cycle Assessment of petroleum and natural gas exploitation.

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

Exhibit 2

Crops for
Sustainable Energy

Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts

Perennial Grass Benefits

Switchgrass, big bluestem, and warm season grassland mixtures provide numerous benefits. Existing field equipment, herbicides, and cultivar improvement promote rapid establishment in the planting year. These grasses typically produce a harvestable yield after frost in the planting year and are near full production in the year after planting if moisture is adequate. Typical baled yield at the field scale after establishment exceeds 5 tons per acre in areas east of the arid section of the country. These grasses can be productive for 10 years or longer with good management.

- Provides multiple uses for bioenergy, grazing, hay, and wildlife
- Productive during drought; can withstand wet conditions
- Reduces soil erosion; increases nutrient cycling
- Stores about one ton of carbon per acre in the soil each year
- Requires less fertilizer and herbicide each year than row crops

Key Management Strategies

Stand Establishment—Switchgrass is productive in areas suitable for dryland corn; it grows best in warm conditions. Plant 2 to 3 weeks before or after optimum corn planting date for your location. Use certified seed. No fertilizer nitrogen (N) should be used the first year.

Seeding—Develop seedbed that promotes good seed-to-soil contact. Use properly calibrated grassland drill; plant at a seeding rate of 30 to 40 pure live seed (PLS) per square foot depending on your latitude.

Controlling Weeds—Weed competition is the most common challenge in managing weeds during establishment. Herbicides and mowing both can be used.

Controlling Insects—Insect control is important, especially in grasses grown for seed. Early detection and control are essential.

Controlling Diseases—Disease control is critical in minimizing yield and quality losses. It is achieved by planting resistant cultivars, using clean seed, fungicide seed treatments, scouting for early detection, and foliar fungicide application.

Harvest—Harvest once each year after killing frost to a 4" stubble. Can be harvested with typical haying equipment.

Storage—Dry the material to less than 20% moisture before baling. Square bales should be covered to maintain physical and chemical properties; covering is optional for round bales.

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Perennial Grass Options for the Midwest

Switchgrass

Switchgrass is native to the grasslands of North America east of the Rocky Mountains. "Liberty" is the first bioenergy-specific switchgrass cultivar developed for the Great Plains and Midwest.

New cultivars have been developed that show significant improvement in yield and performance.

Immediately after planting, apply quinclorac-based herbicides such as FacetL® at 32 ounces per acre to control grassy weeds. Do not apply imazapic-based herbicides to newly seeded switchgrass since switchgrass seedlings do not tolerate imazapic.*

Big Bluestem

Big bluestem was the dominant grass in the tallgrass prairie. "Bonanza" and "Goldmine" are two cultivars that have proven to be productive and persistent throughout the Corn Belt. Consult Extension, NRCS, or other professionals for cultivar options in your area to meet your specific needs.

In addition to excellent biomass production, these cultivars have produced average daily gains of 2.8 pounds/head/day when grazed by yearling steers.

Immediately after planting, apply imazapic-based herbicides such as Plateau® at 4 ounces per acre to control grassy weeds.*

Warm-season Grass Mixture

This mixture includes big bluestem, indiangrass, and sideoats grama.

These mixed-species stands increase species diversity and provide more desirable wildlife habitat than single-species stands. Sideoats grama serves as a nurse crop in the establishment year, improving the yield potential in the seeding year.

This mixture is established and managed using the same approach as for big bluestem.

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Always read and follow label instructions for specific herbicides. Herbicides are labeled for specific use, but they are not labeled in all states.

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Using Perennial Grasses in Cattle Operations

- Begin grazing in early June to take advantage of quality forage.
- Harvest hay around the 1st of August to optimize yield and quality.
- Rest pastures 30 to 45 days before first killing frost to promote quality stands.
- Pastures can be grazed during winter but will require protein supplementation.
- Resources are available at http://www.ianrpubs.unl.edu/epublic/live/g1908/build/g1908.pdf.

LINK TO RESOURCES

For these and many other resources dealing with perennial grass production, go to http://www.extension.org/pages/72584.

- Switchgrass Establishment and Weed Control
- Planting and Managing Switchgrass as a Biomass Energy Crop
- Control Weeds in Switchgrass (Panicum virgatum L.) Grown for Biomass
- Optimizing Harvest Logistics of Perennial Grasses Used for Biofuel
- Biofuel Quality Improved by Delaying Harvest of Perennial Grass

Keys to reliably establishing warm-season grasses:

- Plant high-quality certified seed of adapted cultivars. Cheap seed is not a bargain.
- Develop a firm seedbed. No-till planting into soybean stubble provides an excellent seed bed.
- Use a well-calibrated grassland drill to dispense at least 30 pure live seed (PLS) per square foot.
- Plant within 2 to 3 weeks of the recommended corn planting date in your area.
- Plant seeds ¼" to ½" deep. Planting deeper often results in poor establishment.
- Control weeds early with pre-emergent herbicides for annual grassy weeds and post-emergent herbicides for broadleaf weeds.
- Do not apply nitrogen (N) fertilizer in the planting year.

Keys to successfully managing established stands:

- After the year of establishment, apply N in late April at 8 to 10 pounds of actual N per ton of expected yield.
- Determine if broadleaf weeds are present early and control with 2,4-D. Broadleaf weed control typically is needed only once every 3 or 4 years after successful establishment.
- Harvest once each year about 2 weeks after the first killing frost.
- Harvest at a 4" stubble height with commercially available haying equipment.
- Wrap round bales with 2 layers of net-wrap to reduce storage losses. Covering square bales during storage reduces dry matter loss and maintains feedstock quality.

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USDA United States Department of Agriculture — National Institute of Food and Agriculture

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

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Exhibit 3

THIRD ANNUAL • October 21, 2015

National Bioenergy Day

Celebrating Nature's Energy Source

*****MEDIA ADVISORY*****

What:
Wednesday, October 21, marks the Third Annual National Bioenergy Day, with nearly 60 organizations participating in the United States and Canada. Iowa State University is participating in this historic event to demonstrate the many benefits that bioenergy provides on the local level, including at Iowa State University and in the state of Iowa.

We hope you will be able to attend our event, which aims to educate Iowa State's 36,000+ students about the many research, educational, extracurricular, and career opportunities related to bioenergy at Iowa State as well as the state of Iowa. It will feature exhibits and activities from more than 10 organizations. See www.biorenew.iastate.edu/bioenergyday

When:
Noon to 4:00 p.m. on Wednesday, October 21

Where:
Iowa State University
Sukup Atrium, Biorenewables Complex, Ames, IA

Who:
Iowa State University. Host organizations are the Bioeconomy Institute, CenUSA Bioenergy, and Iowa NSF EPSCoR.

Contact:
Robert Mills, Bioeconomy Institute, Iowa State University, rmills@iastate.edu or 515-294-4459.

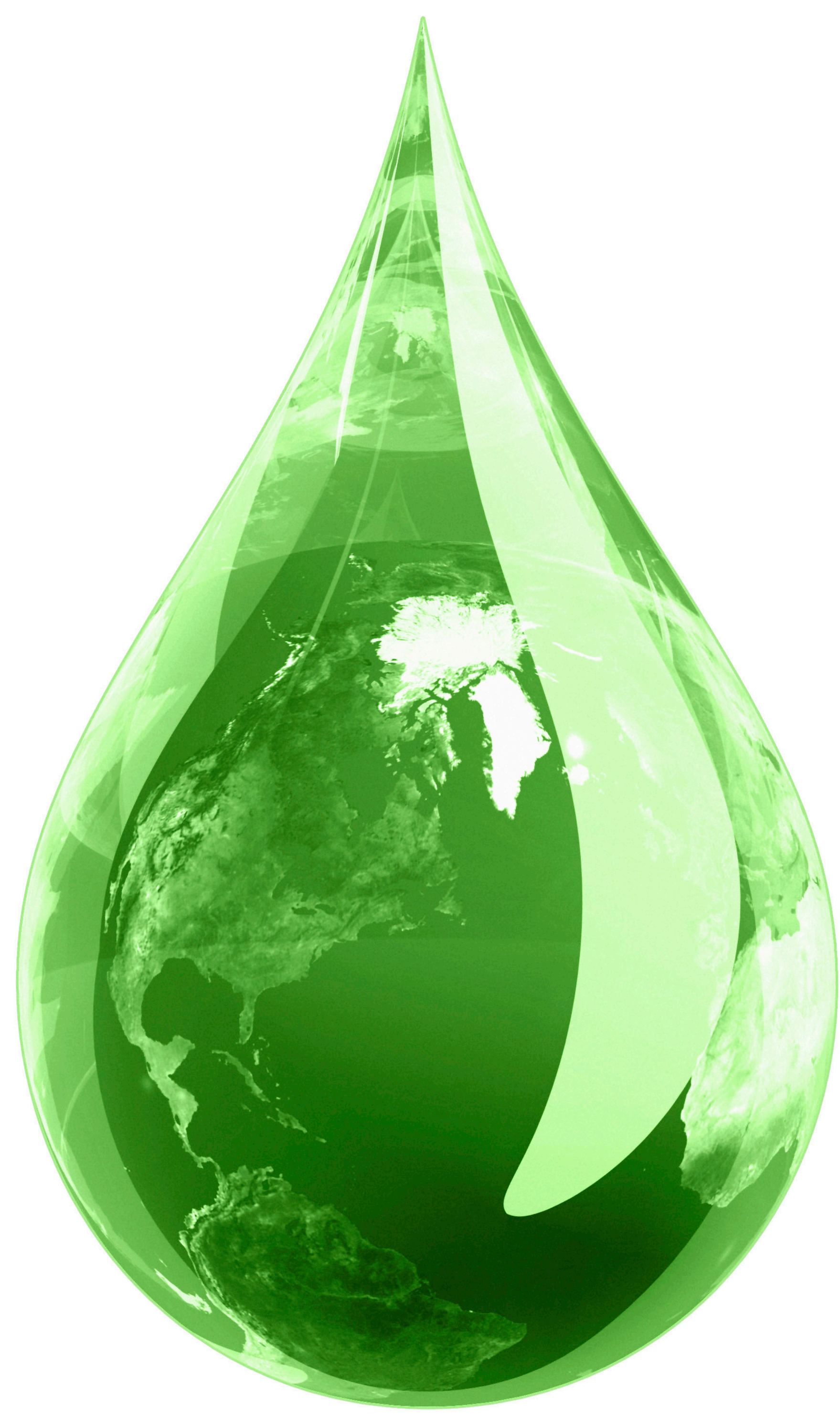
For more information on National Bioenergy Day activities across the country, please contact Carrie Annand at carrie@usabiomass.org or 703-506-3391.

BIOMASS POWER ASSOCIATION · U.S. Industrial Pellet Association USIPA www.theusipa.org · Pellet Fuels Institute · Plum Creek · BTEC Biomass Thermal Energy Council · Forest Service U.S. Department of Agriculture · U.S. Department of Energy | Energy Efficiency & Renewable Energy · Bioenergy Technologies Office

THIRD ANNUAL • October 21, 2015

National Bioenergy Day

Celebrating Nature's Energy Source



TODAY

Noon to 4:00 pm
Sukup Atrium

IOWA EPSCoR

IOWA STATE UNIVERSITY
Bioeconomy Institute

cenusa bioenergy

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