cenusa bioenergy

Quarterly Progress Report

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

May 2013

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

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NOTICE

This quarterly 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)

Quarterly Report: February 1, 2013 – April 30, 2013

PROJECT ADMINISTRATION

- **Project Organization and Governance Accomplishments**

  Ken Moore (Professor, Iowa State University) continues as the CenUSA Bioenergy Project Director. Anne Kinzel (Chief Operating Officer) and Val Evans (Financial Manager) handle project coordination, communication, and data sharing among the project's research partners (Purdue University, University of Wisconsin, Madison, University of Minnesota, Twin Cities, University of Nebraska, Lincoln, University of Illinois, Champaign, University of Vermont-Burlington, and the USDA Agricultural Research Service). Kinzel is also responsible for the day-to-day project management including the preparation of quarterly and annual progress reports, meetings, and maintenance of the project's public face (website/social media outlets). Evans continues to be responsible for all project financial activities, including the development and implementation of administrative policies and procedures and the management of subcontracts with the projects research partners to ensure effective financial operation and oversight of the project. In addition, Evans has assumed responsibility for coordinating planning of the 2013 CenUSA Annual Meeting with Iowa State University's Conference Planning Services and host Jeff Volenec (Purdue University).

  As we enter CenUSA's third year each of our nine CenUSA objectives is showing satisfactory progress in meeting CenUSA's deliverables schedule. This quarter has seen a number of exciting project governance activities take place.

- **Featured Third Quarter Activities**

  - **Project Reapplication – Year 3**. The CenUSA original award terms and conditions (August 2011) require us to submit a separate application for Project Years 3, 4 and 5. Given the size and the multi-discipline and multi-institution nature of the project this was not an inconsequential endeavor. Each of the project's nice separate objectives participated in preparing the required materials. While the task did take time it also allowed us to make a mid-project assessment and measure our accomplishments relative to the project's deliverables schedule. This review confirms that much has been accomplished and that we remain on track to complete our objectives by the end of the fifth year.

  - **Delivering Feedstock to Industry**. At the December 2012 *Roadmap to Commercialize Thermochemical Biofuels and Bio-Processing in the Midwest* workshop we made agreements with industry partners to provide them with feedstock in exchange for a commitment to sharing data from their conversion process. The arrangements for the types of feedstock desired were completed and we have been delivering the feedstocks and will continue to do so into early in the fourth quarter of this year, presumably in May and June 2013.[1]

- **2013 CenUSA Annual Meeting**. All preparations for the 2013 CenUSA Annual Meeting (July 30 – August 2, 2013) hosted by Jeff Volenec and Purdue University are on track. We have an excellent agenda (See Exhibit 1) and to date registration has been very good. We anticipate that all objectives will be well represented as will the project's Advisory Board. We have also invited a number of industry professionals who attended the December workshop as well as the project directors of the other NIFA-CAP projects. The NIFA-CAP project directors will be participating in a panel to educate our CAP collaborators on the status of our fellow CAP grantees. As at our two previous annual meetings our Advisory Board will also be providing extensive feedback in the form of a panel discussion and followed up with a written comment report.[2]

- **Environmental Interest Group Workshop**. CenUSA will host a workshop in Minneapolis, Minnesota for environmental interest groups. The meeting is tentatively scheduled for the 23-25th of September 2013. CenUSA CoPd Jason Hill (System Performance Metrics, Data Collection, Modeling Analysis, and Tools) and Jill Euken (CoPd, Extension and Outreach) will lead this effort. The meeting will be jointly held with the Mississippi River Basin Watershed Nutrient Taskforce (http://water.epa.gov/type/watersheds/named/msbasin/index.cfm).

  Hill and Euken have applied for a USDA-NIFA conference grant to support the event. This meeting was a direct outcome from discussions that took place at the CenUSA Bioenergy mid –year meeting that took place immediately following the Commercialization Workshop.

- **Advisory Board**

  The Advisory Board continues to provide valuable feedback and advice to the research team. Advisory Board members have been attending the new monthly research seminars. The Advisory Board will also be attending the 2013 Annual Meeting. Early indications indicate there will be an excellent Board turnout at the Annual Meeting.

- **Coordination, Collaboration, and Communication**

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[1] The workshop was held December 11-12, 2012 at Iowa State University in Ames, Iowa. A full description of the workshop has been provided in the second quarter report.
[2] As we have done in previous project years we will hold a special online meeting with the Advisory Board and the project leadership team to discuss the Advisory Board's written comments.

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

- **Objective and Team Meetings.** All nine CenUSA Objectives continue to participate in scheduled and ad hoc meetings using the CenUSA Adobe Connect meeting room or in face-to-face meetings. The five Extension and Outreach Objective teams also meet via Adobe Connect or face-to-face gatherings.[3]

- **Communication Platforms.** CenUSA continues to focus on expanding the quality and sophistication of the CenUSA website (www.cenusa.iastate.edu) and other social media outlets. Our website (http://www.cenusa.iastate.edu) has been upgraded and continues to provide an excellent public presence for the project.

- **Webinars/Videos**. Our project webinars and videos are disseminated via three separate sites to provide multiple outlets to view CenUSA-webinars and videos: 1) the CenUSA website, 2) a CenUSA Bioenergy "YouTube Channel" (www.youtube.com/user/CenusaBioenergy) and 3) a CenUSA Bioenergy Vimeo site (https://vimeo.com/cenusabioenergy) to provide an additional outlet to view CenUSA webinars and videos.

  We added two videos to our sites this quarter:

  - ✓ *2013 Switchgrass Planting Practices for Stand Establishment.*
  - ✓ *2013 Thermochemical Conversion of Biomass to Drop- in Biofuels*

- **Financial Matters.** The Administrative Team continues to monitor all project budgets and subcontracts to ensure adherence to all sponsor budgeting rules and requirements.

- **Program Matters.** We will continue to focus on project coordination, communication, meetings and data sharing across Objectives, and on reaching the revised timelines milestones.

[3] The teams are Broader Public/Master Gardener/Youth Programs, Economics and Decision Tools, Evaluation/Administration, Extension Staff Training/eXtension, Health and Safety, and Producer Research Plots/Perennial Grass. For more information see www.cenusa.iastate.edu/Outreach.

Germplasm to Harvest

Objective 1. Feedstock Development

Feedstock Development focuses on developing perennial grass cultivars and hybrids that can be grown on marginal cropland in the Central United States for the production of biomass for energy. In 2012, the focus was on the establishment of new breeding and evaluation trials.

1. **Significant Accomplishments Summary**

- **Publications**

  - ✓ One journal paper on switchgrass selection criteria for biomass yield was accepted for publication in *Crop Science* (Mike Casler – ARS Madison): Price, D.L. and M.D. Casler. 2013. Predictive relationships between plant morphological traits and biomass yield in switchgrass. *Crop Sci*. (in press). Summary**:** Switchgrass is undergoing transformation to become a perennial bioenergy crop. Breeding for increased biomass yield per acre is a significant component of this transformation. Because most switchgrass breeding is done in large nurseries containing tens of thousands of plants that are visually evaluated under relatively non-competitive conditions, breeding for biomass yield is relatively inefficient. This research showed that tillering (spreading) traits are typically the most important for predicting biomass yield of plants grown under non-competitive conditions, but that plant height and leaf area traits are more important for plants grown under real-world competitive conditions. These results will help to refine the objectives of switchgrass breeding programs, improving their efficiency, and increasing the rate of progress toward higher yielding varieties.

  - ✓ Two journal papers on inheritance of secondary traits affecting yield in switchgrass have been submitted for publication and are currently in journal review (M. Casler, ARS-Madison): Price, D.L. and M.D. Casler. 2013. Inheritance of secondary morphological traits for among-and-within-family selection in upland tetraploid switchgrass. *Crop Sci.* (in review). Summary: Efforts to increase the rate of progress for increasing biomass yield of switchgrass are focusing on an increased emphasis of morphological traits related to yield, including flowering time, plant height, and number of stems. Research demonstrated that each of these traits has a positive heritability value, indicating that there is significant genetic variation that can be utilized in a breeding program. Because flowering time had a very high heritability value, results suggested that this trait be given the greatest emphasis to select the best plants within the best families. These results will be of direct value to switchgrass breeding programs with improvement in biomass yield as a major goal.

- ✓ Price, D.L. and M.D. Casler. 2013. Divergent selection for secondary traits in upland tetraploid switchgrass and effects on sward biomass yield. BioEnergy Res. (in review). **Summary:** Efforts to increase the rate of progress for increasing biomass yield of switchgrass are emphasizing morphological traits related to yield, including flowering time, plant height, and number of stems. This study was conducted to validate predictions made in two previous studies that selection for increased plant height, increased number of stems, and later flowering would be effective mechanisms for increasing biomass yield of switchgrass. Contrary to expectations, selection for taller plants or plants with more stems failed to increase biomass yield of the progeny, despite evaluation of progeny at five locations. However, selection for later flowering was highly effective, resulting in a 25% difference in biomass yield between early and late-flowering progeny. These results confirm previous results and expectations that switchgrass for biomass production in the northern USA should be moved toward later flowering varieties. These results will have direct impact on breeding programs, agronomy research programs, and outreach programs that serve the biomass and biofuel industry.

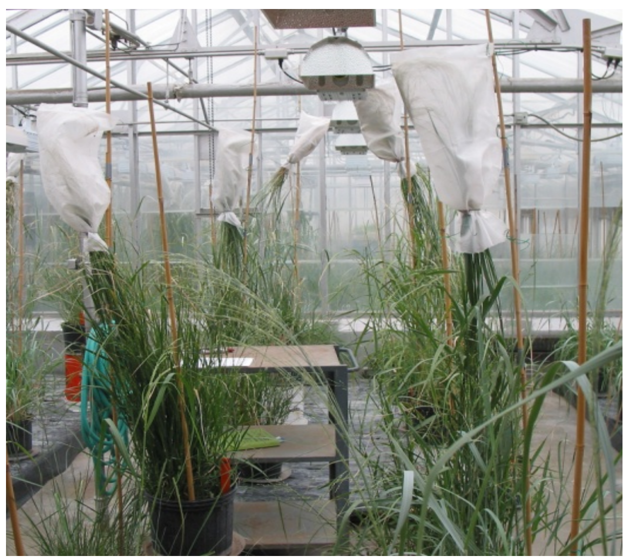

Figure 1. Switchgrass Crossing

- **New Switchgrass Crossing Procedure**

  - ✓ A new switchgrass crossing procedure was developed and evaluated for improving seed yield from matings of individual plants in the greenhouse (Ken Vogel, ARS-Lincoln). The crossing in the greenhouse involved bagging panicles of plants from two different populations that were flowering at the same time. The panicles were bagged using bags made of polyester material that had mesh openings of 40 microns. Switchgrass pollen has a diameter of 45 to 50 microns. Because switchgrass is self-incompatible, the crosses can be made without emasculation. Greenhouse day length has to be manipulated for plants with maturity differences to synchronize flowering. The micro-fiber bags resulted in much higher seed set than paper pollination bags used previously. Micro-fiber bags were made at the Lincoln with purchased fabric using textile glues.

Bioenergy Switchgrass Release

- Liberty currently in release process
- Progeny of hybrid Kanlow x Summer plants were random mated and selected for winter survival, high yield & low stem lignin

Mead, NE	Tons/acre
Liberty	8.1
Shawnee	5.6
DeKalb, IL	**Tons/acre**
Liberty	7.3
Shawnee	5.7

Figure 2. Liberty Switchgrass in release process. Yield data summarized over three production years from multi-location trials

- **Breeding for Biomass Yield in Switchgrass**.
  - ✓ **Integrated Project Impact**

    Seed of the experimental strain that is now being released as Liberty was used to establish the systems plots in Objective 2. *Sustainable Feedstock Production Systems* studies in 2012.

2. Planned Activities

- **Breeding and Genetics – ARS-Lincoln, Nebraska** (Ken Vogel)
  - ✓ Complete greenhouse crosses, clean and process seed from crosses.
  - ✓ Complete grinding of 2012 biomass samples. Complete 75% of NIRS scans. Complete NIRS prediction of samples from selection nurseries scheduled for completion in 2013.
  - ✓ Summarize first biomass mineral analysis study comparing methods and laboratories.
  - ✓ Complete early spring work on field nurseries.
  - ✓ Complete planned purchase of new NIRS unit and have laboratory technicians trained in its use.
- **Breeding and Genetics – ARS-Madison, Wisconsin** (Mike Casler**)**
  - ✓ Complete establishment of 40K seedlings of switchgrass and big bluestem in greenhouse.
  - ✓ Submit switchgrass manuscript on 20 years of breeding for increased biomass yield.
  - ✓ Submit first set of parental genotypes to Joint Genome Institute for sequencing. Conduct fertilization, weed control, and soil sampling on all field studies in Wisconsin.
- **Compositional Analyses – ARS-Peoria, Illinois** (Bruce Dien)
  - ✓ Finalize protocol for compositional analysis of neutral and acidic carbohydrates and Klason lignin and validate with calibration set.
  - ✓ Initiate analyses of lowland switchgrass sample set (CenUSA Set 1) differing in lignin and ash.
- **Pyrolysis – ARS-Wyndmoor, Pennsylvania** (Akwasi Boateng)
  - ✓ Complete and submit for publication a manuscript on pyrolysis products from upland switchgrass genotypes differing in stem lignin concentration.
  - ✓ Initiate py-GC/MS analyses of lowland switchgrass sample set (CenUSA Set 1) differing in lignin and ash concentration.
- **Entomology - University Nebraska-Lincoln** (Tiffany Heng-Moss)

- ✓ Collaborate with Drs. Vogel, Mitchell and Casler to develop insect sampling plans for Year 2.
- ✓ Begin sampling nurseries for insects and other arthropods in late May 2013.

- **Plant Pathology – University Nebraska- Lincoln** (Gary Yuen)

- ✓ Determine presence of satellite PMV (SPMV) in samples from PMV-infected switchgrass plants.
- ✓ SPMV is a separate virus species that can infect plants only in conjunction with PMV. Research with other plant species indicated that co-infection of the two viruses results in severe stunting.
- ✓ Coordinate with other project personnel a survey of multistate field experiments for diseases.
- ✓ Analyze virus severity data collected from breeding nurseries to identify genotypes exhibiting lowest and highest levels of virus symptoms.
- ✓ Continue efforts in pathogenicity testing of organisms isolated from switchgrass (i.e. organisms referenced above in accomplishments 2 and 3.

3. Actual Accomplishments (Planned Activities)

- **Breeding and Genetics – Lincoln, Nebraska** (Ken Vogel)

All planned activities completed and milestones were met. Specific accomplishments are listed below.

- ✓ Fifty-eight reciprocal paired plant crosses were made in the greenhouse between plants of two lowland tetraploid populations and plants of a tetraploid upland population. A new crossing procedure was used (see "Significant Accomplishment Summary"). Six population sets of full sib families were produced. Seed was cleaned, treated to break dormancy, and planted in the greenhouse for transplanting in a field evaluation and selection nursery in late spring of 2013. Parent cultivars were included as checks.

  The purpose of the field study is to determine the following:

  - o Extent if any of mid-parent and greater parent heterosis for biomass yields for the full-sib progeny in comparison to their parent population.
  - o Genetic variation among progeny within and between full sib family sets for

biomass yield and other traits.

- Potential improvement in biomass yield between parent source cultivars and the populations developed from them by breeding including the hybrid progeny for biomass yield.

- Serve as a selection nursery to identify the best hybrid full-sib families for within and among family selection to produce synthetic populations. Identify superior parent plants based on their progeny performance.

✓ Two addition switchgrass selection nurseries were established in the greenhouse for transplanting into field selection nurseries in the spring.

✓ Biomass samples from 2012 were processed as scheduled.

✓ Mineral analysis work was completed for the first mineral analyses study which was designed to evaluate laboratory precision and instrumentation. A data analysis is in progress.

✓ A new NIRS unit is currently in the USDA purchasing process.

✓ The new switchgrass cultivar 'Liberty' that is in the release process has been approved by the University of Nebraska Variety Release Committee and is currently in the USDA-ARS approval process. Arrangements have been made to have a 10-acre Foundation seed field established under irrigation by the University of Nebraska Foundation Seed Division (Husker Genetics) in late spring of 2013 using breeder seed provided by ARS-Lincoln.

✓ All early spring fieldwork was completed on all field nurseries as scheduled.

- **Breeding and Genetics - Madison, Wisconsin** (Mike Casler**)**

All planned activities completed and milestones were met. Specific accomplishments are listed below.

✓ Three journal papers were completed. One has been accepted and two are in journal review. See significant accomplishments section.

✓ Transplanted 40,000 switchgrass and big bluestem seedlings into 10 new selection nurseries at either Arlington or Hancock, Wisconsin field sites.

✓ Collected survivorship data on SWAG1, SWAG2, and SWAG3 genomic selection nurseries.

- ✓ Finished scanning the remainder of 2012 biomass samples using NIRS.
- ✓ Selected a new set of 40 diverse switchgrass samples for wet-laboratory analysis to expand and update NIRS calibrations. Samples were submitted to Bruce Dien and Akwasi Boateng for analysis

- **Entomology - University Nebraska-Lincoln** (Tiffany Heng-Moss)

All planned activities completed and milestones were met. Specific accomplishments are listed below.

- ✓ Pitfall traps and stick boards were installed in switchgrass, big bluestem and Indiangrass nurseries at Nebraska and Wisconsin.
- ✓ All sampling data from year 1 have been summarized.
- ✓ We continue to conduct greenhouse screenings to evaluate selected switchgrass, big bluestem, and indiangrass cultivars and experimental strains for their susceptibility to greenbugs and sugarcane aphids.

- **Plant Pathology – University Nebraska-Lincoln** (Gary Yuen)

All planned activities completed and milestones were met. Specific accomplishments are listed below.

- ✓ Determined the presence of satellite PMV (SPMV) in samples from PMV-infected switchgrass plants. Approximately 30% of switchgrass sample collected in 2012 that contained PMV were found to also contain SPMV. Therefore, co-infection by PMV and SPMV, which had not been reported previously in switchgrass, was shown to occur at significant frequencies, which could account the high numbers of virus stunted plant observed in 2012.
- ✓ Coordinated with other project personnel a survey of multistate field experiments for diseases. Arrangements are being made but not finalized.
- ✓ Analyzed virus severity data collected from breeding nurseries to identify genotypes exhibiting lowest and highest levels of virus symptoms. Initial statistical analysis has revealed significant differences between half-sib families in regards to virus disease severity levels in 2012. From the results, genotypes were identified for greenhouse experiments to be conducted this fall.
- ✓ Continued efforts in pathogenicity testing of organisms isolated from switchgrass (i.e. organisms referenced above in accomplishments 2 and 3. Switchgrass clonal plant material was obtained from Noble Foundation and is being propagated for

pathogenicity tests. The purpose of using vegatatively-propagated material for such test is to eliminate genetic variability in seeded plants that could complicate testing of potential pathogens.

- **Compositional Analyses – ARS-Peoria, Illinois** (Bruce Dien)

All planned activities completed and milestones met. Specific accomplishments are listed below.

✓ Protocol for compositional analysis of neutral and acidic carbohydrates and Klason lignin was validated with the five-sample switchgrass calibration set. The results were compared with prior results and confirmed to be similar (Table 1) and were included in a publication (see publications list). These compositional results were used to demonstrate that Kanlow switchgrass had similar or better conversion quality for sugars and ethanol yields than Cave-in-Rock switchgrass even though Cave-in-Rock has higher forage quality than Kanlow. This result is especially significant because Kanlow has higher biomass yields. The work also demonstrated that dilute ammonium pretreatment is effective for biochemical conversion of switchgrass to sugars and biofuels.

Table 1. Composition for switchgrass samples calibration set (g/kg, dry basis)

Cultivar Lignin	Harvest Maturity Carbohydrates	Glucan[1]	Xylan	Arabinan	Acetate	Total Klasson
Native Biomass Composition						
MPV1[3]	**pre-boot**	317.1 ± 0.7[2]	223.7 ± 0.05	33.6 ± 0.1	128.8 ± 1.9	579.3
MPV2	**anthesis**	361.1 ± 2.8	218.8 ± 1.8	35.1 ± 2.1	141.6 ± 1.7	612.5
MPV3	**post-frost**	354.5 ± 2.8	237.9 ± 0.6	39.9 ± 0.1	167.4 ± 11.0	626.6
MPV4	**anthesis**	363.1 ± 3.4	238.7 ± 0.1	45.9 ± 0.4	160.3 ± 4.43	631.5
MPV5	**post-frost**	385.0 ± 7.3	245.6 ± 0.6	49.1 ± 03	165.0 ± 24.5	660.3

[1]Glucans include starch. Starch contents for MPV1 – 5 were 3.47, 61.50, 2.00, 2.55, and 1.78 g/kg, respectively.
[2]standard deviation of duplicate samples
[3]MPV1 – MPV3 are Cave in Rock upland ecotype variety and MPV4 and MPV5 are Kanlow N1 lowland ecotype variety

- **Pyrolysis – ARS- Wyndmoor, Pennsylvania** (Akwasi Boateng)

✓ A manuscript on the relationships between genetic differences in switchgrass stem lignin concentration and pyrolysis yields has been written and is in revision. Co-author is Gautam Sarath, ARS-Lincoln.

- ✓ A set of 54 switchgrass samples was received from ARS-Lincoln that represents families that differ in biomass lignin and ash concentration. Elemental analysis, water content, and ash content were determined. Averages and standard deviations are presented in Table 2.

Table 2. Ultimate analysis of first 54 switchgrass samples, CHNO on dry and ash-free basis

	% water (wt)	% ash (wt)	% C (wt)	% H (wt)	% N (wt)	% O (wt)
Average	6.187	4.498	49.878	5.541	0.623	43.958
Standard Deviation	0.217	0.478	0.816	0.305	0.099	0.978

- ✓ Began py-GCMS runs on switchgrass samples. Ran similarity searches for 15 most prominent peaks in GC curve, found in all samples, based on mass spectrometer data (Table 3).

Table 3. Most prominent peaks in GC curve and similarity search results, first 54 samples

Peak #	Most common MS Similarity Search Result	**Avg. Retention Time (min)**	**Avg. Peak Area**	**Avg. % of area under curve**
1	'Acetic acid'	6.25	1.45E+07	0.89%
2	'2-Propanone, 1-hydroxy-' (Acetol)	7.03	7.74E+06	0.47%
3	'Acetic acid, methyl ester'	10.31	2.74E+06	0.17%
4	'Propylene oxide'	11.87	1.88E+06	0.12%
5	'Propanoic acid, 2-oxo-, methyl ester' (Pyruvic acid, methyl ester)	12.09	1.62E+06	0.10%
6	'Furfural'	12.52	2.19E+06	0.13%
7	'Cyclohexanone'	17.71	2.87E+06	0.18%
8	2-Cyclopenten-1-one, 2-hydroxy-3-methyl-'	22.43	1.96E+06	0.12%
9	'Phenol'	24.42	1.19E+06	0.07%
10	'Phenol, 2-methoxy-' (Guaiacol)	24.62	1.89E+06	0.12%
11	Unidentified*	29.40	2.24E+06	0.14%
12	'4-Hydroxy-3-methylacetophenone'	35.59	4.38E+06	0.27%
13	'Benzofuran, 2,3-dihydro-'	35.96	6.57E+06	0.40%
14	'Phenol, 2,6-dimethoxy-' (Syringol)	37.91	1.98E+06	0.12%
15	'.beta.-D-Glucopyranose, 1,6-anhydro-' (Levoglucosan)	50.57	2.94E+06	0.18%
Similarity searches for peak #11 did not yield any good matches, further analysis is needed				

4. Explanation of Variances

Laboratory Py-GCMS began to malfunction during switchgrass runs and was taken offline for repairs. Statistical analysis cannot be performed until py-GCMS is fixed and pyrolysis yields are determined.

5. Plans for Next Quarter:

- **Breeding and Genetics – ARS-Lincoln, Nebraska** (Ken Vogel)
  - ✓ Establish two switchgrass and three big bluestem polycross nurseries.
  - ✓ Establish three new field selection and genetic evaluation nurseries.
  - ✓ Complete all late spring and summer field cultural practice work.
  - ✓ Complete stand counts and winter survival ratings on all nurseries.
  - ✓ Collect data on flowering time and plant height of plants in specific nurseries.
  - ✓ Complete statistical analyses of Biomass Mineral Analysis Study 1.
  - ✓ Complete initial summary of data from first set of comprehensive composition and pyrolysis analyses for set of switchgrass families differing in lignin and mineral concentration.
  - ✓ Develop additional sets of switchgrass, big bluestem, and indiangrass samples for composition and NIRS analyses.
  - ✓ Complete NIRS purchase and set up.
- **Breeding and Genetics – ARS-Madison, Wisconsin** (Mike Casler**)**
  - ✓ Maintenance of switchgrass and big bluestem nurseries at two locations.
  - ✓ Maintenance and management of CenUSA cultivar trials at 3 locations, including oversight and coordination of 10 additional locations.
  - ✓ Collect data on flowering time and plant height of all plants in all nurseries.
  - ✓ Harvest plots, measure biomass yield, and collect quality samples for all nurseries and field trials.
- **Compositional Analyses – ARS-Peoria, Illinois** (Bruce Dien)

Analyze first set of switchgrass biomass samples (52 samples) and begin development of ferulic acid measurement assay.

- **Pyrolysis – ARS- Wyndmoor, Pennsylvania** (Akwasi Boateng)

  ✓ Complete manuscript on the relationships between genetic differences in switchgrass stem lignin concentration and pyrolysis yields with Gautam Sarath.

  ✓ Resolve issues with py-GCMS and continue experiments as described with switchgrass pyrolysis sample set 1. Compare results with composition data. Initiate work with project geneticists to determine switchgrass genetic effects on pyrolysis yields.

- **Entomology - University Nebraska- Lincoln** (Tiffany Heng-Moss)

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

  ✓ Process samples from sampling Year 2 to identify potential pests and beneficial arthropods and characterize their seasonal abundance.

  ✓ Continue to screen selected switchgrass, big bluestem, and indiangrass cultivars and experimental strains for their susceptibility to greenbugs and sugarcane aphids.

- **Plant Pathology – University Nebraska- Lincoln** (G. Yuen)

  ✓ Re-evaluate switchgrass selection nurseries (PV1103, PV1104 and PV910-2102) for the second growing season for virus and fungal leaf disease severity. These nurseries were evaluated in 2012.

  ✓ Resample the switchgrass genetic and yield nurseries two viruses, Panicum mosaic virus (PMV) and satellite PVM (SPMV).

  ✓ Monitor additional perennial grass and research trials for diseases including CenUSA yield and systems analyses trials at the University of Nebraska's Agricultural Research and Demonstration Center (ARDC) near Mead, Nebraska.

6. Publications / Presentations/Proposals Submitted

- Dien, Bruce S., O'Bryan, Patricia J., Hector, Ronald E., Iten, Loren B. & Robert B. Mitchell, Qureshi, Nasib, Sarath, Gautum, Vogel, Kenneth P. & Michael A. Cotta. (2013). *Conversion of switchgrass to ethanol using dilute ammonium hydroxide pretreatment: influence of ecotype and harvest maturity. Environmental Technology* (Accepted).

- Price, David L., and Michael D. Casler. (2013). Predictive relationships between plant morphological traits and biomass yield in switchgrass. Crop Sci. (in press).

- Sarath, Gautum, Hammer, N. Sasthoff, A., Mullen, C., Boateng, Akwasi, Mitchell, Robert B., Vogel, Kenneth P., & Sattler, S. (2013, April 29 - May 2). Switchgrass, cell walls and pyrolysis. 35th Symposium on Biotechnology for Fuels and Chemicals (Abstract, oral presentation), Portland, OR.

- Stewart, Catherine L, Yuen, Gary Y., Vogel, Kenneth P., Pyle Jesse D. &. Scholthof, Karen-Beth G. (2013, August). Panicum mosaic virus - a potential threat to biofuel switchgrass production. Abstract accepted for the 2013 Annual Meeting of the American Phytopathological Society, Austin, TX.

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.

1. Planned Activities

Much of the research planned for this quarter dealt with sample processing and planning for the next quarter. Nearly all planned research for this first quarter was completed on schedule.

2. Actual Accomplishments

Iowa State University

- **Armstrong System Plots**. Switchgrass plots were reseeded (6.4 lbs-seed/ac) and sprayed (8 oz. Paramount, 32 oz. Roundup/ac) to control weeds. These are the plots which did not establish well during the 2012 drought. The control plots were planted to corn.

  Frequency of occurrence stand counts for the high diversity, low diversity and switchgrass plots were completed on May 13, 2013. At that time the switchgrass had just been re-planted and had not yet emerged. Most common weeds included: dandelion, yellow mustard, shepard’s purse, and lambsquarter. Some plots were covered with mustards; many plots had annual grasses and dicots that were just emerging.

Table 4. Frequency Stand Counts (Based on 100-square Grid)			
Planted	**Treatment**	**Dicots**	**Grass**
High D	Biochar	92.5	10.0
High D	None	96.1	10.1
Low D	Biochar	95.5	16.5
Low D	None	93.1	15.8
SG	Biochar	6.8	0.0
SG	None	4.0	0.0

Decagon 5TE sensors capable of simultaneously measuring soil moisture, temperature, and electrical conductivity were installed at four depths in each of 32 locations (two per large plot/one per split plot) in the System Analysis plots. Data loggers were also installed so that soil moisture, temperature, and electrical conductivity are now being monitored every half hour. Baseline soil analysis is continuing on schedule for the 138 1.2 M soil cores, with anticipated completion in August or September 2013.

- **Field 70/71**. The plots received spring tillage where appropriate and were planted.
- **Sorenson Farm Long-term Rotation plots**. Switchgrass, corn, soybeans, and triticale were planted in the appropriate phase of each rotation. Biochar was applied on May 13, 2013 on split plots during the first year of the corn in the 6-year rotations; corn and soybeans were planted on May 15, 2013.

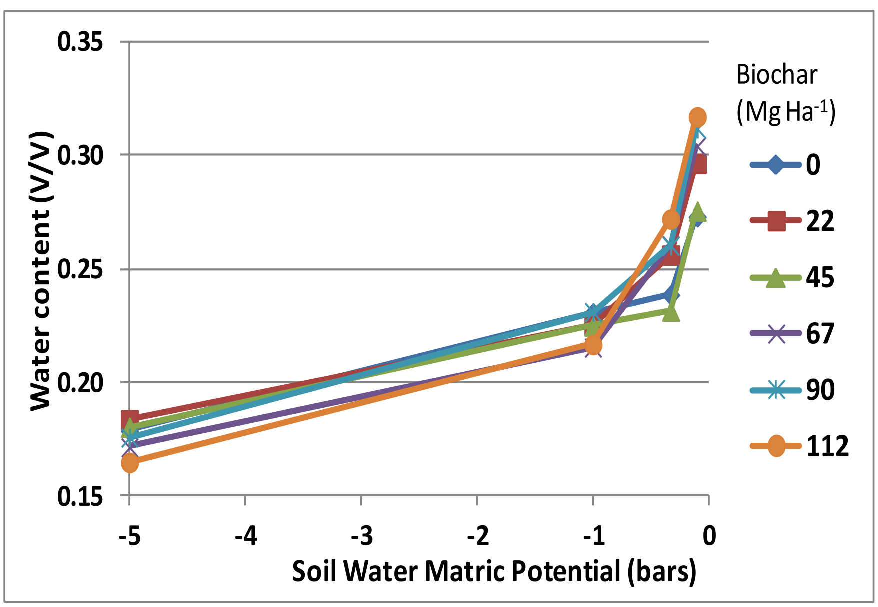

Figure 3. Ave. surface soil temperature retention curves, Boyd Farm plots receiving biochar treatment

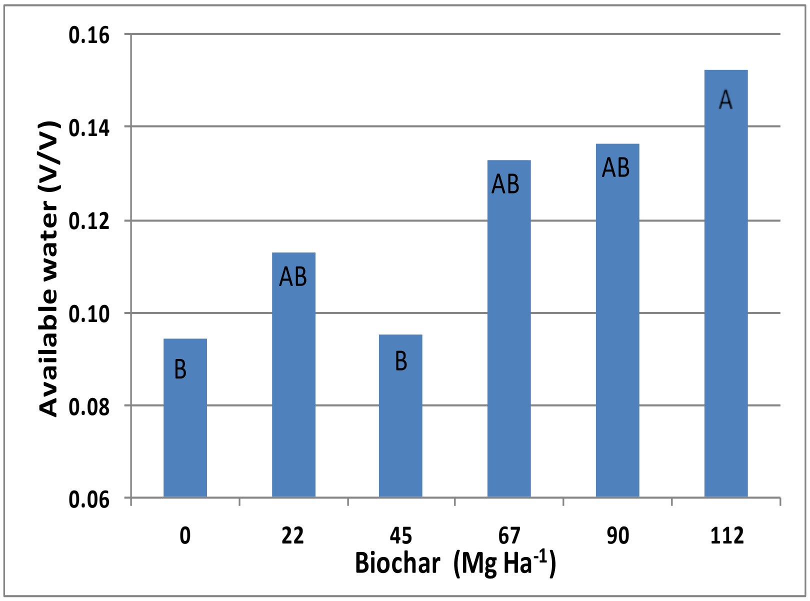

Figure 4. Impact of biochar treatments on plant available water (defined as water retained between -0.1 and -5 bars soil matric potential). Bars with different letters are significantly different at the 0.05 level.

- **Boyd Biochar Plots**.

  All plots were successfully planted to corn during the brief spell of dry weather. Base stations for monitoring greenhouse gas (GHG) emissions were installed in each plot. Soil moisture retention curves were completed. The results indicate that soils in plots receiving the high biochar application rate (112 Mg ha^{-1}) have the capacity to retain 60% more plant available water than soils in the control plots that did not receive biochar applications.

University of Illinois Urbana-Champaign

- **Illinois 2012 Factor Analysis Plots**. The plots were expected to have poor stands because of 2012 drought and weed pressure. We evaluated stand frequency in March and April 2013. Switchgrass plots had the best stands, but stand counts were still less than 5 plants m^{-2} and we decided to replant. All plots were treated with glyphosate to burn down all existing weeds before planting. The plots were reseeded using a no-till drill on May 15, 2013 and pre-emergence herbicides were applied based on recommendations from Dr. Rob Mitchell on May 16, 2013.

- **Illinois 2013 Factor Analysis Plots**. The plot area was tilled in fall 2012 and sprayed with glyphosate. Due to excessive weed pressure, glyphosate was applied twice in March and May 2013 before planting. The plots were planted using a no-till drill on May 15, 2013 and pre-emergence herbicides applied based on recommendations on May 15, 2013.

We are planning to do soil analysis for the Factor Analysis plots in 2013.

- A comparison field trial of switchgrass, big bluestem, prairie cordgrass, and Miscanthus *x* giganteus was harvested on November 15, 2012 and biomass yield data has been analyzed during this quarter (Fig. 3). The plots were transplanted in 45-cm and 90-cm spacings on wet marginal land in 2010.

  Overall, plots with 45- cm spacing produced more biomass than 90- cm spacing until 3 years after transplanting. Severe drought stress was observed in prairie cordgrass and Mxg plots during the 2012 growing season and biomass yields for prairie cordgrass and Mxg was lower than switchgrass. Kanlow switchgrass biomass yield was very high (25 Mg/ha) even under extreme drought conditions.

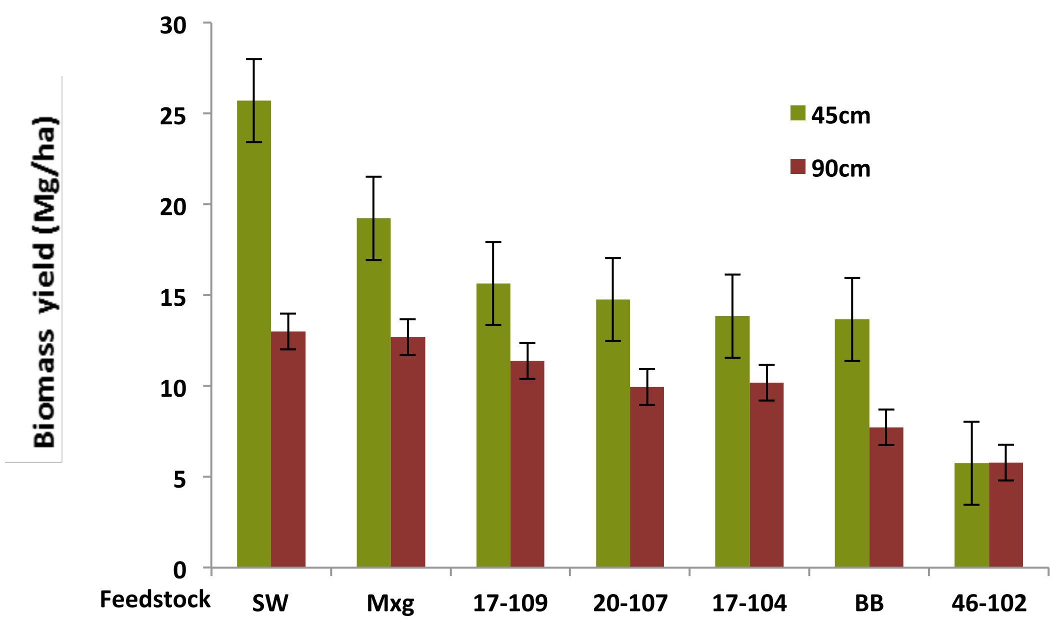

Figure 5. Biomass yield of ‘Kanlow’ switchgrass (SW), *Miscanthus x giganteus* (Mxg), big bluestem (BB), and four prairie cordgrass natural populations (’17-109’, ’20-104’, ’17-104’, and ’46-102’) at 45cm and 90 cm spacing in 2012.

University of Minnesota

- Factor Analysis plots at Becker, Minnesota were harvested on October 30, 2012 using a Carter harvester (0.9 m x 4.6m). The soil at this site is a Hubbard loamy sand. Biomass was weighed wet in the field. Two subsamples (0.25m x 0.25m) were collected from each subplot, stored in plastic bags under cool conditions, dried at 60 C, and then weighed to determine dry matter content. Harvest photos and data summary results are below.

Figure 6. Biomass yield of 'Kanlow' switchgrass (SW), Miscanthus x giganteus (Mxg), big bluestem (BB), and four prairie cordgrass natural populations ('17-109', '20-104', '17-104', and '46-102') at 45cm and 90 cm spacing in 2012.

Figure 7. Carter Harvester

- In general, biomass yields were quite variable making it difficult to draw any conclusions at this point. We expect that with time, yield differences will become more distinct.
- Susan Hawkins (UVM) approached us for assistance with an article on switchgrass nutrient management to be published on eXtension.org. We delivered the finished product to Susan on April 14, 2013.

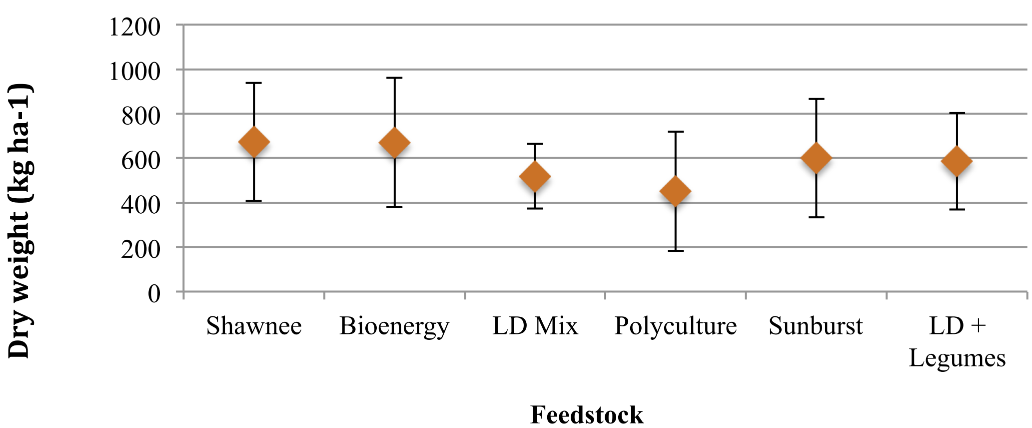

Figure 8. Calculated dry weight harvest of feedstocks (mean and std. dev.), Becker, MN, 2012

We have had a very cold spring with several large snowstorms in April followed by a prolonged wet period in May. We were able to plant the 2013 Factor Plots at Lamberton, however, on May 16, 2013.

- N application at Becker Factor plots. Due to the potential for N losses in sandy soil at Becker, we are doing a split application of N. The first application was applied on May 23, 2013. The second will be applied in early-mid June.

Purdue University

- **Throckmorton Purdue Agricultural Center Factor Analysis Plots**. Baseline greenhouse gas (GHG) emission data from a subset of the Factor Analysis Plots at the Throckmorton Purdue Agricultural Center (TPAC) were acquired. These data were averaged over weekly measurements taken April 22 to May 7, 2013 prior to field operations. Results suggest that perennial biomass production systems may produce slightly more CO_2 and low to moderate levels of CH_4 and NO_2 when compared to maize and biomass sorghum. Addition of 100 kg N/ha to maize and sorghum increases CO_2 and NO_2 emissions over the unfertilized plots.

Table. 5 Impact of biomass cropping system and nitrogen (N) rate on greenhouse gas emissions.

Biomass System	Nitrogen rate, kg/ha	CO_2, mg/h/m^2	CH_4, mg/h/m^2	NO_2, mg/h/m^2
Native Prairie	0	225	0	0.009
Switchgrass (Shawnee)	0	340	0	0.014
	100	228	0	0.003
Miscanthus	0	215	0.0005	0.004
	100	282	0	0.008
Sorghum	0	142	0	0.004
	100	182	0.005	0.013
Conventional corn	0	146	0.004	0.011
	100	162	0	0.028

- ✓ **Mineral Analysis - TPAC**. Mineral analyses at the TPAC Factor Analysis plots are being completed. Variable rates of N (0 to 150 kg N/ha/yr) are being applied to Shawnee switchgrass established at a site that had received annually high rates of P and K or left unfertilized (0 or 75 kg/ha P; 0 or 400 kg K/ha) for 8 years of alfalfa production that resulted in large differences in soil P and K levels (See Table 4).

Table 6. Impact of nitrogen (N), phosphorus (P), and potassium (K) fertilization on nutrient concentrations and total carbon (C) in switchgrass biomass.					
Nutrient	**Rate, kg/ha/yr**	**Tissue N, g/kg**	**Tissue P, g/kg**	**Tissue K, g/kg**	**Tissue C, g/kg**
Nitrogen	0	5.17**	0.42	1.92**	469
	50	5.50	0.41	2.01	470
	100	6.17	0.41	2.02	469
	150	6.94	0.41	2.20	470
Phosphorus	0	5.87	0.27**	2.11**	470
	75	6.02	0.56	1.96	469
Potassium	0	6.02*	0.45**	1.70**	468**
	400	5.87	0.38	2.37	471

*, ** Nutrient effect on tissue composition significant at the 5 and 1% levels of probability, respectively.

Preliminary results of the main effects of the analysis reveal the following:

- Tissue N increased with the addition of N fertilizer but declined with high soil test K.
- High soil test P increased tissue P concentrations whereas high soil test K decreased tissue P concentrations.
- Tissue K concentrations increased with the addition of N fertilizer and with high soil test K levels, but declined with high soil test P concentrations.
- Tissue C concentrations were unaffected by N and P fertility, but increased slightly with high soil test K.
- Significant interactions among N, P, and K also were identified for some variables, but details of these results are beyond the scope of this interim report. Details will be made available upon request.

✓ **Fiber and Sugar Analysis - TPAC**. Fiber and sugar analyses at the TPAC Factor Analysis plots are being completed. Variable rates of N (0 to 150 kg N/ha/yr) are being applied to Shawnee switchgrass established at a site that had received annually high rates of P and K or left unfertilized (0 or 75 kg/ha P; 0 or 400 kg K/ha) for 8 years of alfalfa production that resulted in large differences in soil P and K levels.

Table 7. Impact of nitrogen (N), phosphorus (P), and potassium (K) fertilization on concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ash, and soluble sugars in switchgrass biomass.

Nutrient	Rate, kg/ha/yr	NDF, g/kg	ADF, g/kg	ADL, g/kg	Ash, g/kg	Sugar, g/kg
Nitrogen	0	717	398	66*	44	13.8
	50	718	397	68	43	13.8
	100	716	403	70	42	13.4
	150	714	394	69	42	14.0
Phosphorus	0	721*	402*	69*	42*	14.0
	75	712	395	67	44	13.5
Potassium	0	712	397	68	44*	13.7
	400	721	399	68	41	13.8

*, ** nutrient effect on tissue composition significant at the 5 and 1% levels of probability, respectively.

Preliminary results of the main effects of the analysis reveal the following:

- Neutral detergent fiber (NDF) was not affected by N or K nutrition, but was reduced significantly with high soil test P levels.
- Trends in acid detergent fiber (ADF) mirrored those of NDF.
- Acid detergent lignin (ADL) concentrations increased with N fertility, but declined as soil test P levels increased.
- Biomass ash concentrations were unaffected by N, but increased as soil test P levels increased. In contrast, ash concentrations declined as soil test K increased.
- Biomass soluble sugars averaged approximately 13.8 g/kg and were not affected by soil test P and K, not N fertilizer application.
- Significant interactions among N, P, and K also were identified for some variables, but details of these results are beyond the scope of this interim report. Details will be made available upon request.

✓ **Mineral Analyses – TPAC Miscanthus x g Factor Analysis Plots**. Analyses at the TPAC Miscanthus x g Factor Analysis plots also are being completed. Variable rates of N (0 to 150 kg N/ha/yr) are being applied to a site that soil tests indicated differed in P and K levels. Plots were blocked and high rates of P and K (“plus” treatment: 75, 400 kg/ha, respectively) were applied or plots were left unfertilized with P and K (minus treatment). The goal is to explore the interaction between P/K fertility and N nutrition of this understudies biomass system.

Table 8. Impact of nitrogen (N), and phosphorus (P) plus potassium (K) fertilization on nutrient concentrations and total carbon (C) in *Miscanthus* biomass. The "plus" PK treatments were fertilized at 75 kg P/ha/yr and 400 kg K/ha/yr, while the "minus" PK plots were left unfertilized.

Nutrient	Rate, kg/ha/yr	Tissue N, g/kg	Tissue P, g/kg	Tissue K, g/kg	Tissue C, g/kg
Nitrogen	0	4.01**	0.45*	3.56	463
	50	4.47	0.45	4.27	461
	100	4.90	0.34	4.37	462
	150	5.26	0.36	4.28	462
P and K	Minus	4.59	0.38	3.80*	461
	Plus	4.73	0.42	4.43	463

*, ** nutrient effect on tissue composition significant at the 5 and 1% levels of probability, respectively.

Preliminary results of the main effects of the analysis reveal the following:

- Tissue N increased with the addition of N fertilizer, but there was no effect of P and K on tissue N concentrations.
- Tissue P concentrations were reduced with N fertilizer application.
- Tissue K concentrations were unaffected by N fertilizer application, but were increased with application of P and K fertilizers.
- Tissue C concentrations were unaffected by N and P/K fertility.
- Significant interactions between N and P/K also were identified for some variables, but details of these results are beyond the scope of this interim report. Details will be made available upon request.

✓ **Fiber and Sugar Analyses - TPAC *Miscanthus x g* Factor Analysis**. Fiber and sugar analyses at the TPAC *Miscanthus x g* Factor Analysis plots also are being completed. Variable rates of N (0 to 150 kg N/ha/yr) are being applied to a site that soil tests indicated differed in P and K levels. Plots were blocked and high rates of P and K ("plus" treatment: 75, 400 kg/ha, respectively) were applied or plots were left unfertilized with P and K ("minus" treatment). The goal is to explore the interaction between P/K fertility and N nutrition of this understudies biomass system.

Table 9. Impact of nitrogen (N), and phosphorus (P) plus potassium (K) fertilization on concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ash, and soluble sugars in *Miscanthus* biomass. The "plus" PK treatments were fertilized at 75 kg P/ha/yr and 400 kg K/ha/yr, while the "minus" PK plots were left unfertilized						
Nutrient	**Rate, kg/ha/yr**	**NDF, g/kg**	**ADF, g/kg**	**ADL, g/kg**	**Ash, g/kg**	**Sugar, g/kg**
Nitrogen	0	771	481	81.8	42.8	19.3
	50	771	475	81.9	44.2	18.8
	100	771	480	83.9	44.4	17.8
	150	754	469	81.9	43.9	20.8
P and K	Minus	762	480	83.5	43.4	20.2*
	Plus	771	473	81.3	44.2	18.1
*, ** nutrient effect on tissue composition significant at the 5 and 1% levels of probability, respectively.						

Preliminary results of the main effects of the analysis reveal the following:

- Concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and biomass ash were unaffected by N or P/K nutrition.
- Biomass soluble sugars were unaffected by N, but were reduced with application of both P and K fertilizers.
- Significant interactions among N, P, and K also were identified for some variables, but details of these results are beyond the scope of this interim report. Details will be made available upon request.

USDA-ARS, Lincoln, Nebraska

- A fact sheet on establishing bioenergy demonstration sites has been authored by Rob Mitchell, Jeff Volenec, and Pam Porter is in the final stages of development.
- The 2012 Nebraska and Minnesota feedstock samples are ready for NIRS analysis.
- We made two site visits to the Iowa System Analysis plots to evaluate stands, discuss seeding and spraying protocols, and deliver seed. Management recommendations were followed.
- We distributed all seed for the project demonstration sites in Iowa, Indiana, Minnesota, and Nebraska.
- We distributed all seed for the 2013 Factor Analysis plots and for the 2012 Factor Analysis plots that needed re-seeding.

- We have scheduled an establishment field day with Dr. Kevin Shinners for the 11th or 12th of July 2013 (weather dependent) to showcase herbaceous perennial feedstock establishment.
- We have distributed frequency grids to the demonstration site coordinators.
- We burned the 2012 Nebraska Demonstration site, re-seeded thin spots in the stand, and seeded the 2013 Nebraska Demonstration site.
- We sampled the Nebraska System Analysis plots at 30-d intervals (as conditions allowed) to determine DM losses over winter. Data evaluation is in process.
- Preliminary establishment-year biomass data from the post-frost harvest in the System Analysis plots demonstrate the ability of perennial warm-season grasses to be productive, even in extreme drought.
  - ✓ Switchgrass: 3.4 tons/acre
  - ✓ Big bluestem: 1.2 tons/acre
  - ✓ Low diversity mixture: 1.9 tons/acre
  - ✓ Rainfed maize grain yield: 102 bu/acre plus 1.4 tons/acre of corn stover removed
- We completed Spring 2013 stand counts on the System and Factor Analysis plots and preliminary data indicates excellent stands following extreme drought in 2012.
- We applied fertilizer treatments to the 2012 Factor Analysis plots.
- We began sampling GHG, soil water content, and biomass at weekly intervals in the Nebraska System Analysis plots.
- We attended the Sun Grant Switchgrass Meeting to develop a national switchgrass yield map for both upland and lowland strains.
- We continue to work with the National Wildlife Federation to develop best management guidelines for perennial grasses for bioenergy.
- We shipped switchgrass bales to Iowa State University for distribution to industry partners.

3. Explanation of Variance

There were no variances – we accomplished all that we had planned during this period.

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

   None submitted.

Objective 3. Feedstock Logistics

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

University of Wisconsin

1. **Planned Activities**

   Planned research activities included:

   - Analysis of data collected in 2012;
   - Management of the bale storage study;
   - Development of machine configurations to combine cutting/intensive conditioning/tedding;
   - Collection of post-storage size-reduction energy requirements of bales, and
   - Establishment of native grass fields for demonstration and research use.

2. **Actual Accomplishments**

   Bales were placed into storage in the fall of 2012 to investigate means to reduce DM losses from dry bales stored outdoors. Four treatments were considered in this dry bale study, including indoor and outdoor storage and bales wrapped in plastic film (either individually or in a tube). The bales have been monitored during the spring to ensure the study is progressing as planned. Bales will be removed from storage in early summer 2013.

   In 2012, we determined that both intensive conditioning and wide-swath drying enhance the drying rate of switchgrass. We have begun development of a machine configuration to combine cutting, intensive conditioning, and tedding into a single operation. This system will involve a front-mounted mower on a tractor which will also tow an intensive conditioner equipped with a mounted tedder. We have arranged for the loan of a tractor and mower to accomplish the first operations and have now acquired an intensive conditioner and tedder.

The re-configured intensive conditioner/tedder is now capable of completing three operations –cutting, intensive conditioning and wide-swath tedding in a single-pass, eliminating two field operations. Initial functional tests will be conducted using alfalfa and grasses in the summer before harvesting our perennial grasses in the fall.

We continue to quantify the energy required to size-reduce perennial grasses post-storage. Our work during the spring of 2013 involved quantification of energy required to chop overwintered switchgrass using a self-propelled forage harvester. We will begin work on quantifying energy required to size-reduce grass bales in the early summer of 2013.

Finally, we have rented 32 acres of marginal land in which we will establish a variety of perennial grasses. Rob Mitchell, Objective 2 CoPd, has provided valuable input on the type and variety of grasses. The fields have been planted in mixtures of switchgrass, big bluestem, and indiangrass. A grass establishment outreach field day is planned for early July.

3. Explanation of Variance

There were no variances – we accomplished all that we had planned during this period.

4. Plans for Next Quarter

We plan to:

- Finish analyzing our 2012 data and continuing the preparation of manuscripts for the American Society of Agricultural and Biological Engineers meeting;
- Complete our bale storage study;
- Conduct the initial evaluation of the combined cutting/intensive conditioning/tedding machine;
- Collect post-storage size-reduction energy requirements of bales removed from storage; and
- Continue establishment of perennial grasses on rented acreage and conduct an outreach field day.

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Iowa State University

All activities remain on task for completion as specified in the Plan of Work.

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 Objective 4 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 received a final acceptance for a paper that studies that the potential for cellulosic feedstocks to reduce the frequency and magnitude of flood events in the Raccoon River Watershed in Iowa (Schilling et al.) where we use a watershed based hydrologic model to represent changes in water movement under different land uses in the watershed. First, we develop a baseline scenario of flood risk based on the current land use and typical weather patterns. We then simulate the effects of varying levels of increased perennials on the landscape under the same weather patterns and compare the change in stream flows and water quality to the baseline scenario.

   We continue work on a project entitled "Optimal placement of Second Generation Biofuels in a Watershed: Is Marginal Land the Answer?" for presentation at the annual meeting of the Agricultural and Applied Economics Association. This paper will address concern about how competition between corn used for ethanol production and corn used for feed has led to the suggestion that second generation feed stocks, such as switchgrass and other perennial grasses, be restricted to low productivity "marginal" land to avoid food price effects of biofuel production. Although perennial grasses have promising environmental attributes related to GHG emissions, soil erosion, and water quality, the technology to cost effectively convert them to liquid fuels is still under development. Further, these feedstocks are bulky and there are likely to be large agglomeration economies by locating fields near each other. From an environmental perspective, the optimal location of switchgrass will likely depend on the typography of fields in a watershed, proximity to waterways and soil characteristics. We present a simple model of agricultural land use to study the efficiency tradeoffs associated with restricting switchgrass to marginal land vs. allowing it to be located where it would be most profitable or achieve the greatest water quality benefits. We consider these tradeoffs explicitly for the Raccoon River watershed.

A major component of the ISU-CARD modeling work in this objective involves the improvement of SWAT models for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds. There is now a much denser subwatershed delineation; e.g., 5,279 12-digit subwatersheds versus 131 8-digit subwatersheds for the UMRB. This modeling structure will provide the ability to perform enhanced scenarios including greatly refined targeting scenarios to study placement of switchgrass and other biofuel crops in the landscape to evaluate to evaluate the water quality and carbon effects at the landscape level. Initial calibrations of the model are complete. We have moved into a phase of in-depth testing of the Upper Mississippi River Basin (UMRB) and Ohio-Tennessee River Basin (OTRB) SWAT models. At present, the focus is on using automatic calibration via the SWAT-CUP software (http://www.eawag.ch/forschung/siam/software/swat/index) using simpler model structures which are delineated with the 12-digit subwatersheds but with no HRUs (for descriptions of 12-digit and other standard watershed classifications see http://pubs.usgs.gov/tm/tm11a3/).

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

Continue work on the first two tasks: 1) to adapt existing biophysical models to best represent field trials and other data and 2) to adapt existing economic land-use models to best represent cropping system production costs and returns. We hope to have a draft of a paper studying the optimal placement of switchgrass with respect to both bioenergy and water quality goals completed by the summer.

5. Publications, Presentations, and Proposals Submitted

- Gonzalez-Ramirez, Jimena, Valcu, Adriana & Catherine. Kling. (2012). An Overview of Carbon Offsets from Agriculture. Annual Review of Resource Economics 4 (2012) 145-160.
- Kling, Catherine. National Science Foundation. *Climate and Human Dynamics as Amplifiers of Natural Change: A Framework for Vulnerability Assessment and Mitigation Planning*. Principal Investigator, 2012-2016, $480,000.
- Kling, Catherine L., Gassman, Philip W., Schilling, Keith E., Wolter, Calvin F., Jha, Manoj K. &. Campbell, Todd D. The Potential for Agricultural Land Use Changes in the Raccoon River Basin to Reduce Flood Risk: A Policy Brief for the Iowa Flood Center. Available at http://www.card.iastate.edu/environment/presentations.aspx.
- Schilling, Keith E., Gassman, Philip W., Kling, Catherine L., Campbell, Todd, Jha, Manoj, K., Wolter, Calvin F. & Arnold, Jeffrey G. (2013, June 8). The Potential for Agricultural Land Use Change to Reduce Flood Risk in a Large Watershed. Hydrological Processes (2013). Available at http://onlinelibrary.wiley.com/doi/10.1002/hyp.9865/abstract online. DOI: 10.1002/hyp.9865

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) and Task 2 (Adapt existing economic land-use models to best represent cropping system production costs and returns), and Task 3 (Integrate physical and economic models to create spatially-explicit simulation models representing a wide variety of biomass production options).

2. **Actual Accomplishments**

   We are continuing our analysis of switchgrass and corn trial yields in our investigation of yield gaps. We have expanded this analysis to consider other perennial crops. We are nearing completion of our revisions on our manuscript comparing U.S. federal agency bioenergy feedstock production scenarios for achieving Renewable Fuel Standard (RFS2) biofuel volumes. As in last quarter, we are continuing to compile production cost and return data for switchgrass, explore different biodiversity models for use in our InVEST modeling, and write scripts to automate the modeling of biomass production placement on the landscape.

3. **Explanation of Variance.**

No variance has been experienced.

4. **Plans for Next Quarter**

   Next quarter will include continued work on Tasks 1, 2, and 3, as well as continued work on Task 4 (Evaluate the life cycle environmental consequences of various bioenergy landscapes).

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

   Objective 4 CoPd Jason Hill has submitted a proposal to USDA/NIFA: "A6101: Enhancing agriculture's ecosystem services through sustainable bioenergy production." We anticipate the funding decision will be made in early summer 2013.

POST-HARVEST

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

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

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

Sub-objective 1. Perform Technoeconomic Analysis

1. **Planned Activities**.

   Start the development of the catalytic pyrolysis process model. Develop an experimental plan to test mild catalytic pyrolysis.

2. **Actual Accomplishments**.

   The fast pyrolysis and catalytic pyrolysis process models in Chemcad have been updated and finalized. Initial experiments testing mild catalytic pyrolysis have commenced. Initial tests are utilizing commercially available zeolite catalysts on both standard and Tandem Frontier Micropyrolysis units.

3. **Explanation of Variance**.

No variance has been experienced and accomplishments are on schedule.

4. **Plans for Next Quarter**.

   Continue with experiments to provide inputs to process model; monitor data from the Boateng group (Objective 1) and adjust model assumptions and inputs as needed.

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

   None to report this period.

Sub-objective 2. Prepare and characterize biochar

1. **Planned Activities**.

   Data analysis for Boehm titrations will be completed; work will start on a draft manuscript. Ash content/X-ray diffraction analysis of inorganic components of biochars are planned.

2. **Actual Accomplishments**.

   - Bohem titrations for four new biochars were completed using a newly developed Bohem titration procedure (Fig. 9). The latest results indicate that an integrated Bohem procedure that uses the sparge method with sodium bicarbonate, the barium method with the sodium carbonate, and the barium method with sodium hydroxide consistently give reasonable results. The new results also show that use of the cartridge method with sodium hydroxide gives unreasonably low results for three of four studied biochars. The first draft of a manuscript describing problems associated with use of the traditional Bohem titration procedure and the proposed revised procedure to characterize the concentrations of reactive functional groups on the surfaces of biochars has been prepared.
   - X-ray diffraction analysis of 12 biochar samples was completed. The results indicate the presence of various crystalline phases within biochars, including graphite, sylvite, and calcite. Shown in Figure 2 are XRD patterns for biochars prepare at 700C using Cellulose, corn stover, and alfalfa meal.

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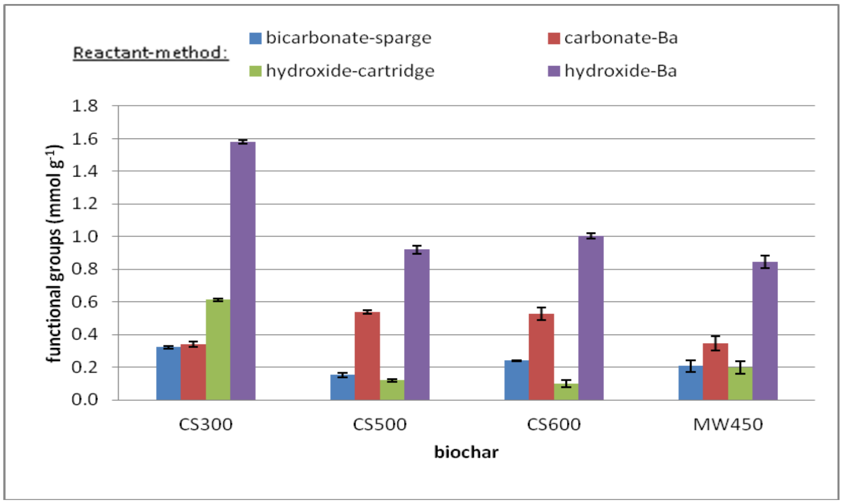


Figure 9: Bohem titrations for biochars were prepared from corn stover at 300C (CS300), 500C (CS500), 600C (CS600) and mixed wood at 450C (MW450).

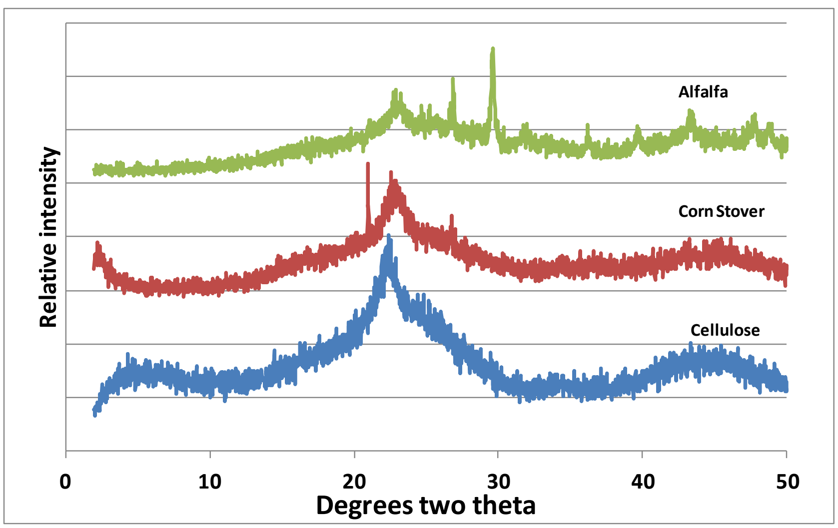


Figure 10: X-ray diffraction patterns for biochars prepared form cellulose, corn stover, and alfalfa at 700C. The results indicate that the type of feedstock influences crystalline phases found in biochars.

3. Explanation of Variance.

No variance has been experienced and accomplishments are on schedule.

4. Plans for Next Quarter.

Complete editing and submit the Bohem titration manuscript for publication. Conduct X-ray fluorescence analysis to quantify inorganic compounds in the ash of biochars.

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

   None submitted.

Objective 6. Markets and Distribution

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

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

1. **Planned Activities**

   Our team anticipated a total of four activities for the third quarter of the second year of the project.

   - Continue to push forward progress on access to farm-level CRP data (Keri Jacobs).
   - Continue development of the spatial model of biomass supply with heterogeneous producers (Richard Perrin).
   - Continue to interact with industry (Du Pont, Deere, and Stine Seeds) on a project to model the use of feedstocks as a fast pyrolysis fuel source. The business model involves a distributed system of fast pyrolysis that provides as byproducts biochar and bio-oil. Biochar will be sold as a soil amendment, and bio-oil will be sold for use in furnaces for heat. The group includes soil scientists, chemical engineers and mechanical engineers (Dermot Hayes).
   - Continue modeling and analysis efforts of the regional supply curve for grasses and stover using a real options framework (Dermot Hayes).

2. **Actual Accomplishments**

   - **Farm-level CRP data**. Little progress has been made in securing these data. We knew this was a possibility. Funding issues within the USDA and legislative language that addresses data privacy make this a difficult endeavor.
   - **Spatial model of biomass supply**. This activity is ongoing.

- **Industry Interaction - Model the use of feedstocks as a fast pyrolysis fuel source**. This activity is ongoing.
- **Modeling the regional supply curve for grasses and stover**. This activity is ongoing.

3. Explanation of Variance

No variance has been experienced and accomplishments are on schedule.

4. Plans for Next Quarter

During the fourth quarter (Year 2), our team will work on the following activities:

- Prepare for the CenUSA Intensive Program held in Ames, Iowa during June 2013.
- Prepare for the CenUSA Bioenergy Annual Meeting to be held in West Lafayette, Indiana July 30 – August 2, 2013. Our team will brief the entire CenUSA team on our Year 2 activities.
- Continue development of the spatial model of biomass supply with heterogeneous producers (Richard Perrin).
- Continue to interact with industry on an Iowa State University Bioeconomy Institute project to model the use of feedstocks as a fuel source for fast pyrolysis. The business model involves a distributed system of fast pyrolysis that provides as byproducts char and bio-oil. Char will be sold as a soil amendment, and bio-oil will be sold for use in furnaces for heat (Dermot Hayes).
- Complete modeling and analysis efforts of the regional supply curve for grasses and stover using a real options framework (Hayes). Present one of these at an international conference on this subject in late June 2013. We anticipate publishing two peer-reviewed papers in this area.

5. Publications, Presentations, and Proposals Submitted

- None submitted in the third quarter.

Objective 7. Health & 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 Feedstocks

a. Planned Activities

The team is modifying the collection of the various tasks/responsibilities associated with producing biofeedstocks by subdividing some tasks into smaller and more specific subtasks. The major headings or grouping of tasks remains under these five areas:

1. Establishment
2. Maintaining
3. Harvest
4. On-site processing and storage
5. Transportation

The different risk assessment methods are being evaluated for those established tasks.

b. Actual Accomplishments

Good progress on refining the accumulated listing of tasks/responsibilities was made. Criteria for comparisons of risk assessments for handling the evaluation of the various tasks were begun and the standard risk assessment tool to use for tasks in biofeedstock production is still being constructed.

The team strengthened the cooperative arrangement with Dennis Murphy, the investigator at Penn State University who is also working with another biofuel CAP project, to collaborate in developing a standard to assess risk in these types of tasks. The plan is to co-author some presentations and papers.

c. Explanation of Variance

None to report.

d. Plans for Next Quarter

Continued refinement of the accumulated listing of tasks/responsibilities will be accomplished. Criteria for comparisons of risk assessments for handling the evaluation of the various tasks will be made with the expected outcome of determining the standard risk assessment tool to use for tasks in biofeedstock production.

e. Publications, Presentations, and Proposals Submitted

A presentation has been submitted for the Biomass and Biofuels session of the *2013 North American Agricultural Safety Summit* hosted by the Agricultural Safety & Health Council of America. The event will be in Minneapolis, Minnesota on September 25-27, 2013.

Previous publication submitted: Schwab, C. V., and M. Hanna. 2012. Master Gardeners' safety precautions for handling, applying, and storing biochar. Cenusa bioenergy publication. ISU University Extension and Outreach, Ames, IA 50011.

2. Task 2 – Assessing Primary Dust Exposure

a. Planned Activities

The locations for dust exposures are compiled and those currently identified are being examined for determination of the most likely place to find the highest/hazardous exposure rates. This will be the selection process to determine where the pilot analysis of actual dust exposure will take place.

Appropriate monitoring equipment is still being identified for the pilot study. Approvals for human subjects and procedures have begun, but approval has not been received.

b. Actual Accomplishments

The prioritized list of locations for dust exposures is being evaluated in more detail and the primary location to be measured still remains uncertain at this time. The identification of the monitoring equipment needed to take dust samples was started but remains on hold until the exact details of the location and expected exposure are confirmed.

c. Explanation of Variance

No variance has been experienced and accomplishments are on schedule.

d. Plans for Next Quarter

Appropriate monitoring equipment will be obtained to conduct the pilot study. Approvals for human subjects and procedures will be obtained.

e. Publications, Presentations, and Proposals Submitted

None to report this period.

Outreach and Extension

Objective 8. Education

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

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

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

Subtask 1: Curriculum Development

1. **Planned Activities**

   - **Module 2. Perennial Grass Establishment and Management**

     Complete internal review and submit to Journal of Natural Resources and Life Sciences Education for peer review

   - **Module 3. Perennial Grass Harvest Management**

     Complete internal review for harvesting machinery lessons.

   - **Module 4. Storage Management**

     Continue module development activities with Amy Kohmetscher

   - **Module 5. Integrating Bioenergy Production into Current Systems**

     Complete module development activities with Amy Kohmetscher.

   - **Module 6. Balancing Energy Demand with Food, Feed and Fiber Needs**

     Complete module development activities with Amy Kohmetscher.

- **Module 7 – Overview Module (lead author John Guretzky)**

  Complete outline of the remaining content.

- **Module 8 – Ecosystems Services for Dedicated Bioenergy Crops**

  We are starting the process of outlining module content.

2. **Actual Accomplishments**

- Identified specific goals and developed initial evaluation tools for evaluating modules in an off-line environment (Evaluation lead: Gwen Nugent).
- Attended workshop on ADA compliance of on-line materials – will adapt new practices that improve accessibility of module activities for differently-abled students.
- Made changes to the module format for ease in publishing the content.
- **Module 1. Perennial Grass Physiology, Growth, and Development** (lead author John Guretzky) status of components:
  - ✓ Seedling emergence activity accepted for publication in *Natural Science Education*.
- **Module 2. Perennial Grass Establishment and Management** (lead author John Guretzky) status of components:
  - ✓ Initial internal review completed and edits made to the module.
  - ✓ Filmed and edited demonstration on use of frequency grid to determine perennial grass establishment success.
- **Module 3. Perennial Grass Harvest Management**. (Lead authors Pat Murphy, CenUSA CoPd and Iman Beheshti Tabar) status of components:
  - ✓ We are conducting the internal review for the mowing and conditioning lesson.
  - ✓ We have developed an additional lesson for sizing of biomass harvesting equipment.
- **Module 4. Storage Management.** (Lead authors Pat Murphy and Iman Beheshti Tabar) status of components:

  Continued module development activities with Amy Kohmetscher.

- **Module 5. Integrating Bioenergy Production into Current Systems**. **(**Lead author Nicole Olynk Widmar) status of components:

- ✓ Recording Camtasia lectures from PowerPoint slides
- ✓ Continued module development activities with Amy Kohmetscher.

- **Module 6. Balancing Energy Demand with Food, Feed and Fiber Needs** (lead author Nicole Olynk Widmar) status of components:
  - ✓ We are recording Camtasia lectures from PowerPoint slides
  - ✓ Continued module development activities with Amy Kohmetscher
- **Module 7. Introduction to Perennial Grasses as a Feedstock** (lead author John Guretzky) status of components:

  Finished conversion of webinar into lesson.
- **Module 8. Ecosystems Services for Dedicated Bioenergy Crops** (lead authors David Schlueter and Patrick Murphy)
  - ✓ Developed module content outline

3. **Explanation of Variance**

Significant changes in the format of Module 3 needed to be made for ADA compliance prior to submittal for internal and external review. These changes have been made and will not affect the schedule, plan of work or budget.

4. **Plans for Next Quarter**

- **Module 3. Perennial Grass Harvest Management**
  - ✓ Submit machinery lessons to *Journal of Natural Sciences Education* for peer review.
  - ✓ Continue module development activities with Amy Kohmetscher for harvest management and machinery sizing lessons.
- **Module 4. Storage Management**

  Continue module development activities with Amy Kohmetscher.
- **Module 5. Integrating Bioenergy Production into Current Systems**

  Continue module development activities with Amy Kohmetscher.
- **Module 6. Balancing Energy Demand with Food, Feed and Fiber Needs**

  Continue module development activities with Amy Kohmetscher.

- **Module 8: Ecosystems Services for Dedicated Bioenergy Crops**

  Begin outlining module content

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

   None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. **Planned Activities**

   - Continue to promote the undergraduate internship program and encourage application submissions through March 15, 2013 application deadline.
   - Centrally vet and rank applicants based on letter of interest, academic achievement, previous research experience and letters of recommendation.
   - Pool of likely candidates given to faculty hosts for review during week of March 18, 2013 with selection decisions by March 25, 2013.
   - First offers to students on March 25, 2013; second offers to students on April 1, 2013 with cohort (11 students) finalized on April 15, 2013.
   - Arrange travel for accepted students.
   - Secure housing for students who will be placed with faculty mentors at partner institutions.

2. **Actual Accomplishments**

   - Robust promotion of the program yielded a pool of highly qualified applications by the March 22, 2013 deadline (we extended the original March 15, 2013 deadline by one week).
   - Central vetting and ranking of the applications was completed on March 28, 2013.
   - Pool of likely candidates given to faculty hosts for review on March 29, 2013; selection decisions provided back by April 8, 2013.
   - Student phone interviews with Raj Raman took place the week of April 8, 2013.
   - First offers extended in early April, second offers in mid-April, and a cohort of ten students finalized in late April 2013.

3. **Explanation of Variance**

- The original deadline of March 15 extended to March 22, 2013 to allow for submission of applications from the Nebraska Indian Community College.
- With the extension of the program from eight-weeks to ten-weeks (to ensure a full research internship experience for the student), we will have ten students in the 2013 cohort rather than 12.

4. Plans for Next Quarter

- Finalize all logistics; student travel, lodging at Iowa State and all three partner institutions (University of Minnesota, University of Nebraska, Lincoln, and Idaho National Labs), and administration of stipends.
- Provide mentor training using a 15-minute video (created by Raj Raman). We will share the link with the internship mentors (faculty/grad student/post doc) in mid-May, followed by a combined face-to-face (for ISU-based mentors) and virtual (via WebEx for partners) meeting to clarify any questions and concerns.
- Launch the program on May 28, 2013 with the arrival of the students. Run the orientation at Iowa State from May 29 – June 1, 2013; send students to appropriate lab placements for start date on June 3, 2013; schedule weekly meetings (June 5 – July 24) with student interns to discuss progress, face-to-face for ISU students and virtual (via WebEx) for partner-placement students.

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Subtask 2B – Training Graduate Students via Intensive Program

1. Planned Activities

- We will compile a list of intensive program attendees.
- We will provide faculty with full program agenda and details of each objective leaders' responsibilities for their portion of the intensive program.
- We will arrange travel for graduate student participants and faculty presenters.

2. Actual Accomplishments

- We compiled list of intensive program attendees.
- We provided faculty with full program agenda and details of each objective leaders' responsibilities for their portion of the intensive program.

- We arranged travel for graduate student participants and faculty presenters.

3. Explanation of Variance

Not applicable.

4. Plans for Next Quarter

- Finalize list of intensive program attendees
- Gather final presentation titles and field experience description and details from faculty presenters
- Request final exam questions from each of the objective areas
- Finalize all logistics (travel, Iowa State accommodations for graduate student attendees and non-ISU faculty presenters, opening reception, poster session and closing awards luncheon)
- Launch the Intensive Program:

✓ **Sunday, June 9:**

Participants arrive at Iowa State in the afternoon

6:00 PM: Welcome Dinner and Overview of Program

7:00 PM – 8:00 PM: Grad Student Research Poster Session

✓ **Monday, June 10:**

9:00 AM – 11:30 AM: Objective 1 – Feedstock Development lecture by Ken Vogel

1:00 PM – 4:00 PM: field tours at the ISU Agronomy Farm led by Ken Moore and Ken Vogel

✓ **Tuesday, June 11:**

9:00 AM – 11:30 AM: Objective 2 – Field Level Sustainability lecture by Rob Mitchell

1:00 PM – 4:30 PM: Biochar field tour led by David Laird and Doug Karlen

✓ **Wednesday, June 12**

9:00 AM – 11:30 AM: Seminar – Responsible Conduct of Research by Dr. Clark Wolf, ISU Center for Bioethics

1:00 PM – 4:00 PM: Objective 3 – Feedstock Logistics lecture followed by BioCentury Research Farm tour by Stuart Birrell

- ✓ **Thursday, June 13:**

  9:00 AM – 11:30 AM: Objective 5 – Feedstock Conversion/Refining lecture by Robert Brown

  1:00 PM – 4:00 PM: lab experience at the Biorenewables Research Lab led by Robert Brown and staff

- ✓ **Friday, June 14:**

  8:00 AM – 10:00 AM: Objective 7 – Health and Safety lecture by Mark Hanna

  10:15 AM – 12:00 PM: Objective 9 – Extension and Outreach lecture/visioning exercise led by Jill Euken

  1:30 PM – 3:00 PM: Industrial Advisory Board Panel Session moderated by Raj Raman

- ✓ **Saturday, June 15:**

  9:00 AM – 12:00 PM: Teams of 5-8 grad students discuss challenges presented by the Industrial Advisory Board

  1:00 PM – 3:00 PM: Teams report on response to challenges to Ken Moore, Raj Raman, and Patrick Murphy

- ✓ **Sunday, June 16:**

  Free Day – Recreation Option – a guided Boone River canoeing trip

- ✓ **Monday, June 17:**

  9:00 AM – 11:30 AM: Objective 4: System Performance lecture by Jason Hill

  1:00 PM – 3:30 PM: Objective 6: Markets and Distribution lecture by Keri Jacobs

- ✓ **Tuesday, June 18:**

  9:00 AM – 12:00 PM: Final Exam

  12:00 – 1:00 PM: Awards Luncheon

  1:00 PM: Participants depart Iowa State

5. Publications, Presentations, and Proposals Submitted

None to report this period

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

1. Planned Activities

- Organize the first three research webinars.
  - ✓ Objective 1 – February 22
  - ✓ Objective 2 – March 29
  - ✓ Objective 3 – April 25

2. Actual Accomplishments

- Held Objective 1. *Feedstock Development* research webinar on February 22, 2013:
  - ✓ *Twenty Years of Switchgrass Improvement to Create a Dedicated Bioenergy Crop* by Michael Casler.
  - ✓ *Genomic Selection to Improve Biomass Yield of Switchgrass* by graduate students Emily Rude and Guillaume Ramstein.
- Held Objective 2. *Sustainable Feedstock Production Systems* research webinar on March 29, 2013:
  - ✓ *Biochar mediated changes in soil quality, nutrient uptake, and maize yield in tow ongoing field trials* by Natalia Rogovska.
- Held Objective 3. *Feedstock Logistics* research webinar on April 25, 2013:
  - ✓ *Perennial grass feedstock logistics* by Kevin Shinners and Stuart Birrell.

3. Explanation of Variance

Not applicable.

4. Plans for Next Quarter

- Considering the heavy load we have with educational programming (10 undergraduate research interns, and the delivery of the graduate Intensive Program on June 9-18, we are holding off on any CenUSA research seminars until the monthly CoPd meeting scheduled for August 30, 2013.

- Since we have completed seminars on objectives 1-3, we will pick up in August with Objective 4.
- Begin organization of next three webinars (Objectives 4-6) to be delivered Aug – October 2013.

5. Publications, Presentations, and Proposals Submitted

Guretzky, John, Kohmetscher, Amy & Namuth-Covert, Deanna. (2013) Grass Seed Structure and Seedling Emergence. *Nat. Sci. Educ.* 42:1-1. doi:10.4195/nse.2012.0018w

Objective 9. Extension and Outreach

The Outreach and Extension Objective (Objective 9) 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.

- **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 will focus on the development of crop enterprise decision support tools to analyze the economic possibilities associated with converting acreage from existing conventional crops to energy biomass feedstock crops.

- **Health and Safety Team**

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

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

  This team focuses on two separate areas:

  ✓ **Youth Development.** The emphasis is on developing a series of experiential programs for youth that introduce the topics of biofuels production, carbon and nutrient cycling, and biochar as a soil amendment.

  ✓ **Broader Public Education/Master Gardener.** These programs acquaint the non-farm community with biofuels and biochar through a series of outreach activities using the Master Gardener volunteer model as the means of introducing the topics to the public.

- **Evaluation/Administration Team**

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

1. Extension Staff Training/eXtension Team

a. Planned Activities

✓ One webinar for Extension Educators

✓ One article and one fact sheet

✓ Conference grant application

✓ Extension Energy Summit presentation

b. Actual Accomplishments

✓ Organized and held the webinar "Thermochemical Conversion of Biomass to Drop-In Biofuels" for Extension Educators, producers and industry professionals.

✓ Hosted the "Farm Energy Education Case Studies" seminar (22 participants).

✓ Taught one presentation at the Extension Energy Summit in Colorado (April 29-May 1, 2013,Colorado State University – Fort Collins, CO).

- ✓ Participated in round-table conversations with extension delegates from five of the six NIFA Bioenergy CAPS, addressing issues and successes of projects and how to work together (8 participants) at the Extension Energy Summit in Colorado.
- ✓ Completed an extension article "Setting Up A Perennial Grass Energy Crop Demonstration Plot."
- ✓ Prepared a conference grant application to AFRI for a 2014 National Bioenergy and Environment Summit for University Extension, not-profit conservation leaders and agricultural and natural resource outreach and policy professionals.

c. Explanation of Variance

We did not experience any variance from our expected plans.

d. Plans for Next Quarter.

- ✓ We will begin building CenUSA Image gallery in the eXtension website (http://farmenergymedia.extension.org). The goal for the quarter is 30 images.
- ✓ We will identify CenUSA topics for the "eXtension Ask an Expert" function and identify specialists to provide responses to incoming questions.
- ✓ We will continue planning for the 2014 Extension Energy Summit.

e. Publications, Presentations, Proposals Submitted

"Establishing and Managing Perennial Grass Energy Crop Demonstration Plots."

2. Producer Research Plots/Perennial Grass Team

a. Planned Activities

- ✓ Monitor emergence from on-farm plots established in Year 1.
- ✓ Finalize arrangements with farmers who are establishing on-farm plots in Year 2.
- ✓ Arrange for seed, fertilizer, herbicides, etc. for plots.

b. Actual Accomplishments

- ✓ **Iowa**.
  - o The spring has been wet and cold.
  - o We continued monitoring the Year 1 plot.

- We burned about 20% of 2012 plot in early May 2013.
- We established a second plot at Iowa State University's Southeast Demo Farm on May 21, 2013. We planted into tilled corn residue. We will spray with herbicide last part of May 2013.

✓ **Nebraska**.

- We continued monitoring the Year 1 plot.
- We burned and assessed the stand and interseeded where needed.
- We sprayed plots with Paramount and Atrazine and applied nitrogen fertilizer according to protocol.
- The second year site at Milford has been planted, sprayed and applied according to protocol. We will take stand counts in June 2013.

✓ **Indiana**.

- A Year 2 plot will be planted late May or early June 2013 at the FFA Leadership Center.
- We are evaluating the need to reseed the first plot in North Central Indiana.
- A field day is planned for June 21, 2013 in cooperation with the Indiana Forage Council. The field day will include a tour of the Year 1demonstration site, stand counts, and seed drill calibration.

✓ **Minnesota**

- Spring has been late and wet.
- The Year 2 demonstration plot is ready to be seeded and will likely be seeded at the end of May 2013 or in the first part of June depending on weather.
- Erosion and stand establishment issues at the Year 1 site may lead to limited data from that location (Note: poor stand is its own teaching tool as soil type, topography, etc. make for challenging stand establishment).

c. Explanation of Variance

We did not experience any variance from our expected plans.

d. Plans for Next Quarter

- ✓ We will continue demonstration plot establishment processes (herbicide treatments, etc.).
- ✓ We will a co-host for the June 21, 2013 *Indiana Forage Day* field day in Indiana (co-hosted by the Miami County Soil and Water Conservation District and the Indiana Forage Council, - See more at: http://www.thecropsite.com/news/13946/forage-day-to-cover-bioenergy-crop-uses#sthash.oUNFeZGG.dpuf)
- ✓ We will complete final revisions and publish "Switchgrass Weed Control"; and "Switchgrass Nutrient Management."
- ✓ We will run quarterly Google Analytics on eXtension CenUSA pages and maintain and update the index.
- ✓ We will host two webinars. The tentative topics are: entomology and plant pathology related to perennial grass production for biofuel production.
- ✓ We will gather raw footage for two videos (entomology, water quality or plant pathology).
- ✓ We will write and produce a fact sheet related to hydro-ecological and water quality benefits of perennial grasses.
- ✓ We will convert eXtension e-electronic fact sheets to PDF format.

e. Publications, Presentations, Proposals Submitted

- ✓ The eXtension Farm Energy website has published "Index: Resources from CenUSA - Sustainable Production and Distribution of Bioenergy for the Central USA" (http://www.extension.org/pages/68136).[4] Access these newly published resources through the index:
- ✓ **Fact Sheets, Guides and Articles**
  - Switchgrass (*Panicum virgatum* L.) for Biofuel Production
  - Switchgrass (*Panicum virgatum* L.) Stand Establishment: Key Factors for Success
  - Logistical Challenges to Switchgrass (*Panicum virgatum* L.) as a Bioenergy Crop
  - Test Plots Show How Perennial Grasses Can Be Grown for Biofuels
  - How to Successfully Harvest Switchgrass Grown for Biofuel

[4] These resources are also available through other CenUSA sites such as the CenUSA website and the YouTube and Vimeo CenUSA channels.

- ✓ **Research Summaries**
  - Biochar Can Improve the Sustainability of Stover Removal for Bioenergy
  - Biofuel Quality Improved by Delaying Harvest of Perennial Grass
- ✓ **Frequently Asked Questions - FAQs**
  - Why is it important to be able to grow a consistent and uniform supply of a biomass feedstock?
  - Should I fertilize switchgrass when I plant it?
  - When should I plant switchgrass?
  - Will switchgrass grow well in my region?
  - How can I get a switchgrass crop to dry faster in the field once it's been cut?
  - How high should I cut switchgrass? I am growing it as a bioenergy crop.
  - Can I use my regular haying equipment to harvest switchgrass grown as a biofuel?
  - How can I reduce dry matter losses to a biomass crop during storage?
- ✓ **CenUSA** Video **Channels**
  - **Vimeo Channel** (https://vimeo.com/cenusabioenergy). This social media/video channel continues to have impact. During this quarter the 23 CenUSA videos archived on Vimeo have 153 Vimeo plays (without loads) and 5,666 loads. CenUSA videos were embedded on various web pages 2,881 times this quarter, meaning that people are sharing the CenUSA videos with others through their own pages. All total, 8,547 people were exposed to the CenUSA project.
  - **YouTube Channel** (www.youtube.com/user/CenusaBioenergy). There were 940 total "views" of CenUSA videos during this quarter for a total of 3140 minutes. We also gained 6 new channel subscribers for a total of 21 subscribers.

3. Economics and Decision Tools

a. Planned Activities

Build spreadsheet model to help evaluate economic and environmental impacts of switching marginal land in MN to switchgrass.

b. Actual Accomplishments

A spreadsheet model was developed and a first run was completed. The model will be available in the summer of 2013.

c. Explanation of Variance

We did not experience any variance from our expected plans.

d. Plans for Next Quarter

We will continue planning for the CenUSA/Mississippi River Basin Watershed Nutrient Taskforce joint workshop (including economics/environmental sessions), tentatively scheduled for September 23-25, 2013 in Minneapolis, Minnesota (http://water.epa.gov/type/watersheds/named/msbasin/index.cfm).

e. Publications, Presentations, Proposals Submitted

Spreadsheet model (See above).

4. Health and Safety

See Objective 7 report above.

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

a. Planned Activities – Youth Development

- ✓ Plan a 4-H science workshop.
- ✓ Develop e-learning modules for high school aged learners.
- ✓ Get biochar activities into second Indiana classroom at local middle school utilizing relationships established during the previous quarter.
- ✓ Complete youth biofuel fact sheets.

b. Actual Accomplishments – Youth Development

- ✓ Workshop planning is nearly complete and we are ready for students to arrive in June 2013.
- ✓ eModules are under development.
- ✓ Development of school based programing lessons and activities are underway.
- ✓ Youth biofuels fact sheets are with editor.

- ✓ We have hired undergraduate students to assist with various aspects of project.
- ✓ We are meeting with the state FFA Executive Director regarding establishment of the educational test plot.

c. Explanation of Variance

No variance has been experienced and accomplishments are on schedule.

d. Plans for Next Quarter

- ✓ We will complete the 4-H Science Renewable Energy Workshop.
- ✓ We will continue the expansion of the online modules and lesson plans. We will further develop the working outline for 4-H curriculum and school-based activities.
- ✓ We will finish the youth biofuels fact sheets.
- ✓ We will evaluate the data from 4-H Science Workshop.

e. Publications, Presentations, Proposals Submitted

- ✓ The youth biofuels fact sheets are with editor.
- ✓ We have submitted an abstract for presentation at National Science Teachers Association National Conference in 2014.

3.B Broader Public Education/Master Gardener Program

a. Iowa

- ✓ **Planned Activities**
  - o We will hold an Adobe Connect meeting, "Biochar 101" for Muscatine County Master Gardeners on March 12, 2013 for recruitment of MG volunteers for the biochar project.
  - o We will hold the "Biochar 101" presentation for the Cass County Master Gardener potluck meeting on March 26, 2103 for volunteer recruitment. We invited Bernie Havlovic of the Armstrong Research Farm to attend and report on 2012 biochar activities to the group.
  - o We will present "Biochar 101" for Boone County Master Gardener meeting on April 8, 2013 to recruit volunteers.

- We will present "Biochar 101" at Story County Master Gardener meeting on April 8, 2013 to recruit volunteers.

✓ **Actual Accomplishments**

- We prepared the presentation "Biochar 101."
- We tested the Adobe Connect session with the Muscatine group two hours prior to meeting time, with everything working fine. At start of meeting, excessive feedback situation forced shutdown of the session.
- We held the "Biochar 101" presentation at the Cass County ISU Extension Office meeting on March 26, 2013 for volunteer recruitment with 32 people in attendance. Obtained a sign-up of 17 Master Gardeners interested in volunteering for the CenUSA project.
- We presented "Biochar 101" at the Boone County ISU Extension Office on April 8, 2013 with 8 potential volunteers attending. Three Master Gardeners volunteered to help with the CenUSA project.
- We presented "Biochar 101 at the Story County ISU Extension Office in Nevada, with approximately 40 people attending on April 14, 2013. Fifteen Master Gardeners signed up to help with the CenUSA biochar gardens.
- We planted test plot seeds and took photos.
- We transplanted seedlings to six packs.
- We had a telephone meeting with CenUSA Youth Horticulture team on April 1, 2013.

✓ **Explanation of Variance**

- The Muscatine, Iowa Adobe Connect meeting was not held as scheduled due to excessive audio feedback and high pitched squealing that could not be corrected.

✓ **Plans for Next Quarter**

- We will hold meeting with Minnesota CenUSA team to discuss planting, data collection and reporting.
- We will sort test plot plants for shipping to the three Iowa sites.
- We will plant test plots at the three Iowa location with Master Gardener assistance.

- We will hold follow-up trainings at each test site to instruct Master Gardeners in proper data collection and reporting expectations.
- We will develop reporting methods for data collection.
- We will obtain volunteer t-shirt and glove sizes and distribute to each group.

b. Minnesota

✓ **Planned Activities**

- We will order seeds for biochar garden sites; contract with grower to start some of the seeds early.
- We will recruit volunteers for biochar garden sites in Minnesota.
- We will update applications, position descriptions and procedures for volunteers.
- We will participate in CenUSA Extension Staff Training team phone meeting on April 1, 2013 to review upcoming activities.
- We will participate in the Anoka County Extension Master Gardeners Home Landscaping and Garden Fair event on April 13, 2013. A non-staffed biochar exhibit will be put on display.
- Kurt Spokas will develop a webinar explaining what biochar is and where it comes from for the purpose of training volunteers.
- We will order more biochar from Royal Oak for the new site.

✓ **Actual Accomplishments**

- We ordered seeds for the biochar garden sites and contracted with grower to start some of the seeds early.
- We recruited 35 volunteers for the CenUSA biochar garden sites in the Twin Cities metro and another 22 volunteers and staff for the Fond du Lac site.
- We updated volunteer applications, position descriptions and procedures.
- We held Extension Team meeting on April 2013 to review upcoming activities.
- We set up a CenUSA Biochar Horticulture exhibit at the Anoka County Extension Master Gardeners Home Landscaping and Garden Fair and provided a sign-up sheet so visitors could obtain additional information. Five people requested

additional information. The CenUSA Master Gardener Annual Report and the CenUSA website were sent within one week of the event.

- Kurt Spokas developed a webinar explaining what biochar is and how it is produced for the purpose of training volunteers in late May 2013.
- We arranged for another 450 lbs. of biochar to be shipped from Royal Oak (Royal Oak donated the biochar; project covered the cost of shipping).

✓ **Explanation of Variance**

No variance has been experienced and accomplishments are on schedule.

✓ **Plans for Next Quarter**

- We will hold a meeting with the Iowa CenUSA Master Gardener team in Clear Lake Iowa on May 6, 2013.
- We will hold a local Extension Master Gardener site leader meeting on May 15, 2013.
- We will plant three metro gardens during the week of May 20, 2013.
- We will apply biochar to the new Fond du Lac Reservation site in late May or early June 2013.
- Plant new Fond du Lac Reservation site in early June 2013.
- Conduct soil tests for each site.
- Prepare biochar exhibits for local county fairs and events and the 2013 Minnesota State Fair.
- Blog about progress at the gardens.
- Attend the CenUSA Annual meeting in Indiana in July.
- Participate in the Extension team phone meeting on June 3rd.
- Collect data on select plants in the gardens May, June, and July.

✓ **Broader Public Education/Master Gardener Program - Publications, Presentations, Proposals Submitted**

- eXtension blog about the CenUSA Biochar Gardens.

- Draft Kurt Spokas presentation on "Biochar: What is it?"
- Updated Master Gardener volunteer position description and application.
- Updated Master Gardener volunteer tool "Data Collection Instructions and 2013 Harvest Dates: CenUSA Biochar Project.
- "Biochar Utilization 101" presentation.

6. Evaluation and Administration

a. Planned Activities

- ✓ We will follow up with industry contacts who attended the December 2012 CenUSA workshop to finalize details regarding quantity and processing they want for the biomass samples.
- ✓ We will secure CenUSA perennial grasses and corn stover for industry collaborators from CenUSA Breeding and Agronomy teams.
- ✓ We will make arrangements to process the CenUSA biomass to ship to CenUSA industry collaborators.
- ✓ We will assist all CenUSA Extension staff members with developing, administering and tabulating evaluations.
- ✓ We will prepare grant application to submit to USDA NIFA conference grant.
- ✓ We will meet with Iowa Secretary of Agriculture and Land Stewardship Bill Northey to discuss a potential joint workshop between CenUSA and the Mississippi River Basin Watershed Nutrient Task Force.
- ✓ We will form a planning committee to develop the between CenUSA and the Mississippi River Basin Watershed Nutrient Task Force and plan and conduct meetings for the committee.

b. Actual Accomplishments

- ✓ We provided material to ADM.
- ✓ We secured and arranged for grinding of CenUSA biomass for shipment to KiOR.
- ✓ We secured and arranged for grinding of CenUSA biomass for shipment to Renmatix.
- ✓ We prepared and submitted grant application to USDA NIFA for an Extension Renewable Energy Summit in 2014.

- ✓ We participated in meeting of CAP Extension teams.
- ✓ We met with Secretary Northey to discuss the potential joint workshop between CenUSA and the Mississippi River Basin Watershed Nutrient Task Force.
- ✓ We formed a CenUSA - Mississippi River Basin Watershed Nutrient Task Force joint meeting planning committee meetings and held three meetings for the joint workshop.
- ✓ We finalized locations for the Joint Workshop and signed contracts with hotel for meeting rooms and hotel rooms.

c. Variance

No variance has been experienced and accomplishments are on schedule.

d. Plans for Next Quarter:

- ✓ We will continue meeting with and supporting Extension CenUSA teams.
- ✓ We will recruit industry collaborators to attend CenUSA Annual meeting.
- ✓ We will continue planning for the CenUSA and Mississippi River Basin Watershed Nutrient Task Force joint workshop.

e. Publications, Presentations, Proposals Submitted

A grant application to USDA-NIFA for 2014 Extension Renewable Energy Summit.

A Science Experiment in an 8th Grade Classroom: Growing Plants in Biochar vs. Regular Soil

Matthew Kararo, Doctoral Student, Purdue University,
Department of Youth Development and Agricultural Education

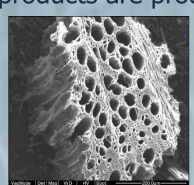
EXHIBIT 1

Introduction

As part of the Purdue GK-12 program, a lesson about biofuels and biochar was developed and taught in a classroom at Tecumseh Junior High School. This lesson took place in an 8th grade science classroom and had the students apply their basic chemistry knowledge in a scientific way by performing a plant science experiment in their classroom. Each lab group planted two pots with identical seeds, but different soils. One pot was filled with regular potting soil, while the other was filled with a biochar-soil mix. Biochar, as the students learned, increases the carbon content of the soil and can reduce the need for water and fertilizer. Students hypothesized if they would observe a difference between the two pots, and will test their hypotheses by recording their observations over the following months.

Research Connection

Before beginning the experiment, students watched a video about a process called pyrolysis, which occurs when plant material is heated to a very high temperature in a container without oxygen. Three products are produced, and they are:



Biochar under microscope

- Bio-oil, which can be refined into biofuels
- Biogas, which can be used like natural gas
- Biochar, which can be added to soil to increase soil quality

Pyrolysis is the next generation of technology being developed to produce biofuels (fuels made from plants). This technology can reduce our dependence on fossil fuels and offer a source of renewable energy. The entire production process, from growing the plants to the final products, is being studied by a group called CenUSA Bioenergy that includes Purdue University.

CenUSA is supported by Agriculture and Food Research Initiative Competitive
Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture.

Classroom Experiment

Biochar was premixed with soil and used as the treatment for the plant experiment. Approximately 10-20% of the mixture was biochar.

Each of the five classes broke into their lab groups. Each lab group planted identical seeds in two pots. One pot contained plain potting soil, while the other contained the biochar-soil mixture.

Students hypothesized what, if any, differences they would see between the two different soils in plant growth and production.

The pots were placed under plant lights in the classroom. Students water their pots almost daily, and record their observations weekly.

What's next?

Over the next few months, the students will be comparing the growth rates and plant production between their two pots. This will have them not only apply their science skills, but also their math skills by graphing plant growth rates. Stop by Mrs. Blocher's 8th grade science classroom and check it out!

Welcome

eXtension is an interactive learning environment delivering the best, most researched knowledge from the smartest land-grant university minds across America.

Find a U.S. Institution (#)

Exhibit 2

Resources from CenUSA - Sustainable Production and Distribution of Bioenergy for the Central USA

Last Updated: June 18, 2013

CenUSA Bioenergy (http://www.cenusa.iastate.edu/) is a coordinated research and education effort investigating the creation of a regional system in the Central US for producing advanced transportation fuels from perennial grasses 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 in soil and increasing carbon sequestration.

CenUSA Bioenergy researchers from Iowa State University, Purdue University, University of Wisconsin, University of Minnesota, University of Nebraska, University of Illinois and the USDA Agricultural Research Service cover topics of interest to producers and growers in the following resources. Learn more about the CenUSA Bioenergy Project.

Sponsoring Partner

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.

CenUSA Bioenergy Learning Modules - Table of Contents

Module 1. Feedstock Development

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- Switchgrass (Panicum virgatum) for Biofuel Production (/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production) ; Rob Mitchell, USDA-ARS

Webinars

- Switchgrass and Perennial Grasses, Biomass and Biofuels - Part 1 (http://farmenergymedia.extension.org/video/part-1-switchgrass-and-perennial-grasses-biomass-and-biofuels-captions) ; Ken Vogel, USDA-ARS
- Switchgrass and Perennial Grasses, Biomass and Biofuels- Part 2 (http://farmenergymedia.extension.org/video/part-2-switchgrass-and-perennial-grasses-biomass-and-biofuels) ; Ken Vogel, USDA-ARS
- Switchgrass Production Industry Perspectives (http://farmenergymedia.extension.org/video/david-stock-switchgrass-production-industry-perspectives) - David Stock, Stock Seed Farms

Module 2. Sustainable Feedstock Production

Fact Sheets

- Switchgrass (Panicum virgatum L) Stand Establishment: Key Factors for Success (/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success) ; Rob Mitchell (http://www.ars.usda.gov/pandp/people/people.htm?personid=31809) , USDA-ARS Grain, Forage, and Bioenergy Research Unit (http://www.ars.usda.gov/main/site_main.htm?modecode=54-40-20-00) , Lincoln, NE
- Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop (/pages/68053/logistical-challenges-to-switchgrass-panicum-virgatum-l-as-a-bioenergy-crop)
- Test Plots Show How Perennial Grasses Can Be Grown for Biofuels (/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels)

Webinars

- Switchgrass Establishment, Weed Control, and Seed Quality (http://farmenergymedia.extension.org/video/switchgrass-establishment-weed-control-and-seed-quality) – Rob Mitchell
- No-Till Drill Calibration Training Video (+Captions) (http://farmenergymedia.extension.org/video/no-till-drill-calibration-training-video-captions) – Rob Mitchell
- Switchgrass and Bioenergy Crop Logistics (http://farmenergymedia.extension.org/video/switchgrass-and-bioenergy-crop-logistics) – Stuart Birrell
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- Intro to No-Till Drill Calibration for Switchgrass (+Captions) (http://farmenergymedia.extension.org/video/intro-no-till-drill-calibration-switchgrass-captions) – Rob Mitchell
- Switchgrass Planting Practices for Stand Establishment (http://farmenergymedia.extension.org/video/switchgrass-planting-practices-stand-establishment) – Rob Mitchell
- How to Measure Stand Establishment Using a Grid (http://farmenergymedia.extension.org/video/how-measure-stand-establishment-using-grid) – John Gurtzky
- Harvesting Native Grass for Biofuel Production (+Captions) (http://farmenergymedia.extension.org/video/harvesting-native-grass-biofuel-production-captions) – Rob Mitchell
- Optimizing Harvest of Perennial Grasses for Biofuel (http://farmenergymedia.extension.org/video/optimizing-harvest-perennial-grasses-biofuel) – Kevin Shinners
- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird

Research Summaries

- Biochar Can Improve the Sustainability of Stover Removal for Bioenergy (/pages/68052/research-summary:-biochar-can-improve-the-sustainability-of-stover-removal-for-bioenergy) - David Laird
- Biofuel Quality Improved by Delaying Harvest of Perennial Grass (/pages/67841/research-summary:-biofuel-quality-improved-by-delaying-harvest-of-perennial-grass) - Emily Heaton

Module 3. Feedstock Logistics: Harvest & Storage

Fact Sheets

- Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop (/pages/68053/logistical-challenges-to-switchgrass-panicum-virgatum-l-as-a-bioenergy-crop) - Amy Kohmetscher; Stuart Birrell.
- How to Successfully Harvest Switchgrass Grown for Biofuel (/pages/68054/how-to-successfully-harvest-switchgrass-grown-for-biofuel) ; Kevin Shinners

Webinars

- Switchgrass and Bioenergy Crop Logistics (http://farmenergymedia.extension.org/video/switchgrass-and-bioenergy-crop-logistics) – Stuart Birrell

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- Harvesting Native Grass for Biofuel Production (+Captions) (http://farmenergymedia.extension.org/video/harvesting-native-grass-biofuel-production-captions) – Rob Mitchell
- Optimizing Harvest of Perennial Grasses for Biofuel (http://farmenergymedia.extension.org/video/optimizing-harvest-perennial-grasses-biofuel) – Kevin Shinners

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

Resources will be published later in the CenUSA Project, as research progresses.

Module 5. Feedstock Conversion and Biofuels Co-Products

Additional resources will be published later in the CenUSA Project, as research progresses.

Research Summary

- **Biochar Can Improve the Sustainability of Stover Removal for Bioenergy (/pages/68052/research-summary:-biochar-can-improve-the-sustainability-of-stover-removal-for-bioenergy)**

Webinars

- Thermochemical Conversion of Biomass to Drop-In Biofuels (http://farmenergymedia.extension.org/video/thermochemical-conversion-biomass-drop-biofuels) – Robert Brown
- Thermochemical Option: Biomass to Fuel (http://farmenergymedia.extension.org/video/thermochemical-option-biomass-fuel) – Robert Brown

Module 6. Markets and Distribution

Resources to be published later in the CenUSA Project, as research progresses.

Module 7. Health and Safety

Resources to be published later in the CenUSA Project, as research progresses.

"Formal" Educational Programs and Curriculum

In order to prepare the next generation of workers for the emerging bioeconomy, CenUSA is providing interdisciplinary training and engagement opportunities for undergraduate and graduate students; and developing a bioenergy curriculum core for the Central region of the United States.

Educational resources will be published later in the CenUSA Project, as research progresses.

Extension Programs

Upcoming CenUSA Webinars (https://learn.extension.org/events/tag/cenusa)

Archived CenUSA Webinars (http://farmenergymedia.extension.org/videos?type=webinar&field_terms_tid=All&keywords=cenusa&sort_by=field_video_date_value&sort_order=DESC)

Biochar Demonstration Gardens Report (http://blogs.extension.org/mastergardener/tag/cenusa-bioenergy/)

CenUSA Bioenergy Resources by MediaType

(same resources as above, but organized by type)

Fact Sheets, Guides and Articles

- Switchgrass (Panicum virgatum) for Biofuel Production (/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production)

- Switchgrass (Panicum virgatum L) Stand Establishment: Key Factors for Success (/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success)
- Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop (/pages/68053/logistical-challenges-to-switchgrass-panicum-virgatum-l-as-a-bioenergy-crop)
- Test Plots Show How Perennial Grasses Can Be Grown for Biofuels (/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels)
- How to Successfully Harvest Switchgrass Grown for Biofuel (/pages/68054/how-to-successfully-harvest-switchgrass-grown-for-biofuel)

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- Biofuel Quality Improved by Delaying Harvest of Perennial Grass (/pages/67841/research-summary:-biofuel-quality-improved-by-delaying-harvest-of-perennial-grass)

Archived Webinars (http://farmenergymedia.extension.org/videos?type=webinar&field_terms_tid=All&keywords=cenusa&sort_by=field_video_date_value&sort_order=DESC)

- Part 1: Switchgrass and Perennial Grasses, Biomass and Biofuels (Captions) (http://farmenergymedia.extension.org/video/part-1-switchgrass-and-perennial-grasses-biomass-and-biofuels-captions) – Ken Vogel
- Part 2: Switchgrass and Perennial Grasses, Biomass and Biofuels (http://farmenergymedia.extension.org/video/part-2-switchgrass-and-perennial-grasses-biomass-and-biofuels) – Ken Vogel
- Switchgrass Establishment, Weed Control, and Seed Quality (http://farmenergymedia.extension.org/video/switchgrass-establishment-weed-control-and-seed-quality) – Rob Mitchell
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- Switchgrass Production Industry Perspectives (http://farmenergymedia.extension.org/video/david-stock-switchgrass-production-industry-perspectives) - David Stock
- Thermochemical Conversion of Biomass to Drop-In Biofuels (http://farmenergymedia.extension.org/video/thermochemical-conversion-biomass-drop-biofuels) – Robert Brown
- Thermochemical Option: Biomass to Fuel (http://farmenergymedia.extension.org/video/thermochemical-option-biomass-fuel) – Robert Brown

Instructional Video (http://farmenergymedia.extension.org/videos?type=instruction&field_terms_tid=All&keywords=cenusa&sort_by=field_video_date_value&sort_order=DESC)

- 2012 CenUSA Bioenergy Overview (http://farmenergymedia.extension.org/video/2012-cenusa-bioenergy-overview)
- CenUSA Bioenergy-Opportunities in Biofuel (http://farmenergymedia.extension.org/video/cenusa-bioenergy-opportunities-biofuel)
- 2012 CenUSA Bioenergy Farmer Focus (http://farmenergymedia.extension.org/video/2012-cenusa-bioenergy-farmer-focus) - Kevin Ross
- Intro to No-Till Drill Calibration for Switchgrass (+Captions) (http://farmenergymedia.extension.org/video/intro-no-till-drill-calibration-switchgrass-captions) – Rob Mitchell
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- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird

Classroom Curriculum - see above (#Educational%20Programs%20and%20Curriculum)

Frequently Asked Questions - FAQs

- Why is it important to be able to grow a consistent and uniform supply of a biomass feedstock? (/pages/68135/why-is-it-important-to-be-able-to-grow-a-consistent-and-uniform-supply-of-a-biomass-feedstock)
- Should I fertilize switchgrass when I plant it? (/pages/68046/should-i-fertilize-switchgrass-when-i-plant-it-i-am-growing-switchgrass-as-a-bioenergy-crop)
- When should I plant switchgrass? (/pages/68045/when-should-i-plant-switchgrass)
- Will switchgrass grow well in my region? (/pages/68044/will-switchgrass-grow-well-in-my-region)
- How can I get a switchgrass crop to dry faster in the field once it's been cut? (/pages/68095/how-can-i-get-a-switchgrass-crop-to-dry-faster-in-the-field-once-its-been-cut)
- How high should I cut switchgrass? I am growing it as a bioenergy crop. (/pages/68094/how-high-should-i-cut-switchgrass-i-am-growing-it-as-a-bioenergy-crop)
- Can I use my regular haying equipment to harvest switchgrass grown as a biofuel? (/pages/68093/can-i-use-my-regular-haying-equipment-to-harvest-switchgrass-grown-as-a-biofuel)
- How can I reduce dry matter losses to a biomass crop during storage? (/pages/68134/how-can-i-reduce-dry-matter-losses-to-a-biomass-crop-during-storage)

CenUSA Bioenergy Overview

cenusa bioenergy

CenUSA is supported by Agriculture and Food Research Initiative (http://www.csrees.usda.gov/funding/afri/afri_synopsis.html) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

Browse related Articles by tag: ag energy (http://www.extension.org/category/ag_energy) , nifa (http://www.extension.org/category/nifa) , ag energy feedstocks (http://www.extension.org/category/ag_energy_feedstocks) , ag energy processing (http://www.extension.org/category/ag_energy_processing) , ag energy sustainability (http://www.extension.org/category/ag_energy_sustainability) , cenusa (http://www.extension.org/category/cenusa) , afri (http://www.extension.org/category/afri) , ag energy pyrolysis (http://www.extension.org/category/ag_energy_pyrolysis) , ag energy biochar (http://www.extension.org/category/ag_energy_biochar) , ag energy logistics (http://www.extension.org/category/ag_energy_logistics)

This resource area was created by the: Farm Energy (http://www.extension.org/pages/26624/farm-energy-community-page) community

Exhibit 3

Establishing and Managing Perennial Grass Energy Crop Demonstration Plots

Researchers, farmers, and industry representatives across the country are interested in testing the performance of energy crops. Setting up a test plot in your region can be useful in showing producers the potential for growing bioenergy feedstocks on their farms. The test plot can demonstrate best management practices and yield potential as well as how to establish perennial grasses quickly and economically. Additionally it can also demonstrate differences between the forage and bioenergy strains of various perennial grasses. Here are suggestions from CenUSA researchers for establishing your own energy crop test plot.

CenUSA Researchers:
Rob Mitchell is a research agronomist with USDA-ARS and a professor of agronomy at the University of Nebraska-Lincoln. *Jeffrey Volenec* is a professor of agronomy at Purdue University. Their role in the CenUSA project is analyzing both the agronomic potential and environmental impacts of promising bioenergy crops and management systems using a network of fourteen fields strategically located across the Central United States. So far, the project has established test plots on marginally productive land (land considered marginal for row crop production) in Illinois, Indiana, Iowa, Minnesota, Nebraska and Wisconsin. *Pamela Porter* is an Outreach Specialist for the University of Wisconsin. She assists CenUSA in developing science based materials for Extension educators and the agricultural and horticultural industry.

Choosing and Setting Up a Test Plot Site
Each site should be a size that would work on a farm. As such, there are no standard dimensions, but CenUSA recommends a minimum plot size of one-fourth acre for each species. Planting and harvesting are facilitated best by planting long narrow strips, like those used in most row crop yield trials.

Select the species and cultivars of perennial grasses you are interested in testing. You might wish to evaluate one species of grass or mixtures of grass species. Seed each plot with high-quality, certified seed. The interest of your audience and geographic location will determine which perennial

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Extension and Outreach
Ames, Iowa | May 2013

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CenUSA bioenergy, a USDA-funded research initiative, is investigating the creation of a sustainable Midwestern biofuels system.

Research Partners
Iowa State University - Lead
USDA Agricultural Research Service (ARS)
Purdue University
University of Illinois
University of Minnesota
University of Nebraska - Lincoln
University of Vermont
University of Wisconsin

www.cenusa.iastate.edu

grasses to plant and which cultivars to select, but a good selection of perennial grasses for the Great Plains and Midwest could include:

- Switchgrass
- Big bluestem
- Indiangrass
- A low-diversity mixture, such as switchgrass, big bluestem, indiangrass, and sideoats grama
- A high-diversity mixture of approximately 10 species including native grasses, legumes, and forbs.[1]

Perennial grasses like switchgrass are among energy crops that are high yielding and provide conservation benefits. Photo: Pamela Porter

Switchgrass (*Panicum virgatum*) is a warm-season perennial grass native to the tall-grass prairie region of the U.S. (an area commonly known as the cornbelt). It is considered the leading grass energy crop because of its ease of propagation, high yield potential, compatibility with conventional farming, low input requirements, and excellent conservation and wildlife attributes (Kszos et al., 2000). Other perennial grasses being evaluated for energy use include big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), and prairie cordgrass (*Spartina pectinata*). Miscanthus (*Miscanthus x giganteus*) is a high-yielding, non-native perennial grass feedstock that may fit well in many areas. However, it may not offer as many conservation attributes as one of the native perennial grasses.

Establishment

In the central Great Plains and Midwest, time planting for two to three weeks before or after the optimum corn-planting date—earlier is better than later. Seed at a rate of 30 pure live seed (PLS) per square foot planted 1/4- to 1/2-inch deep in 6- to 7-inch rows. This is typically 4 to 6 pounds per acre of PLS. If you're seeding small plots, seed from the center of alley to the center of alley to ensure complete seed coverage in the plot. Make sure the drill is calibrated accurately. You can find two videos explaining how to calibrate a drill here:
Drill Calibration Walk Through (4:59 min)
No Till Drill Calibration Training Video (20:06 min)

For plantings that include big bluestem or indiangrass which have fluffy (or chaffy) seeds, use a no-till drill with a seed box attachment for chaffy seeds. Switchgrass seed is clean, flows easily and doesn't require a seed box attachment for chaffy seed. No-till seed into soybean stubble or clean-tilled field and pack firmly enough to leave a faint footprint in the soil when you walk on it. If tillage is used, prepare the seedbed as you would for alfalfa.

If you don't have grass-seeding equipment, contact your local Extension or USDA Natural Resource Conservation office, or a local equipment dealer. Conservation organizations such as Ducks Unlimited, Pheasants Forever, or The Nature Conservancy may have information on native grasses and or equipment you can borrow or rent. They may also have volunteers who can assist you. A video that demonstrates planting switchgrass and other native warm-season grasses is available at:
Switchgrass Planting Practices for Stand Establishment (5:16 min)

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[1] In terms of sustainability, ecologists are interested in maximizing the diversity of seeding mixtures for energy crops.

Weed Management
Compared to cool-season grasses, establishing a warm-season grass stand takes more weed management. Weed competition is one of the biggest reasons warm-season grass seedings fail, so weed control in the seeding year is very important, both during and after seeding (Mitchell et al., 2008). Manage weeds in switchgrass with a pre-emergent application of 1 quart of atrazine plus 8 ounces per acre of quinclorac (Paramount®). On big bluestem, indiangrass, and sideoats grama, use a pre-emergent application of 4 ounces per acre of imazapic (Plateau®). On all plots, control broadleaf weeds in the seeding year by mowing in July and/or spraying with one to two quarts per acre of 2,4-D. Biomass grown during the seeding year can be harvested or grazed after a killing frost or left standing in the field over winter. If the residue is left standing over winter, mow the residue for hay or burn before spring greenup.

CenUSA researcher and University of Nebraska's Dr. Ken Vogel is one of the country's leading plant breeder's of native grasses. Photo: Pamela Porter

Always read and follow label directions, and contact your local Extension agent for issues specific to your area—pesticides may not be approved in all states for these purposes.

Harvesting
It is recommended to harvest perennial grasses used for biomass in the fall, after a killing frost. Waiting until after frost allows carbohydrates and nitrogen to be translocated from leaf and stem tissue to roots, increasing plant winter hardiness and reducing future nitrogen fertilizer needs. For large yield trials, harvest each feedstock with field-scale haying equipment (swather and baler). Be sure to bale each plot individually to properly track the yield for each plot. Count and weigh the individual bales to determine the yield for each feedstock. Adjust the yield to a dry matter (DM) basis (see below) in tons of DM per acre.

For small plots, mow alleys to less than a 4-inch stubble height. Determine biomass by cutting and weighing a 3-foot wide swath the length of each small plot, using a flail-type plot harvester with a cutting height of 4 inches. Determine the harvested area in square feet and convert the yield estimate to tons per acre. Do not harvest the outer edges of the plots, to reduce border effects. Weigh the harvested material immediately in the field. If a flail-type plot harvester is not available, clip material by hand from a 3' x 3' quadrat to a 4-inch stubble height, weigh the material, and convert yield to DM tons per acre.

To determine dry matter weight, take a subsample of biomass from each plot, weigh and dry each sample at 120 to 130 F (50 degrees C) for at least 72 hours in a forced-air oven. Then reweigh to determine the dry matter (DM) concentration. (Mean DM concentration of these samples will be used to adjust field biomass to an oven dry basis; the oven-dry weight of the hand-collected material will be added back to the harvested material to accurately represent plot biomass). You can find out more about harvesting switchgrass in these two CenUSA videos:
Optimizing Harvest of Perennial Grasses for Biofuel (4:50 min)
Harvesting a Native Grass for Biofuel Production (2:58 min)

Testing Plant Quality

If you are interested in having your plants tested for their fiber or mineral content, collect subsamples prior to harvest, using hand clippers. Clip samples to a 4-inch stubble height from multiple locations within each plot, dry the samples as described above. Use a Wiley mill to grind the samples to pass a 20 to 40 mesh (1 to 2 millimeter) screen. Mix up the ground material. Take several scoops of the ground material (approximately one third of a quart-sized ziplock bag) to make a representative subsample. Send the subsample to a plant anlysis laboratory for testing.

A frequency grid is a simple method for estimating the success of your stand. Photo: CenUSA Bioenergy

How Well is the Stand Doing?

Immediately after harvest, evaluate plant populations using a frequency grid (Vogel and Masters, 2001). Make a frequency grid from a piece of concrete remesh with 6-inch-by-6-inch squares. Cut the remesh into a 5-by-5 square grid containing a total of 25 squares.

Evaluate your stand in the first year, after the grass plants have three to four leaves and are easy to see. Choose at least four locations in the field. At each location place the frequency grid on the ground and count the number of squares that have a grass plant contained inside the square. Record that number. Squares that contain plants count as one (1). Squares without plants count as zero (0). Only those squares that have the base of a plant located inside the square are counted.

Total the 100 squares to calculate the stand frequency percentage for that location. For example: 15 plants/25 squares + 17 plants/25 squares + 23 plants/25 squares + 20 plants/25 squares = 75 plants/100 squares or 75%. This means that 75% of that location had a grass plant growing in it.

Repeat the process at three other locations in your field to calculate an average stand frequency. A stand frequency of 50 percent or greater indicates a successful stand. A stand frequency between 25 and 50% is marginal to good. Stands with less than 25 percent frequency should be reseeded.

A video demonstrating the use of the frequency grid is available on the CenUSA website here:
How to Measure Stand Establishment Using a Grid (9:05 min)

References:

Kszos, Lynn Adams, M.E. Downing. L.L. Wright, J.H. Cushman, S.B. McLaughlin, V.R. Tolbert, G.A. Tuskan and M.E. Walsh. Bioenergy Feedstock Development Program Status Report. Environmental Sciences Division Publication Number 5049. Oakridge National Laboratory. (2000).

Mitchell, Rob, K.Vogel and G. Sarath. Managing and Enhancing Switchgrass Grown as a Bioenergy Feedstock. Biofuels, Bioproducts and Biorefining. 2:530-539 (2008).

Vogel, Kenneth P. and R.A. Masters. Frequency Grid: A Simple Tool for Measuring Grassland Establishment. Journal of Range Management. 54:653-655 (2001).

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 4

Research Summary: Biochar Can Improve the Sustainability of Stover Removal for Bioenergy

Last Updated: May 07, 2013

By returning biochar created by fast pyrolysis to the soil, more stover residue can be harvested for bioenergy without degrading soil quality or hurting crop yields in the long run.

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Research Activities

Biochar being incorporated by tillage.

Photo: David Laird, Iowa State University.

David Laird, professor of agronomy at Iowa University, hypothesized that biochar could be used as a soil amendment to enhance the sustainability of stover harvest. Biochar helps maintain soil quality; it can also help mitigate greenhouse gas emissions and climate change by sequestering carbon in the soil.

Biochar was surface-applied at a rate of 10 tons per acre on 16 large plots at the Iowa State University Armstrong research farm and incorporated by tillage to a depth of 6 inches. The experiment is a split-plot design with continuous no-tillage corn as a control; and bioenergy switchgrass, low-diversity high-input polyculture, and high-diversity low-input polyculture cropping systems. The changes in soil quality, soil carbon sequestration, stand density and diversity, and biomass and grain production are being monitored.

Laird's research is part of CenUSA Bioenergy, a coordinated research and education effort, funded by the USDA's National Institute of Food and Agriculture.

What We Have Learned

In Midwest prairie states, like Iowa, biochar is a natural ingredient in soils, the result of thousands of years of prairie fires. In that ancient system, however, the fire's energy was wasted. Today biochar can be created as a by-product of the fast pyrolysis process, turning biomass like corn stover into useable energy.

Then, by returning biochar to the soil as an amendment, growers can harvest more of a crop's stover for bioenergy without jeopardizing soil quality or yields. In fact, biochar may improve crop yields in poorer soils. Biochar retains about half the nutrients of the original biomass, including potash, phosphorus, nitrogen and minerals, and also boosts soil organic matter.

"Biochar is the manure of the bioenergy industry, a way of building soils," according to Laird.

Why is This Important?

Farmers growing corn and other feedstocks for renewable energy usually want to remove as much stover as possible, not only to make more money from selling it for bioenergy but because more stover removal usually boosts corn yields.

But that is a benefit only in the short run. In the long run, as less residue is left behind, the soil will be more susceptible to erosion, and soil quality will decline as organic matter —humus—and moisture-holding capacity drop off.

Biochar being applied.

Photo: David Laird, Iowa State University.

The ability of soil to retain moisture is especially critical in drought years like 2012.

It's a short-term benefit with a long-term cost," Laird says. "The key thing is, if we go on with business as usual and harvest residue for bioenergy products, it's not going to be sustainable. So we have to change practices if we want to harvest stover, and find new ways to compensate for removal," Laird says.

Biochar is one of the most promising new practices. For instance, in one study, biochar improved soil's water-holding capacity by 15 percent. Biochar may also be able to improve crop yields in fields with less than optimal soil.

For More Information

- Contact Dr. David Laird, Professor of Agronomy, Iowa State University, 515-294-1581, email: dalaird@iastate.edu (mailto:dalaird@iastate.edu) .
- US Biochar Conference 2012. Video on the Role of Biochar in Achieving a Carbon Negative Economy (http://2012.biochar.us.com/profile/85/david-laird-phd)
- This Research Summary is part of the CenUSA Learning Module on Sustainable Feedstock Production (/pages/68136/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa#Module%202) .

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CenUSA Bioenergy (http://www.cenusa.iastate.edu/) is a coordinated research and education effort investigating the creation of a regional system in the Central US for producing advanced transportation fuels from perennial grasses 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 in soil and increasing carbon sequestration.

CenUSA is supported by Agriculture and Food Research Initiative (http://www.csrees.usda.gov/funding/afri/afri_synopsis.html) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/).

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Exhibit 5

Research Summary: Biofuel Quality Improved by Delaying Harvest of Perennial Grass

Last Updated: April 18, 2013

Research shows decreased nitrogen contaminants in perennial grasses, such as switchgrass, grown for biofuel by delaying harvest.

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Abstract

Nitrogen ash and other mineral matter can be a problem in processing perennial grasses into biofuel through the fast pyrolysis method. Delaying biomass harvest until after senescence can dramatically decrease the amount of N contaminants in the final product. In addition, the amount of N in the perennial grass crop is a good predictor of the amount of N in the resulting biofuel.

Research Purpose

Farmers who grazed livestock learned thousands of years ago that the timing of the hay crop harvest was important—their animals much preferred green, leafy forage to older, stemmy grass. But for producers growing perennial grasses such as switchgrass to turn into biofuel, does harvest timing still matter? Danielle Wilson and Emily Heaton of the Department of Agronomy at Iowa State University researched this question as part of CenUSA Bioenergy, a coordinated research and education effort funded by the USDA's National Institute of Food and Agriculture. The research was also funded by Phillips 66.

Research Activities

Heaton and Wilson investigated the importance of harvest time on switchgrass, a major biofuel feedstock likely to be processed by fast pyrolysis, a thermal process technology that rapidly heats biomass to convert it into bio-oil. Although fast pyrolysis shows promise as an affordable process to convert biomass into a useable biofuel, contaminants in the biomass itself can reduce the quality of the final bio-oil. Specifically, nitrogen (N) ash and mineral matter in the feedstock can decrease the shelf-stability of the resulting bio-oil.

Although methods to reduce mineral contamination in the final biofuel product are common, little is known about the effect of initial feedstock quality on that product. To answer this question, the researchers used a novel field experiment to find out whether the amount of N in the feedstock correlated to the amount of N in the final bio-oil product.

Heaton and Wilson set up switchgrass field trials at Iowa State University's South Reynoldson Research Farm. Plots were harvested at different times throughout the summer and fall of 2010 and the spring of 2011. They processed the harvested switchgrass into bio-oil using fast pyrolysis, and analyzed the N concentrations in the switchgrass feedstock and in the final bio-oil.

What We Have Learned

Heaton and Wilson showed that that the timing of switchgrass harvest does indeed have an effect on crop N concentration, and that crop N concentration can accurately predict the amount of N in the final bio-oil product. Heaton and Wilson found that switchgrass N dropped as much as 68% between June and November, starting after flowering and continuing throughout plant senescence.

Although holding off on harvest until a killing frost did reduce yields of biomass significantly—22% DM drop between August and November harvests— **more** bio-oil was produced per unit of biomass. Therefore, delaying switchgrass harvest past senescence can result in lower contaminant levels in the bio-oil product.

However, there is no further benefit to waiting until the following spring to harvest. The research found that overwintering the crop reduced biomass yields, by 37%, without also reducing N content further.

Why is This Important?

By understanding the effects of agronomic management on feedstock quality, farmers can plan their harvest for optimal quality and secure higher prices per bale by tailoring their crops to the requirements of the feedstock customers. Refiners will be able to accurately screen the biofuel feedstock they are buying for contaminants and quality.

Agronomic management strategies are also important to the sustainability of biofuel production. N fertilizer can have a high cost, both economically and in carbon emissions. By removing as little N as possible in harvested biomass, less fertilizer N is needed because effective harvest timing can maximize the return of plant N to the soil for future crop growth.

"Improvements in bio-oil quality were realized, not with expensive treatments to the bio-oil, but instead with a simple management strategy, i.e., delayed harvest, that has also been shown to…improve the economic and environmental sustainability of biofuels by minimizing external N fertilizer inputs," Heaton and Wilson write.

For More Information

- Contact: Dr. Emily Heaton, Assistant Professor, Iowa State University heaton@mail.iastate.edu (mailto:heaton@mail.iastate.edu) , 515-294-1310.
- Crop Management Impacts Biofuel Quality: Influence of Switchgrass Harvest Time on Yield, Nitrogen and Ash of Fast Pyrolysis Products; (http://link.springer.com/article/10.1007/s12155-012-9240-0) Danielle M. Wilson, Dustin L. Dalluge, Marjorie Rover, Emily A. Heaton, and Robert C. Brown, BioEnergy Research, July 2012.
- Managing and Enhancing Switchgrass as a Biofuel Feedstock (http://www.spcru.ars.usda.gov/research/publications/publications.htm?seq_no_115=221508) , Robert Mitchell, Kenneth Vogel and Gautam Sarath, USDA-ARS
- When to Harvest Switchgrass and Miscanthus (http://www.grainnet.com/article.php?ID=69305) , BFJ.com podcast with Dr. Emily Heaton (http://www.grainnet.com/article.php?ID=69305) , Assistant Professor, Iowa State University.

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CenUSA Bioenergy (http://www.cenusa.iastate.edu/) is a coordinated research and education effort investigating the creation of a regional system in the Central US for producing advanced transportation fuels from perennial grasses 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 in soil and increasing carbon sequestration.

CenUSA is supported by Agriculture and Food Research Initiative (http://www.csrees.usda.gov/funding/afri/afri_synopsis.html) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

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Exhibit 6

Switchgrass (Panicum virgatum) for Biofuel Production

Last Updated: June 20, 2013

Switchgrass (Panicum virgatum) is a native warm-season grass that is a leading biomass crop in the United States. More than 70 years of experience with switchgrass as a hay and forage crop suggest switchgrass will be productive and sustainable on rain-fed marginal land east of the 100th meridian. Long-term plot trials and farm-scale studies in the Great Plains and plot trials in the Great Plains, Midwest, South, and Southeast indicate switchgrass is productive, protective of the environment, and profitable for the farmer. Weed control is essential during establishment but with good management is typically not required again. Although stands can be maintained indefinitely, stands are expected to last at least 10 years, after which time the stand will be renovated, and new, higher-yielding material will be seeded on the site. Fertility requirements are well understood in most regions, with about 12 to 14 pounds of N per acre required for each ton of expected yield if the crop is allowed to completely senesce before the annual harvest. Historically, breeding and genetics research has been conducted at a limited number of locations by USDA (http://www.usda.gov/wps/portal/usda/usdahome) and university scientists, but the potential bioenergy market has promoted testing by public and private entities throughout the United States. Switchgrass is well suited to marginal cropland and is an energetically and economically feasible and sustainable biomass energy crop with currently available technology.

(/sites/default/files/w/1/14/Switchgrass.jpg)
Mature stand of switchgrass in its third year of production at Michigan State University. Photo: Dennis Pennington.

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Introduction

Grassland scientists have conducted research on switchgrass (*Panicum virgatum*) for more than 70 years, with initial research focusing on livestock and conservation. In 1936, L. C. Newell, an agronomist with the Bureau of Plant Industry, USDA, in Lincoln, Nebraska, began working with switchgrass and other grasses to potentially re-vegetate large areas of the central Great Plains and Midwest that had been devastated by the drought of the 1930s. The first switchgrass cultivar from this program was Nebraska 28 which was jointly released by USDA and the University of Nebraska in 1949. Since that time, establishment and management practices have been developed and refined, genetic resources have been evaluated, seed production has been improved, and a wealth of information has been made available to producers.

Most of the general public first heard about switchgrass on January 31, 2006, when President George W. Bush in his State of the Union Address said, "We must also change how we power our automobiles. We will increase our research in better batteries for hybrid and electric cars, and in pollution-free cars that run on hydrogen. We'll also fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switchgrass. Our goal is to make this new kind of ethanol practical and competitive within six years." Although the USDA ARS (http://www.ars.usda.gov/Main/site_Main.htm?modecode=54-40-00-00) location in Lincoln, Nebraska, has been conducting switchgrass research continuously since 1936, and regionally specific biomass energy research has occurred since about 1987 at universities such as Auburn, Virginia Tech, and Texas A&M, interest in switchgrass increased exponentially following this Presidential address. Recently, significant attention has been given to switchgrass as a model perennial grass for bioenergy production to reduce our dependence on foreign oil, boost our rural economies, reduce fossil fuel emissions, reduce erosion on marginal cropland, and enhance wildlife habitat.

Current Potential for Use as a Biofuel

Switchgrass has excellent potential as a bioenergy feedstock for cellulosic ethanol production, direct combustion for heat and electrical generation, gasification, and pyrolysis. The U.S. Department of Energy (DOE) Bioenergy Feedstock Development Program (https://bioenergy.ornl.gov/) selected switchgrass as the herbaceous model species for biomass energy. Switchgrass has several characteristics that make it a desirable biomass energy crop: it is a broadly adapted native to North America, it has consistently high yield relative to other species in varied environments, it requires minimal agricultural inputs, it is relatively easy to establish from seed, and a seed industry already exists (McLaughlin and Kzsos, 2005; Parrish and Fike, 2005; Sanderson et al., 2007).

Biology and Adaptation

(/sites/default/files/w/4/4b/Switch1.JPG)
Figure 1. Switchgrass is adapted to much of North America. Image: USDA NRCS (http://plants.usda.gov/java/profile?symbol=PAVI2) .

Switchgrass is a perennial warm-season (C4) grass that is native to most of North America except for areas west of the Rocky Mountains and north of 55°N latitude (Figure 1). Switchgrass grows 3 to 10 feet tall, typically as a bunchgrass, but the short rhizomes can form a sod over time. Switchgrass has high yield potential on marginal cropland and will be productive in most rain-fed production systems east of the 100th meridian (Vogel, 2004). Productive switchgrass stands can be grown west of the 100th meridian with irrigation (Biofuels Cropping Systems Research and Extension, Washington State University (http://css.wsu.edu/biofuels/publications/index.html)). Switchgrass is adapted to a wide range of habitats and climates and has few major insect or disease pests. Root depth of established switchgrass may reach 10 feet, but most of the root mass is in the top 12 inches of the soil profile. In addition to potential bioenergy production, switchgrass uses include pasture and hay production (http://www.ianrpubs.unl.edu/epublic/live/g1908/build/g1908.pdf) , soil and water conservation, carbon sequestration, and wildlife habitat.

Switchgrass has distinct lowland and upland ecotypes. Upland ecotypes occur in upland areas that are not subject to flooding, whereas lowland ecotypes are found on floodplains and other areas that receive run-on water (Vogel, 2004). Generally, lowland plants have a later heading date and are taller with larger and thicker stems. Upland ecotypes are either octaploids or tetraploids, whereas lowland ecotypes are tetraploids (Vogel, 2004). Lowland and upland tetraploids have been crossed to produce true F1 hybrids that have a 30 to 50% yield increase over the parental lines (Vogel and Mitchell, 2008). These hybrids are promising sources for high-yielding bioenergy cultivars.

Production and Agronomic Information

(/sites/default/files/w/b/b3/Switch2.JPG)
Figure 2. Soybean stubble provides an excellent seedbed for no-till seeding switchgrass. During the establishment year, all harvests must occur after a killing frost to avoid damaging stands. In the establishment year, good weed management and rainfall will provide about half of the fully established yield potential of the site and cultivar. Photo: Rob Mitchell.

Establishing Stands

Successful stand establishment during the seeding year is mandatory for economically viable switchgrass bioenergy production systems (Perrin et al., 2008). Weed competition is the major reason for switchgrass stand failure. Acceptable switchgrass production can be delayed by one or more years by weed competition and poor stand establishment (Schmer et al., 2006). Vogel and Masters (2001) reported a stand frequency of 50% or greater (two or more switchgrass plants per square foot) indicated a successful stand, whereas stand frequency from 25 to 50% was marginal to adequate, and stands with less than 25% frequency indicated a partial stand. In a study conducted on 12 farms in Nebraska, South Dakota, and North Dakota, switchgrass fields with a stand frequency of 40% or greater provided a successful stand (Schmer et al., 2006).

Switchgrass is readily established when quality seed of an adapted cultivar is used with the proper planting date, seeding rate, seeding method, and weed control. In the central Great Plains, switchgrass can be planted two or three weeks before to two or three weeks after the recommended planting dates for corn (*Zea mays*), typically from late April to early June. Switchgrass should be seeded at 30 pure live seed (PLS) per square foot (5 PLS pounds per acre) based on the quality of the seedlot. Excellent results are obtained by planting after a soybean (*Glycine max*) crop using a properly calibrated no-till drill with depth bands that plant seeds 0.25 inch to 0.5 inch deep followed by press wheels (Figure 2). Row spacing for switchgrass is typically 7.5 to 10 inches. If switchgrass is planted after crops that leave heavy residue such as corn or sorghum (*Sorghum bicolor*), it may be necessary to graze the residue, shred or bale the stalks, or use tillage to reduce the residue. If tillage is required, the seedbed needs to be packed to firm the soil. The packed soil needs to be firm enough so that walking across the field leaves only a faint footprint (Figure 3). Applying 8 oz of quinclorac plus 1 qt of atrazine per acre immediately after planting has provided effective grassy and broadleaf weed control for establishment. The most cost-effective method to control broadleaf weeds in switchgrass fields during the establishment year is to apply 2,4-D at 1 to 2 qt acre^{-1} after switchgrass seedlings have about four leaves. After the establishment year, a successfully established switchgrass stand requires limited herbicide applications.

Nitrogen (N) fertilizer is not recommended during the planting year since N will encourage weed growth, increase competition for establishing seedlings, increase establishment cost, and increase economic risk associated with establishment if stands should fail (Mitchell et al., 2008). Soil tests are recommended prior to planting. Since switchgrass is deep rooted, soil samples should be taken from each 1-foot increment to a depth of 5 feet. In most agricultural fields, adequate levels of phosphorus (P) and potassium (K) will be in the soil profile. If warranted by soil tests, P and K can be applied before seeding to encourage root growth and promote rapid establishment. Recommended P levels for the western corn belt are in Table 1. Switchgrass can tolerate moderately acidic soils, but optimum seed germination occurs when soil pH is between 6 and 8 (Hanson and Johnson, 2005). With good weed management and favorable precipitation, a crop equal to about half of potential production can be harvested after frost at the end of the planting

(/sites/default/files/w/3/34/Switch3.JPG)
Figure 3. Seeding into corn or sorghum stubble may

year, with 75 to 100% of full production achieved the year after planting.

require plowing, disking, and packing to develop a firm seedbed. Pack the tilled soil until walking across the field leaves only a faint footprint to ensure good seed-to-soil contact and prevent soil in-filling of the packer wheel depression. Photo: Rob Mitchell.

Table 1. Phosphorus (P) recommendations for the western corn belt based on two common soil test levels (Anderson and Shapiro, 1990).

	Soil Test Levels		
P Index Value	Bray & Kurtz #1	Olsen P (Na HCO_3)	P Rate
	---------- ppm ----------		lb P_2O_5/Acre
Very low	0-5	0-3	40
Low	6-15	4-7	20
Medium	16-25	8-14	10
High	25+	15+	0

Established Stands

Although switchgrass can survive on low fertility soils, it does respond to fertilizer, especially N. The amount of N required by switchgrass is a function of the yield potential of the site, productivity of the cultivar, and other management practices being used (Vogel et al., 2002). Consequently, the optimum N rate for switchgrass managed for biomass will vary, but a few references indicative of the responses to N in different regions of the United States are included (Table 2). Additionally, biomass will decline over years if inadequate N is applied, and yield will be sustainable only with proper N application (Muir et al., 2001). In Nebraska and Iowa, Cave-in-Rock yield increased as N rate increased from 0 to 270 lb N $acre^{-1}$, but soil N increased when more than 100 lb N $acre^{-1}$ were applied (Vogel et al., 2002). They reported biomass was optimized by applying 100 lb N $acre^{-1}$, with about the same amount of N being applied as was being removed by the crop. A general N fertilizer recommendation for the Great Plains and Midwest region is to apply 20 lb N $acre^{-1}$ yr^{-1} for each ton of anticipated biomass if harvesting during the growing season, with N rate reduced to 12 to 14 lb N $acre^{-1}$ yr^{-1} for each ton of anticipated biomass if harvesting after a killing frost. The N rate can be reduced when the harvest is after a killing frost because switchgrass cycles some N back to roots during autumn. If soil tests indicate a new switchgrass field has high residual N levels, N rates can be significantly reduced during the initial production years using the above information as a guideline. Apply N at switchgrass green-up to minimize cool-season weed competition.

Table 2. Switchgrass publications addressing nitrogen fertilizer application for different regions of the United States listed by state, the major parameters evaluated in the study, and references for each study.

State(s)	**Parameters Evaluated**	**Reference**
AL	N rate and row spacing effect on C partitioning	Ma et al., 2001

IA	Yield and quality parameters for 20 strains	Lemus et al., 2002
IA, NE	Harvest date and N rate effects	Vogel et al., 2002
NC, KY, TN, VA, WV	Long-term yield under different management regimes	Fike et al., 2006a Fike et al., 2006b
SD	Harvest date and N rate effects on biomass, persistence, species composition, and soil organic carbon of switchgrass-dominated CRP	Mulkey et al., 2006 Lee et al., 2007
TX	Yield and stand responses to N and P as affected by row spacing	Muir et al., 2001

Spraying herbicides to control broadleaf weeds typically is needed only once or twice every 10 years in an established, well-managed switchgrass stands. When needed, the most effective and economical approach is with broadcast applications of 2,4-D at 1 to 2 qt $acre^{-1}$. Spray broadleaf weeds as early in the growing season as possible to reduce the impact of weed interference on switchgrass yield. In some cases, cool-season grasses may invade switchgrass stands and reduce yield. Harvesting after switchgrass senescence in autumn but while cool-season grasses are growing, then applying glyphosate at 1 to 2 qt $acre^{-1}$, is an effective method to reduce cool-season grasses. However, make certain switchgrass is dormant when glyphosate is applied, or stands could be damaged. Spring applications of atrazine at 2 qt $acre^{-1}$ can be used to control cool-season grasses in established switchgrass stands.

Harvest and Storage

Maximizing yield currently is the primary objective when harvesting biomass feedstocks. In the Great Plains and Midwest, maximum first-cut yields are attained by harvesting switchgrass when panicles are fully emerged to the post-anthesis stage (~1 August). Sufficient regrowth may occur about one year out of four to warrant a second harvest after a killing frost. Do not harvest switchgrass within six weeks of the first killing frost or shorter than a 4-inch stubble height to ensure translocation of storage carbohydrates to maintain stand productivity and persistence. Dormant season harvests after a killing frost will not damage switchgrass stands but will reduce the amount of snow captured during winter. In general, a single harvest during the growing season maximizes switchgrass biomass recovery, but harvesting after a killing frost will ensure stand productivity and persistence, especially when drought conditions occur, and reduce N fertilizer requirements. Delaying harvest until spring will reduce moisture and ash contents, but yield loss can be as high as 40% compared with a fall harvest (Adler et al., 2006). With proper management, productive stands can be maintained indefinitely and certainly for more than 10 years. Harvesting switchgrass in summer at or after flowering when drought conditions exist is not recommended.

(/sites/default/files/w/1/14/Switch4.JPG)
Figure 4. Rotary head mowers (disc mowers) effectively harvested this 6-ton per acre switchgrass field at anthesis. Additionally, after a killing frost, the multidirectional arrangement of the switchgrass in the windrow was easier to bale than the linearly arranged windrow left by the sickle-bar head. Photo: Rob Mitchell.

Switchgrass can be harvested and baled with commercially available haying equipment. Self-propelled harvesters equipped with a rotary head (disc mowers) have most effectively harvested high-yielding (>6-ton per acre) switchgrass fields (Figure 4). Additionally, after a killing frost, the multidirectional arrangement of the switchgrass in the windrow was easier to bale than the linearly arranged windrow left by a sickle-bar head. Round bales tend to have less storage losses than large square bales (>800 lb) when stored outside, but square bales tend to be easier to handle and load a truck for transport without road width restrictions (Figure 5). After harvest, poor switchgrass storage conditions can result in storage losses of 25% in a single year. In addition to storage losses in weight, there can be significant reductions in biomass quality, and the biomass may not be in acceptable condition for a biorefinery. Switchgrass grown for use in a biorefinery may have to be stored for a full year or longer since biorefineries will operate 365 days a year. Some type of covered storage will be necessary to protect the producer's investment.

(/sites/default/files/w/1/16/Switch5.JPG)
Figure 5. Proper storage of switchgrass bales is imperative to maintain total harvested dry matter and prevent spoilage. Large square bales can spoil from the top and bottom and can lose more than 25% of total dry matter in six months when stored outside in the open (top left), but covering the large square bales with hay tarps (top right) reduces dry matter loss to about 7% in six months. Wrapping big round bales with at least three wraps of net-wrap maintains the structure of the bale and reduces the surface area of the bale that contacts the ground. Covering big round bales stored outside can reduce dry matter loss to less than 3% in six months. Photo: Rob Mitchell.

Potential Yield

Switchgrass yield is strongly influenced by precipitation, fertility, soil, location, genetics, and other factors. Most plot and field-scale switchgrass research has been conducted on forage-type cultivars selected for other livestock-based characteristics in addition to yield. Consequently, the forage-type cultivars in the Great Plains and Midwest are entirely represented by upland ecotypes which are inherently lower yielding than lowland ecotypes. Thus, yield data comparing forage-type upland cultivars like Cave-In-Rock, Shawnee, Summer, and Trailblazer do not capture the full yield potential of switchgrass and are not fair comparisons. For example in Nebraska, high-yielding F1 hybrids of Kanlow and Summer produced 9.4 tons acre^{-1} year^{-1}, which was 68% greater than Summer and 50% greater than Shawnee (Vogel and Mitchell, 2008). New biomass-type switchgrass cultivars will be available in the near future for the Great Plains and Midwest. Knowing the origin of a switchgrass cultivar is important since switchgrass is photoperiod sensitive. Planting a switchgrass cultivar too far north of the cultivar origin area (>300 miles) can result in winter stand loss. Planting a switchgrass cultivar south of its origin area results in less biomass because the shorter photoperiod causes plants to flower too early.

Production Challenges

There are major challenges to using switchgrass for cellulosic ethanol (Mitchell et al., 2008). An ethanol plant requires a reliable and consistent feedstock supply. A 50-million-gallon per year plant will require 625,000 U.S. tons of feedstock per year assuming 80 gallons of ethanol can be produced from one ton of feedstock. Although cellulosic ethanol plants likely will use multiple feedstocks, this example assumes switchgrass will be the only feedstock. Operating every day of the year, the plant will require 1,712 dry matter (DM) tons of feedstock per day, or 342 acres of switchgrass yielding 5 DM tons per acre. If a loaded semi can deliver 30 round bales each containing 0.6 DM tons (18 U.S. tons), the ethanol plant will use 95 semi loads of feedstock per day, requiring a semi to be unloaded every 15 minutes 24 hours per day, 7 days per week.

There must be an available land base in the local agricultural landscape to produce feedstock. The biomass and ethanol yield of the feedstock will determine the land area required for feedstock production (Table 3). Assuming 25 miles is the maximum economically feasible distance feedstock can be transported, all of the feedstock must be grown within a 25-mile radius of the bio-refinery, an area containing about 1.26 million acres. Assuming a 50-million-gallon per year cellulosic ethanol plant requires 625,000 tons of feedstock per year, if feedstock yield is 1.75 DM tons/acre, 28% of the land would need to grow the feedstock, and this is not feasible in most agricultural areas. At 5 DM tons/acre, a commonly-achieved yield with available forage cultivars, only 10% of the land would be needed for feedstock production and is feasible in most agricultural areas. However, at 10 DM tons/acre, only 5% of the land base would be needed for feedstock production and would minimally alter the agricultural landscape. Dry matter yield will exceed 10 tons/acre in many areas of the South and Southeast, so less than 5% of the land base would be needed for feedstock production. This example reinforces the importance of high DM yield to the agricultural feasibility of cellulosic ethanol, not to mention the inability of the producer to profit by growing low-yielding energy crops. A majority of the switchgrass likely will be grown on marginal lands that have suboptimal characteristics (i.e., slope, soil depth, etc.) for producing food and feed, or on lands currently enrolled in conservation programs.

Table 3. Reported dry matter (DM) yield, acres required to grow 625,000 tons of dry matter per year, and the percent of the land base required to provide feedstock for a 50-million-gallon cellulosic ethanol plant for different herbaceous perennial feedstocks in the Great Plains and Midwest.

Feedstock	Yield, DM tons/acre	Acres needed to grow 625,000 DM tons/year	Percent of land in 25-mile radius
LIHD prairie[1]	1.75	357,000	28
Managed native prairie[2]	2.5	250,000	20
Shawnee switchgrass[3]	5	125,000	10
Bioenergy switchgrass[4]	7.4	84,460	6.6
Hybrid switchgrass[5]	9.4	66,489	5.3

[1]Low-input, high-diversity human-made prairies (Tilman et al., 2006).

[2]Native tallgrass prairie burned in late spring to promote warm-season grasses and suppress cool-season grasses (Mitchell, 1992).

[3]Shawnee is an upland forage-type switchgrass cultivar released in 1995.

[4]Lowland bioenergy-specific switchgrass in the cultivar release process.

[5]F1 hybrid of Summer and Kanlow switchgrass that will likely reach field-scale production in less than 10 years (Vogel and Mitchell, 2008).

Growing switchgrass must be profitable for the producer, it must fit into existing farming operations, it must be easy to store and deliver to the ethanol plant, and extension efforts must be provided to inform producers on the agronomics and best management practices for specific regions, all of which have been addressed for switchgrass. Switchgrass fits well into the production systems of most farmers. Harvesting switchgrass after frost is a time when most farmers have completed corn and soybean harvests and handling switchgrass as a hay crop is not foreign to most producers. The economic opportunities of switchgrass for small, difficult-to-farm, or poorly-productive fields will be attractive to many producers.

There are potential difficulties with large-scale switchgrass monocultures, but most are speculation at this point. Concerns arise for potential disease and insect pests, and the escape of switchgrass as an invasive species with the production of millions of switchgrass acres, especially since little research has been conducted on these topics. Most pathogen issues cannot be fully realized until large areas are planted to switchgrass. However, the broad genetic diversity available to switchgrass breeders, the initial pathogen screening conducted during cultivar development, and the fact that switchgrass has been a native component of central U.S. grasslands for centuries will likely limit the negative pest issues. Switchgrass has been used widely throughout the Great Plains and Midwest for pasture and conservation purposes for decades, and no invasive problems have developed or been identified.

Production Cost

Results of a recent economic study based on the five-year average of 10 farms in Nebraska, South Dakota, and North Dakota indicated producers can grow switchgrass at a farm gate cost of $60/ton (Perrin et al., 2008). However, producers with experience growing switchgrass had five-year average costs of $43/ton, and one producer grew switchgrass for $38/ton. These costs include all expenses plus land costs and labor at $10/hour. Each big round bale (Photo 4) represents 50 gallons of ethanol assuming 80 gallons per ton of switchgrass, with a farm gate cost of $0.75/gallon at $60/ton. This research from nearly 50 production environments indicates that growing switchgrass for cellulosic ethanol is economically feasible in the central and northern Great Plains. It should be noted that fuel and land prices have increased since this study, so the cost increases for those inputs need to be considered when determining switchgrass production costs.

Environmental and Sustainability Issues

Sustainable biomass energy crops must be productive, protective of soil and water resources, and profitable for the producer. Numerous studies have reported that switchgrass will protect soil, water, and air quality; provide fully sustainable production systems; sequester C; create wildlife habitat; increase landscape and biological diversity; return marginal farmland to production; and increase farm revenues (McLaughlin and Walsh, 1998; McLaughlin et al., 2002). Switchgrass root density in the surface 6 inches is two-fold greater than alfalfa, more than three-fold greater than corn, and more than an order of magnitude greater than soybean (Johnson et al., 2007). In a five-year field study conducted on 10 farms in Nebraska, South Dakota, and North Dakota, Liebig et al. (2008) reported that switchgrass stored large quantities of C, with four farms in Nebraska storing an average of 2,590 pounds of soil organic C (SOC) $acre^{-1}$ $year^{-1}$ when measured to a depth of 4 feet. However, they noted that SOC increases varied across sites, and the variation in SOC change reiterated the importance of long-term environmental monitoring sites in major agro-ecoregions.

Energy produced from renewable carbon sources is held to a different standard than energy produced from fossil fuels, in that renewable fuels must have highly positive energy values and low greenhouse gas emissions. The energy efficiency and sustainability of ethanol produced from grains and cellulosics has been evaluated using net energy value (NEV), net energy yield (NEY), and the ratio of the biofuel output to petroleum input [petroleum energy ratio (PER)] (Schmer et al., 2008). An energy model using estimated agricultural inputs and simulated yields predicted switchgrass could produce greater than 700% more output than input energy (Farrell et al., 2006). These modeled results were validated with actual inputs from multi-farm, field-scale research to predict energy output. Switchgrass fields on 10 farms in Nebraska, South Dakota, and North Dakota produced 540% more renewable energy (NEV) than nonrenewable energy consumed over a five-year period (Schmer et al., 2008). The estimated on-farm NEY was 93% greater than human-made prairies and 652% greater than low-input switchgrass grown in small plots in Minnesota (Tilman et al., 2006). The 10 farms and five production years had a PER of 13.1 and produced 93% more ethanol per acre than human-made prairies and 471% more ethanol per acre than low-input switchgrass in Minnesota (Schmer et al., 2008). Average greenhouse gas (GHG) emissions from switchgrass-based ethanol were 94% lower than estimated GHG emissions for gasoline (Schmer et al., 2008). Switchgrass for bioenergy is an energetically positive and environmentally sustainable production system for the Great Plains.

Implementing switchgrass-based bioenergy production systems will require converting marginal land from annual row crops to switchgrass and could exceed 10% in some regions depending on the yield potential of the switchgrass strains (Table 3). In a five-year study in Nebraska, the potential ethanol yield of switchgrass averaged 372 gallons $acre^{-1}$ and was equal to or greater than that for no-till corn (grain + stover) on a dry-land site with marginal soils (Varvel et al., 2008). Removing 50% of the corn stover each year reduced subsequent corn grain yield, stover yield, and total biomass. Growing switchgrass on marginal sites likely will enhance ecosystem services more rapidly and significantly than on more productive sites.

Feasibility

Perennial herbaceous energy crops provide several challenges. A stable and consistent feedstock supply must be available year-round to the ethanol or power plant. For the producer, perennial herbaceous energy crops must be profitable, they must fit into existing farming operations, they must be easy to store and deliver to the plant, and extension efforts must be provided to inform producers on the agronomics and best management practices for growing perennial herbaceous energy crops. However, perennial herbaceous energy crops have potential for improvement, and they present a unique opportunity for cultural change on the agricultural landscape. There are numerous environmental benefits to perennial herbaceous cropping systems that can improve agricultural land use practices such as stabilizing soils and reducing soil erosion, improved water quality, increased and improved wildlife habitat, and storing C to mitigate greenhouse gas emissions. There is large potential for achieving all of these benefits, provided agronomic, genomic, and operational aspects of perennial herbaceous cropping systems are fully developed and accepted by farmers. Herbaceous perennial energy crops may be used in conjunction with agriculture residues (corn stover and wheat straw), which likely would be harvested in autumn, and perennial grasses could be harvested in very early spring while they are dry, similar to when prairies are typically burned. This may help reduce the need for feedstock storage by providing feedstock at different times during the year.

Growing seed to meet potential demand for bioenergy will not be an issue. Switchgrass has many desirable seed characteristics and can produce viable seed during the seeding year, especially under irrigation. Established seed production fields can produce 500 to 1,000 pounds of seed per acre with irrigation, and the seed is easily threshed, cleaned, and planted with commercial planting equipment. Seed production systems are well established (Cornelius, 1950), and a commercial industry for switchgrass seed has existed for over 50 years.

Summary

Contrary to popular belief, switchgrass is not a new or novel crop but has more than 70 years of research and farming experience. Currently available plant materials and production practices can reliably produce five tons per acre in the central Great Plains and Midwest and 10 tons per acre in much of the Southeast. New cultivars and management practices will significantly increase yields similar to the yield increases achieved in corn in the last 30 years. The availability of adequate acres of agricultural land and the profit potential provided to farmers for growing switchgrass in a region will determine the success of growing switchgrass for biomass energy. Production practices and plant materials are available to achieve sustainable and profitable biomass production, for both farmers and bio-refineries, to help meet the energy requirements of the nation and reduce our dependence on foreign oil.

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Additional Switchgrass Resources

- CenUSA Resources - Sustainable Production and Distribution of Bioenergy for the Central USA (/pages/68136/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) . Includes fact sheets and media resources on switchgrass development, production, logistics, harvesting, etc.
- Switchgrass as a Bioenergy Crop. ATTRA Publication No. IP302
- Goat Pastures Switchgrass (/pages/19424/goat-pastures-switchgrass)
- Switchgrass (http://bioweb.sungrant.org/Technical/Biomass+Resources/Agricultural+Resources/New+Crops/Herbaceous+Crops/Switchgrass/Default.htm) . Sun Grant Bioweb
- Switchgrass Bioenergy Budgets (http://njaes.rutgers.edu/pubs/publication.asp?pid=E331) . Rutgers NJAES Cooperative Extension
- Economic Potential of Switchgrass as a Biofuel Crop in Florida (http://edis.ifas.ufl.edu/fe900) . University of Florida IFAS Extension

Switchgrass in the News

- Switchgrass Used to Fuel Power Plant (/pages/18085/switchgrass-used-to-fuel-power-plant)
- North Dakota State University Studies Economics of Switchgrass as Fuel (/pages/16094/north-dakota-state-university-studies-economics-of-switchgrass-as-fuel)
- Biofuel Economics: Will Pure Switchgrass Stands Be Required for Cellulosic Ethanol? (/pages/15463/biofuel-economics:-will-pure-switchgrass-stands-be-required-for-cellulosic-ethanol)

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Exhibit 7

Switchgrass (Panicum virgatum L) Stand Establishment: Key Factors for Success

Last Updated: May 07, 2013

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Successful establishment is critical to the long-term economic viability of a switchgrass stand. But it is not difficult if these key management practices are followed: development of a good seedbed, certified seed planted at the correct time, with proper seeding depth and rates, and weed control.

While money spent on good-quality seed and weed control will likely result in a higher *per acre* cost for establishment, the reward is rapid establishment of a productive stand with lower costs *per ton* of harvest.

Why Establishment is Important

Switchgrass is not difficult to establish given good management practices. Successful stand establishment, is critical to economic viability over the life of the switchgrass stand, expected to be at least ten years. Growers in regions with good soils should be able to harvest in the planting year. (In areas with poor or marginal soils, a first-year harvest is likely to produce lower yields and to reduce stand quality and persistence. Delay harvest until the third year after establishment to achieve expected yields on these soils.)

While money spent on good-quality seed and weed control [link to Weed Control] will likely result in a higher *per acre* cost for establishment, the reward is a more productive stand and lower costs *per ton* of harvest (http://www.cenusa.iastate.edu/Content/files/2012_03-30_Field_Day/2012_03-20_Marty_Webinar_CenUSA.mp4) .

Is Switchgrass Feasible for the Area?

First, determine if it is feasible to grow switchgrass in your area. A good rule of thumb is that switchgrass will be productive in an area that is suitable for dryland corn. Switchgrass is a warm-season grass native to most of North

America except Washington, Oregon, and California.

Next, determine which cultivars are best adapted to your area. Switchgrass is broadly adapted, and regionally specific cultivars are available for most of the United States. Lowland cultivars, such as Alamo and Kanlow, are best adapted to the southern and mid-latitude regions of the United States, while upland cultivars, such as Shawnee and Sunburst, grow best in the mid- and northern latitudes. High-yielding bioenergy cultivars are under development for some regions that result in 20 to 30 percent increases in yield compared with forage-type cultivars. Check with your local Extension office to determine which cultivars work best in your area.

With good management, switchgrass can be grown on land that is marginally productive for most crops, but avoid poorly drained soils in the northern United States, where frost heaving can be a problem. West of the 100th meridian, switchgrass can be grown with irrigation.

Soil Conditions and Planting Dates for Switchgrass

Switchgrass establishes and grows best in warm conditions, requiring a soil temperature of 60 degrees F or warmer for germination.. Optimal dates for planting vary across the United States and depend on the region, soil temperature, and moisture. A general guideline is to plant switchgrass two to three weeks before or after the optimum corn planting date for your location; ranging from late March in the Southeast to late June in the northern Great Plains. Planting should be conducted with a grassland drill to place a specific amount of seed at an exact depth to promote rapid and low-cost establishment and reduce risks of seeding failure.

Take a soil test in the fall before planting to determine fertility needs. Do not apply nitrogen (N) fertilizer or manure to switchgrass in the seeding year. Excessive N will encourage weeds that compete with the new seedlings, and increase the cost of establishment. A soil test will indicate whether to apply phosphorus and potassium before seeding for better root growth. Switchgrass can tolerate moderately acidic soils, but optimum seed germination occurs when soil pH is between 6 and 8.

Use a High-Quality Certified Seed

Switchgrass seeds are small and often have 250,000 to 400,000 seeds per pound. Choose high-quality, certified switchgrass seed from an adapted cultivar. Base your seeding rate on Pure Live Seed (PLS, or the percent germination of the seed multiplied by the percent of pure seed of the actual seed in the switchgrass variety), not pounds of seed per acre. A seeding rate of 30 PLS per square foot is recommended.

Switchgrass seed can have high levels of dormancy, so select seed lots that have high germination, high purity, and low dormancy, which results in seed lots with a high percentage of PLS (http://www.plant-materials.nrcs.usda.gov/pubs/lapmctn9045.pdf) . Switchgrass seed lots can vary widely in germination rates and number of seeds per pound.

To make sure the seeding rate is accurate, first determine the percent PLS in the seed lot to be planted. Multiply the total germination rate by the seed purity (both of which are found on the seed tag), then divide by 100. That will give you the percent of PLS in the seed lot. Remember, avoid seed lots with high dormancy. Multiply the desired seeding rate by 100 and divide by the percent PLS to find the actual seeding rate at which you must plant. For instance, if your goal is a seeding rate of 6 pounds per acre and the seed is 60% PLS, you must plant 10 pounds of seed per acre.

Develop a Good Seedbed

The first requirement for establishment is to develop a seedbed that promotes good seed-to-soil contact, especially important because switchgrass seeds are small. Grassland drills with depth bands will place seeds at a consistent depth. No-till seeding may be the most successful method, if the weeds and crop residue are managed before planting. Plant into stubble with a no-till drill with small seed boxes, followed by press wheels. When planting switchgrass after a crop that leaves a heavy residue, such as corn or soybeans, reduce residue by grazing, shredding, or baling it.

If the soil is clean-tilled, harrow the field and pack firmly with a culti-packer to leave only a faint footprint when stepped on. If a prepared seedbed is rained on, harrow and culti-pack it again before planting. A seedbed as prepared for alfalfa is an excellent seedbed for switchgrass.

Planting Methods

Using a properly calibrated grassland drill (http://www.cenusa.iastate.edu/Content/files/2012_03-20_Calibration_Demo_CenUSA.mp4), plant at a seeding rate of 30 PLS per foot. Plant one-quarter to one-half inch deep, but no deeper, because switchgrass seeds are smalland will have trouble emerging if planted too deep. Rows should be spaced six to 10 inches apart.

Manage Weeds ASAP!

The main reason that switchgrass stands fail is because of competition from weeds; therefore weed control is essential. Don't delay. Apply pre-emergent herbicides immediately after planting.

Determining a Successful Stand

Check the stand six to 10 weeks after planting, using a frequency grid (http://naldc.nal.usda.gov/download/27477/PDF). A stand is considered successfully established if seedling frequency of occurrence is greater than 40 percent, or three to six plants per square feet.

A stand that can be harvested in the planting year is essential to an economically viable switchgrass stand. Recent research in Nebraska (http://www.springerlink.com/content/f85977006m871205/fulltext.pdf) found that the total costs of growing switchgrass were nearly $30 per ton higher during a five-year period, if a switchgrass stand failed to be harvestable in the year it was seeded.

Harvest

Be sure to harvest only after a killing frost in the establishment year so the stand is not damaged, and leave at least a 6-inch stubble. A crop equal to about half of the stand's potential production can be harvested after frost at the end of the planting year if there is proper weed control and favorable precipitation. Then, the first year after planting, expect 75 to 100 percent of full production.

For Additional Information

- Switchgrass Establishment, Weed Control, Herbicides, Seed Quality (http://www.cenusa.iastate.edu/Content/files/2012_03-30_Field_Day/2012_03-20_Rob_Mitchell_Webinar_CenUSA.mp4) - Robert Mitchell, Research Agronomist, USDA ARS, Associate Professor UNL Department of Agronomy
- Farm-scale Production Cost of Switchgrass for Biomass, (http://www.springerlink.com/content/f85977006m871205/fulltext.pdf) Richard Perrin, Kenneth Vogel, Marty Schmer and Rob Mitchell, *Bioenergy Research* (2008) 1:91-97.
- Switchgrass Biomass Production in the Midwest USA: Harvest and Nitrogen Management (http://naldc.nal.usda.gov/download/11394/PDF) Kenneth P. Vogel,* John J. Brejda, Daniel T. Walters, and Dwayne R. Buxton, 2002
- Management Guide for the Production of Switchgrass for Biomass Fuel in Southern Iowa (http://www.extension.iastate.edu/Publications/PM1710.pdf), Iowa State University.
- YouTube: Switchgrass Cost of Production (http://www.youtube.com/watch?v=AsrWGhjr4_Y), Marty Schmer
- Planting and Managing Switchgrass as a Biomass Energy Crop (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042293.pdf), USDA-NRCS, Plant Materials Program. (Includes chart of cultivars and their adaptation areas)
- Growing and Harvesting Switchgrass for Ethanol Production in Tennessee (https://utextension.tennessee.edu/publications/Documents/SP701-A.pdf). University of Tennessee AgResearch and

Extension.

- Adjusting and Calibrating a Drill for Planting Switchgrass for Biofuels, (http://forages.tennessee.edu/Page%204-%20Switchgrass%20Adjusting%20and%20Calibrating%20a%20Drill.html) University of Tennessee Institute of Agriculture
- Switchgrass Variety Type (http://switchgrass.okstate.edu/variety-choice) , Oklahoma State University
- CenUSA Project Resources - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production. This Fact Sheet is part of the CenUSA Module on Feedstock Development (/pages/68136/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa#Module%201) .

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cenusa bioenergy

CenUSA Bioenergy (http://www.cenusa.iastate.edu/) is a coordinated research and education effort investigating the creation of a regional system in the Central US for producing advanced transportation fuels from perennial grasses 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 in soil and increasing carbon sequestration.

CenUSA is supported by Agriculture and Food Research Initiative (http://www.csrees.usda.gov/funding/afri/afri_synopsis.html) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

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Exhibit 8

Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop

Last Updated: May 07, 2013

There's more to producing a crop like switchgrass for bioenergy than just growing it. Harvesting, storing, transporting, and selling perennial grass feedstocks must be taken into consideration to make it a successful venture.

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Although switchgrass (*Panicum virgatum L.*) and other perennial grasses such as Indian grass and big bluestem offer producers the potential of a crop that can make marginal crop lands profitable and sustainable, several challenges besides production need to be addressed to make growing these crops viable. Logistical factors such as harvest, storage, transportation and marketing, discussed below, need to be considered as perennial grasses move from research and development to farmers' fields.

Transporting Biofuel Feedstocks with Current Crop Transportation Systems

Despite the fact that transportation systems have been refined over the years to improve the efficiency of moving grain and forage products across the nation, there are still challenges to moving the biomass crop from the field to refinery plant. The supply chain for biomass feedstock will require the transportation of significantly greater volumes of material than current systems. For example, the supply chain required to transport the 800 million tons of agricultural residues identified in the Department of Energy's 2005 billion-ton study (https://bioenergykdf.net/content/billiontonupdate) would need to handle roughly 10 times the volume of grain than that of the current grain logistics system in the United States.

Handling this volume of material will require the development of efficient biomass handling and loading systems and additional vehicles for transporting biomass.

Biomass Harvesting Technology

Current hay-crop harvesting technology will be useful for perennial grasses, but each type of equipment presents certain limitations because they were not designed to handle such high yields of biomass. For example, a round baler is less expensive than a square baler, but round bales do not stack on trailers as efficiently as square bales and require a much greater area for storage than large square bales. A square baler may lead to more efficient transportation and storage, but may not be an economically sound decision for every producer as they are more expensive to purchase and require the use of a 200-horsepower tractor or larger.

Biomass Storage Systems

Significant dry matter losses can occur (up to 25%) during storage. To minimize losses, care needs to be taken during storage. Large round bales tend to have a minimum of 1–4% loss while large square bales lose 2–8% even in ideal conditions. Anaerobic storage options such as bulk silo, Ag-Bag, and bale wrap result in 2–5% losses, as reported in research findings.

Of course, the cost of these storage options must be weighed in conjunction with other options. Buildings cost an average of $10–$12 per square foot to build, and anaerobic storage options cost approximately $9 per ton. A new baler, new building, or silo storage may actually cost more in the end than accepting a certain amount of loss due to the current storage options available in a particular farming operation. Each producer should weigh these costs carefully before purchasing new buildings or equipment.

Selling the Energy Crop

Even after producers address the challenges of growing, harvesting, and storing a perennial grass crop for biofuels, there is still one challenge left: selling it. Research has determined that pyrolysis is one of the best ways to refine perennial grasses for biofuels. Just having a process identified to convert these feedstocks into biofuels, however, is not enough. Producers must also be able to provide consistent supplies to refiners and their customers in order to encourage reliable, profitable markets.

Drought and other environment conditions can pose a threat to supply. Furthermore, these feedstocks are not easily transported across the nation, making it more difficult to bring in an outside material when a local shortage occurs. The refining process is also complicated by the fact that the quality of the feedstocks may vary a great deal between producers. Variation in quality requires adjustments in the refining process for the most efficient conversion of the grass to biofuels. Since on-the-fly adjustments may not be feasible, variations in feedstock quality could significantly affect conversion efficiency during the refining process and therefore make it harder to market such feedstocks.

Conclusion

Perennial grasses as feedstocks for biofuels offer producers a long-term, sustainable, and potentially profitable solution for marginal crop land. Each producer, however, must consider how this perennial grass crop will fit into their existing operation. To maximize profitability of perennial grass feedstocks, producers will need to determine how best to get the crop from the farm to the processing plant using the resources at hand. Before these practices can be implemented on the farm, however, processing plants and storage facilities will need to adopt the idea and offer the necessary accommodations for handling large volumes of feedstock material.

For Additional Information

- Planting and Managing Switchgrass as a Biomass Energy Crop (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042293.pdf) , USDA Natural Resources Conservation

Service, Plant Materials Program.

- CenUSA Bioenergy Overview:

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Exhibit 9

Test Plots Show How Perennial Grasses Can Be Grown for Biofuels

Last Updated: June 06, 2013

Use these protocols to set up test plots of perennial grasses to demonstrate to producers the potential for growing bioenergy feedstocks.

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Researchers, farmers, and industry representatives across the country are interested in testing the performance of energy crops. Setting up a test plot in your region can be useful in showing producers their potential for growing bioenergy feedstocks on their farms. The test plot can demonstrate best management practices and yield potential as well as how to establish perennial grasses quickly and economically. It can also show differences between the forage and bioenergy strains of perennial grasses.

Choose and set up a test plot site

Each site should be a size that would work on a farm. As such, there are no standard dimensions, but CenUSA, a bioenergy research project initiative, recommends a minimum plot size of one acre for each species. Planting and harvesting are facilitated best by planting long narrow strips such as are planted in most row crop yield trials.

CenUSA Bioenergy Crop

Select the species and cultivars of perennial grasses you are interested in testing—one species of grass or mixtures of grass species. Seed each one-acre plot with high-quality, certified seed. The interest of your audience and geographic location will determine which perennial grasses to plant and which cultivars to select, but a good selection of perennial grasses for the Great Plains and Midwest should include:

CenUSA Bioeneregy Crop Field day at USDA-ARS plots. Photo: John Hay University of Nebraska

- Switchgrass
- Big bluestem
- Indiangrass
- A low-diversity mixture, such as switchgrass, big bluestem, indiangrass, and sideoats grama
- A high-diversity mixture of approximately 10 species including native grasses, legumes, and forbs. [1] (#_ftn1)

Switchgrass (/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production) (*L. Panicum virgatum)* is a warm-season perennial grass native to the tall-grass prairie region. It is considered the leading grass energy crop because of its ease of propagation, high yield potential, compatibility with conventional farming, low input requirements, and excellent conservation attributes (Kszos et al., 2000). Other perennial grasses being evaluated for energy use include big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and prairie cordgrass (*Spartina pectinata*). Miscanthus (/pages/26625/miscanthus-miscanthus-x-giganteus-for-biofuel-production) (Miscanthus x giganteus) is a high-yielding, non-native perennial grass feedstock that may fit well in many areas. However, it may not offer as many conservation attributes as one of the native perennial grasses.

[1] (#_ftnref1) In terms of sustainability, ecologists are interested in maximizing the diversity of seeding mixtures for energy crops.

Establishment

In the central Great Plains and Midwest, time planting for two to three weeks before or after the optimum corn-planting date—earlier is better than later. Seed at a rate of 30 pure live seed (PLS) per square foot planted 1/4- to 1/2-inch deep in 6- to 7-inch rows. This is typically 4 to 6 pounds per acre of PLS. If you're doing small plots, consider lowering the seeder outside the plot in the alley and seeding through the plot beyond to the next alley to ensure complete seed coverage in the plot. Make sure the drill is calibrated (http://www.youtube.com/watch?v=7TPLfWLkd_U&feature=youtu.be) accurately (http://www.youtube.com/watch?v=izBHivo5xfw&feature=youtu.be) .

For plantings that include big bluestem or indiangrass, which have fluffy seeds, use a no-till drill with a chaffy seed box. Switchgrass seed doesn't require a chaffy seed box. No-till seed into soybean stubble or clean-tilled field and pack firmly enough to leave a faint footprint in the soil when you walk on it. If tillage is used, prepare the seedbed as you would for alfalfa.

If you don't have grass-seeding equipment, contact your local Extension office, a USDA Natural Resource Conservation Service or a local equipment dealer. Conservation organizations such as Ducks Unlimited, Pheasants Forever, or The Nature Conservancy may also have information on equipment you can borrow or rent.

(See video: Switchgrass Planting Practice (http://farmenergymedia.extension.org/video/switchgrass-planting-practices-stand-establishment))

Managing weeds in a test plot

Compared to cool-season grasses, establishing a warm-season grass stand takes more weed management. Weed competition is one of the biggest reason warm-season grass seedings fail, so weed control in the seeding year is very important, both during and after seeding.

Manage weeds in switchgrass with a pre-emergent application of 1 quart of atrazine plus 8 ounces per acre of quinclorac (Paramount®). On big bluestem, indiangrass, and sideoats grama, use a pre-emergent application of 4 ounces per acre of imazapic (Plateau®). On all plots, control broadleaf weeds in the seeding year by mowing in July and/or spraying with one to two quarts per acre of 2,4-D.

Biomass grown during the seeding year can be harvested or grazed after a killing frost or left standing in the field over winter. If the residue is left standing over winter, mow the residue for hay or burn before spring greenup.

Always read and follow label directions, and contact your local Extension agent for issues specific to your area—pesticides may not be approved in all states for these purposes.

Harvest after a killing frost

It is recommended to harvest perennial grasses used for biomass in the fall, after a killing frost. Waiting until after frost allows carbohydrates and nitrogen to be translocated from leaf and stem tissue to roots, increasing plant winter hardiness and reducing future nitrogen fertilizer needs.

Mow alleys to less than a 4-inch stubble height and trim plots to a 10-inch height. Determine biomass by cutting and weighing a 3-foot wide swath the length of each one-acre plot, using a flail-type plot harvester with a cutting height of 4 inches. Do not harvest the outer edges

of the plots, to reduce border effects. Weigh the harvested material immediately in the field.

To determine dry matter weight, take a subsample of each plot, weigh the "wet" sample, then dry each sample at 50 degrees C (122 F) for at least 72 hours in a forced-air oven. Then reweigh to determine the dry matter (DM) concentration. Mean DM concentration of these samples will be used to adjust field biomass to an oven dry basis.

Test Plant Quality

If you are interested in sampling the plant tissue from your plots for plant analysis, collect subsamples prior to harvest, using hand clippers. Clip samples from multiple locations within each plot, dry the samples for 72 hours at 50 degrees C (122 F). Then grind the samples to pass a 2-millimeter screen in a Wiley mill. Store each sample in a 4-ounce (approximately), sealed container and send it to a plant analysis laboratory for testing. The oven-dry weight of the hand-collected material will be added back to the harvested material to accurately represent plot biomass.

How Well is the Stand Doing?

Immediately after harvest, evaluate plant populations using a frequency grid (http://www.youtube.com/watch?v=AXZN7-PmldU&feature=youtu.be) (Vogel and Master, 2001). Make a frequency grid from a piece of concrete remesh with 6-inch-by-6-inch squares. Cut the remesh into a 5-by-5 grid containing a total of 25 squares.

Frequency grid

When grass seedlings have three to four leaves and are easy to see, choose at least 10 different locations in your field. Place the frequency grid on the ground at each location and count the number of the 25 squares that have a grass seedling rooted inside. Record that number. Flip the frequency grid and repeat three more times for a total of 100 squares. Add the number of squares that contained at least one seedling to come up with the percent frequency of grass seedlings for that location. For example, if there are 50 squares with at least one seedling, the stand frequency is 50 percent. Repeat the process at nine other locations in the field and calculate the average stand frequency for the 10 locations.

A stand frequency of 50 percent or greater (two or more plants per square foot) indicates a successful stand. Stand frequency between 25 and 50 percent is marginal to adequate, and stands with less than 25 percent frequency may need to be over- or re-seeded.

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- Vogel, Kenneth P. and Robert A. Masters. Frequency Grid: A Simple Tool for Measuring Grassland Establishment. Journal of Range Management, Vol. 54, No. 6 (Nov., 2001), pp. 653-655.

For Additional Information

Switchgrass (Panicum virgatum) for Biofuel Production (/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production)

These CenUSA Bioenergy videos, linked above, demonstrate:

- Drill calibration: No Till Drill Calibration Training Video (http://www.youtube.com/watch?v=7TPLfWLkd_U&feature=youtu.be)
- Drill Calibration Walk Through (http://www.youtube.com/watch?v=izBHivo5xfw&feature=youtu.be)
- Harvest: Optimizing Harvest of Perennial Grasses for Biofuel (http://www.youtube.com/watch?v=NMt5Ct-65-Y&feature=youtu.be)
- Harvesting a Native Grass for Biofuel Production (http://youtu.be/_RcJBURXwKc)
- Frequency grid: How to Measure Stand Establishment Using a Grid (http://www.youtube.com/watch?v=AXZN7-PmldU&feature=youtu.be)
- CenUSA Project Resources (/pages/68136/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

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Research Partners lead by Iowa State University: USDA Agricultural Research Service (ARS), Purdue University, University of Illinois, University of Minnesota, University of Nebraska–Lincoln, University of Vermont, and University of Wisconsin.

CenUSA is supported by Agriculture and Food Research Initiative (http://www.csrees.usda.gov/funding/afri/afri_synopsis.html) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

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Exhibit 10

How to Successfully Harvest Switchgrass Grown for Biofuel

Last Updated: May 09, 2013

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Delaying harvest until after a killing frost helps switchgrass survive the winter and reduces fertilizer requirements in the following year; it also lowers ash content. But it's difficult to dry a switchgrass crop in the field in the short days of late fall.

Techniques to speed switchgrass drying and increase bale density are being investigated. Meanwhile, there are some recommendations for successful harvest (https://www.cenusa.iastate.edu/Content/files/2013_01-19_Shinners_Full_MP4_Version_.mp4) of switchgrass:

- Use a disk cutter-bar mower and adjust cutting height.
- Use intensive conditioning accompanied by, if possible, wide-swath drying for the best drying rate.
- Chop switchgrass with a forage harvester to store in bunkers and bags rather than harvest as dry bales.
- Plan bale placement in the field before harvest for most efficient use of fuel and equipment.

Harvesting After Frost Proves Beneficial

In the Midwest switchgrass should be harvested once a year, typically in the fall after a killing frost. Perennial crops such as switchgrass translocate nutrients, particularly nitrogen (N), from their leaves to their roots in the early fall, aiding winter survival and reducing fertilizer requirements for next year's growth (Parrish, 1996; Vogel, 2002).

Delaying harvest until after frost has also been shown to lower ash content, an important consideration for any thermal conversion process. Delayed harvests have also shown a higher ratio of stems to leaves, which are considerably higher in ash content than stems (McLaughlin et al., 1996)

Cutting Switchgrass and Other High-Yield Grasses

Switchgrass Harvester

Switchgrass is a tall (4 to 6 feet) prairie grass being bred to maximize yield, an important goal for an energy crop. Traditional forage harvesting equipment can be used to harvest high-yielding crops like switchgrass, but machine performance will be different than is typical with forage crops. For instance, high throughputs will reduce ground speed, so field productivity will be lower. Disk cutter-bar mowers are the only logical choice for harvesting high-yielding switchgrass, because sickle cutter-bar mowers will provide very low productivity.

Adjust the mowing equipment to accommodate high-yielding biomass crops. Switchgrass should be cut higher than traditional forages, to a 4- to 6-inch stubble height, to trap snow and aid winter survival (Withers, 2009). Also, tire damage has been reported on switchgrass stubble, which can be quite stiff. Cutting higher can reduce this problem, although yields will suffer.

Set the cutting height by adjusting the gauge shoes to an upper position (Fig. 1). Tilting the cutter bar toward the horizontal (Fig. 2) will help reduce cutter-bar wear and mitigate damage to the plant crown.

Switchgrass Drying Rate

High-yielding crops like switchgrass usually dry at a slower rate than traditional forage crops like alfalfa. However, research has shown that switchgrass actually dries more quickly than forage crops (Shinners et al., 2010). That's because the initial moisture is lower at cutting; its stiff stems produce tall, well-formed swaths that promote air movement; and the leaf surface area is large.

Nonetheless, ambient temperatures will be low and daylight length short when switchgrass is harvested after dormancy, conditions that challenge crop drying. The harvest window between dormancy and rain or snowfall that reduce yields will be narrow, so quick field drying is important.

To help achieve timely harvest by speeding up drying, CenUSA researcher Kevin Shinners is investigating two approaches: intensive conditioning and wide-swath drying:

- **Intensive conditioning**. Traditional equipment for cutting and conditioning hay was designed with alfalfa in mind. Mower-conditioners, for example, are designed to be fairly gentle on the crop in order to maintain the nutritious and valuable leaves. But switchgrass has a thick, waxy stem that is difficult to condition for faster drying. Since its leaves are actually less valuable than the stems when using the crop for biomass, more aggressive conditioning can be considered. Intensive conditioning hard-crushes the stem between two rolls with very small clearance, then shreds the stem by passing the crop through rolls with differential speed, disrupting the waxy epidermis of the stem.
- **Wide-swath drying**. Wide-swath tedding after cutting distributes the crop across the full cut-width rather than in more traditional swaths that may only cover 50 percent of the cut-width. Although not consistent across all studies, intensive conditioning generally was more effective than wide-swath drying at improving switchgrass drying rates. A combination of intensive conditioning and wide-swath drying consistently resulted in the greatest drying rate. Future work will concentrate on machine configurations that can produce simultaneous intensive conditioning and full-width swaths at the time of cutting so that no additional field operations are required.

Better Bale Density Cuts Cost

Because of its thick, relatively tough stem, switchgrass resists compression in the baler. Previous research has shown that bale densities of switchgrass in round and large square bales are 10 to 11 pounds per square foot on a dry basis, which is 25 to 33 percent less than with typical forage crops such as alfalfa or grasses.

Increasing the density of switchgrass bales would reduce handling, transportation, and storage costs, as well as maximize truck weight limits. Shinners and his team are evaluating a "pre-cutter," a style of round baler commonly used in Europe that can increase bale density by as much 10 percent, according to initial research. The pre-cutter is a slicing mechanism that sits between the baler's pick-up and bale chamber. It can theoretically slice material as fine as 45 millimeters, making it easier to pack more tightly into the bale.

However, bale densities are still not great enough to insure more efficient transport weights, so more research is required.

Harvest as Dry Hay or Chop for Storage

Switchgrass can be harvested as dry hay with con ventional equipment and stored in round or large square bales. Alternatively, switchgrass can be chopped with a forage harvester and stored in a bunk or bag silo. Each approach has positive and negative attributes.

- **Dry bales**. Although logistic systems for perennial grasses have focused on field drying followed by packaging in bales, there are problems with this approach. Dry bale systems are costly in terms of labor, timeliness, weather-related losses, energy inputs, and storage losses.
    - Round bales. Storing round bales outdoors can lead to large losses of dry matter because outer layers will get weathered. (Shinners et al., 2010). Bale moisture also tends to be highly variable, depending on weather conditions before harvest.
    - Large square bales. These bales must be stored under cover because they do not shed rainfall. They fill the volume of a trailer more completely than round bales and can maximize payload for transport to the biorefinery (Mitchell et al., 2008).

- **Forage harvester**. With a forage harvester, the size of the biomass is reduced at the instant of harvest, possibly eliminating some requirements for processing later. But the material has very low bulk-density, making storage and especially transport less economical.
    - Bunker or silo bag storage for chopped grasses. This may be less expensive, reduce labor needs, and allow switchgrass to be harvested at higher moisture levels.

Bale Handling and Aggregation

Strategic bale placement can reduce the time it takes to load bales by 38 percent and total travel distance in the field by 40 percent. It can also reduce the total fuel required to handle bales, although only a small amount compared to the fuel required for baling.

Round bales of biomass are typically distributed randomly throughout the field. Collecting bales after harvest takes considerable time and equipment, adding to the delivered cost of the feedstock. Also, some bale-handling schemes require considerable traffic across the field, compacting soil and damaging plants.

CenUSA researcher Shinners is investigating strategic bale-placement schemes to improve bale-handling logistics by conducting time and motion studies for various strategies. Handling schemes have included one- and two-person bale retrieval with traditional tractor loaders; single vs. multiple locations of the bale-hauling trailer; and use of specialized bale-moving machines.

Energy Requirements of Harvest and Processing

The cost of reducing the size of the biomass before converting it to biofuels or bioproducts is a significant fraction of the total cost of a feedstock. To accurately estimate the delivered cost of perennial grass biomass, it is important to calculate the energy expended to harvest and process it.

CenUSA researcher Shinners and his team have quantified the energy required to reduce the size of biomass either at the time of harvest or post-storage. Three size-reduction systems were used: round baler with pre-cutter, forage harvester, and tub grinder.

Using a pre-cutter on a baler increased bale density by 0 to 10 percent and increased specific fuel consumption by 10 to 23 percent, with an average of 17percent. A wide particle-size distribution resulted from use of the baler pre-cutter.

Size-reduction by chopping with a forage harvester (Fig. 3) or by tub-grinding produced similar particle size, which was much smaller than with the baler pre-cutter.

However, the combination of baling followed by post-storage tub grinding required more than twice the energy compared to chopping with a forage harvester. Although harvesting by chopping provides a size-reduced feedstock, the material has very low bulk-density, challenging the economics of storage and especially transport.

Shinners and his team are working on ways to store the chopped feedstock in high-density “modules” and on systems to maintain the density during transport. That would eliminate the need for re-densification and shrink transport costs.

Summary

Switchgrass grown as a biofuel will survive the winter and require less fertilization the next year if harvest is delayed until after a killing frost. Getting a switchgrass crop to dry in the field, however, is difficult in late autumn.

There are strategies to speed up switchgrass drying and to successfully harvest a crop, including using the right equipment, adjusted for the crop; using intensive conditioning, and storing in bunkers and bags, if possible.

For Additional Information

This Fact Sheet is part of the CenUSA Feedstock Logistics: Harvest and Storage Module. (/pages/68136/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa#Module%203) CenUSA Project Resources provide information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

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CenUSA Bioenergy (http://www.cenusa.iastate.edu/) is a coordinated research and education effort investigating the creation of a regional system in the Central US for producing advanced transportation fuels from perennial grasses 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 in soil and increasing carbon sequestration.

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"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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