Executive Summary – CenUSA Bioenergy

The North Central US is one of the most agriculturally productive areas in the world. However, intensive crop production on land within this region that is not well suited to row crop production has impaired soil and water quality and led to loss of productivity. Growing dedicated biomass crops on land that is unsuitable or marginal for row crop production would mitigate these problems and provide additional ecosystem services without adversely affecting food production. This integrated and multidisciplinary research, education and outreach project focuses on growing herbaceous perennials for fuel production that provide potentially high biomass production and ecosystem services. A regional system for producing fuels from these biofeedstocks based on pyrolytic conversion is being evaluated. Objectives of the project are to: 1) develop cultivars and hybrids of perennial grasses optimized for bioenergy production, 2) develop sustainable production systems that optimize perennial biomass yields and ecosystem services, 3) develop flexible, efficient, and sustainable logistics systems, 4) identify and characterize sustainable bioenergy systems to achieve social, economic, and environmental goals and understand socioeconomic and environmental consequences of perennial bioenergy systems, 5) identify germplasm characteristics amenable to pyrolytic conversion and evaluate performance of pyrolytic biofuels, 6) evaluate policy, market, and contract mechanisms to facilitate broad adoption by farmers, 7) develop procedures for managing risks and protecting health for each component of the biofuel production chain, 8) provide interdisciplinary education and engagement opportunities for undergraduate and graduate students, and 9) develop outreach programs for all stakeholders of the bioenergy system.

The second year of the project, described in the following report, was extremely productive in terms data collection, education and outreach activities. Moreover, this second year was characterized by significant transdisciplinary interactions across objective areas. The composition of the leadership team (co-project directors) and collaborations is highly diverse representing a network of eight institutions - Iowa State University, 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's Agricultural Research Service and several research disciplines including plant breeding and genetics, crop ecology and management, ecology, systems modeling, economics, biological systems engineering, mechanical engineering and education and extension. Each of the program areas contributes materially and otherwise to the work being conducted by other objective teams. For example, Objective Area 1 (Feedstock Development) is highly integrated with the activities of other areas. In the past project year, they provided seed to Objective Areas 2 (Feedstock Production), 3 (Feedstock Logistics), and 9 (Extension and Outreach). The Project Directors for Objective Area 1 participated fully in education activities developed by our Education and Extension Objective Areas (8 and 9, respectively). Ken Vogel, Co-Pd and co-leader of the Feedstock Development Team, provided two days of instruction for the Intensive Program for graduate students organized by the Education Team and Mike Casler, the other Co-Pd from Feedstock Development organized *Switchgrass II* a three-day workshop that covered the state-of-the-art in native warm-season grass research and production. Student travel to this meeting was subsidized in part through travel scholarships made available through the Education Objective.

Many other interactions occurred within and across objective areas. Rob Mitchell Co-Pd for Feedstock Production (Objective 2), was extremely active in facilitating the establishment of field studies across the fourteen sites under study in that objective. He was also very active in providing educational materials for Education, and providing technical support and training for Extension. It became apparent during the Annual Meeting in Lincoln Nebraska that Objective Areas 4 and 6 had goals that while not the same, required similar approaches. Since that time they have met and actively worked together on research of common interest. There are many other examples of active collaboration and interaction among the diverse disciplines encompassed by the CenUSA team which are described more fully in the sections that follow.

Another important development occurring in year two was the active engagement that occurred with commercial partners in the thermochemical conversion industry. Although such engagement was not part of our original scope, we were encouraged by our National Program Leader to develop more active relationships with companies that would be involved in the commercialization of the technologies we are working one. The first step in this process was to organize a workshop entitled **Roadmap to Commercialize Thermochemical Biofuels and Bio-Products Processing in the Midwest** that was held December 11-12, 2012 at Iowa State University. The workshop was well attended by industry representatives who fully participated in presentations and discussions. The workshop focused on optimal feedstocks and commercial pathways and had three primary goals: 1) fostering relationships between CenUSA researchers, Midwest agricultural producer groups, and the thermochemical processing industry; 2) identifying optimal biomass feedstock characteristics for thermochemical processing of biomass; and 3) identifying commercial pathways for thermal chemical processing of herbaceous biomass to in the Midwest region. A full report on the workshop and its outcomes is included in an exhibit attached to this report. However, a very important and valuable result is the initiation of ongoing collaboration with three of the companies that were in attendance.

A summary of the activities, outcomes, and deliverables from each of the Objective Areas follows below. More details are included in the comprehensive report that commences in the next section.

Executive Summary – Feedstock Development Objective

The Feedstock Development objective focuses on developing perennial grass cultivars and hybrids that can be used on marginal cropland in the Central United States for the production of biomass for energy.

Co-Project Directors

- Ken Vogel, USDA Agricultural Research Service - Northern Plains.
- Mike Casler, U.S. Dairy Forage Research Center. michael.casler@ars.usda.gov / (608) 890-0065

Accomplishments – Year 2

CenUSA funding enabled the ARS breeding projects at Lincoln, Nebraska and Madison, Wisconsin to complete a third year of testing of previous established yields tests in three Midwest states.

- **Breeding for Biomass Yield in Switchgrass**

  - Selection and breeding within WS4U upland switchgrass increased biomass yield by 4% per year for a simple phenotypic recurrent selection program that required only two years per generation.

  - Selection for biomass yield and winter survival within Kanlow lowland switchgrass increased biomass yield by 2% per year.
  - Selection for biomass yield and winter survival within Kanlow x Summer hybrid populations resulted in third-generation populations with superior biomass yield and survivorship across HZ3 through HZ5, combining the best traits of both the upland and lowland parents. On average, the hybrid populations had 43% higher biomass yield than the better of the two parents, regardless of the location.

  - All of the gains in biomass yield were associated with increases in biomass quality traits on a per-hectare basis, e.g. higher yield of ethanol per hectare and more combustible energy produced per hectare.

- **Integrated Project Impact**
  - A 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).

  - 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) and 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).

- **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).

Planned Activities, Outcomes and Impacts – Year 3

- New switchgrass cultivar released. This cultivar will be first lowland biomass type switchgrass that is fully adapted to the Midwest. Journal Registration paper submitted.
- Methods paper on improved method for making specific crosses with switchgrass and other perennial grasses submitted.
- Summary report on variation among and within laboratories using different analytical systems for mineral element composition of switchgrass biomass. Journal paper submitted.
- Seed of new experimental strains (potential breeder seed) of switchgrass, indiangrass produced for use in second set of yield tests.
- Summarized identification of potential arthropod pests and beneficial arthropods (predators, parasitoids, decomposers, pollinators) associated with switchgrass and other bioenergy grasses. Summary published.
- Summarized characterization of the seasonal abundance of selected arthropod pests.
- Evaluation of over 50 switchgrasses and other bioenergy grasses for susceptibility/resistance to aphids.
- Summarized results on the genetic variation in switchgrass upland and lowland populations for field tolerance or resistance to viruses and quantification of their effect on biomass yield in switchgrass.
- Summarized results on the relationship between switchgrass biomass composition and pyrolysis product yields for switchgrass strains/families known to be genetically different for lignin and ash concentration.
- Identification of viral and fungal foliar pathogens infecting experimental switchgrass strains and cultivars in regional trials.

Executive Summary - Sustainable Feedstock Production Systems Objective

This CenUSA Bioenergy 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 goal is to produce a quantitative assessment of the net energy balance of candidate systems and optimize perennial feedstock production and ecosystem services on marginally productive cropland while maintaining food production on prime land.

Co-Project Directors

- Jeffrey Volenec, Purdue University. jvolenec@purdue.edu / (765) 494-8071

- Robert Mitchell, USDA-ARS. Rob.Mitchell@ars.usda.gov / (402) 472-1546
- David Laird, Iowa State University. dalaird@iastate.edu / (515) 294-1581

Major Accomplishments – Year 2

Seed Factor Analysis Plots and Systems Analysis Plots have been re-established in Iowa, Illinois, Indiana, Minnesota, and Nebraska. Soil samples have been secured and analyzed. Plots have been fertilized based on soil test recommendations. Weed competition has been monitored and necessary control measures implemented. Where possible, environmental measurements have started, including greenhouse gas (GHG) measurements.

Planned Activities, Outcomes and Impacts – Year 3

- Monitor growth of newly established perennial System and Factor Plots and intervene as necessary with management tools to aid establishment.
- Continue to monitor weed pressure and establishment and use control measures as necessary.
- Continue soils analysis for nutrients and carbon.
- Where possible, install necessary equipment and begin environmental measurements, including GHG concentrations.
- Analyze tissues for NDF, ADF, ADL, and calculate concentrations of cellulose, hemicellulose, lignin, ash, and other constituents. Analyze biomass and where reserve storage is of interest analyze overwintering tissues for starch, sugars, proteins and amino acid N. Where soil fertility is a management input of interest analyze tissues for N, P, K, and other mineral constituents.
- Harvest plots for biomass at or near the killing frost for each location, and calculate yields.
- Conduct statistical analysis of data.
- Prepare annual reports of data for GHG emissions, biomass production, surface soil characteristics, and management.
- Continue to improve biophysical models by calibrating SWAT and APEX with data from the biophysical measurements.

Executive Summary - Feedstock Logistics Objective

The Feedstock Logistics Objective focuses on developing systems and strategies to enable sustainable and economic harvest, transportation and storage of feedstocks that meet agribusiness