Forage & Biomass Energy Project – Proposed New 5 year Project 2007-2012

"Improved Plants and Production Practices for Grassland and Biomass Crops in the Mid-Continental USA".
Scientists: Ken Vogel, Rob Mitchell, Gautam Sarath

Problems to be Addressed: In the USA there are 120 million acres of land in pastures and 36 million acres have been enrolled in the Conservation Reserve Program (CRP). There are over four million acres of crop land where the soil erosion rate exceeds 5 ton per year indicating that the land needs to be converted to permanent vegetation. The pasture land in the USA is typically managed below its potential productivity level resulting in reduced profits and animal products per acre. With improved management practices including improved cultivars, the productivity and profitability of the nation's cultivated grasslands could be increased by 30 to 50%.

Conservation Reserve Program land and marginal cropland will need to be converted to perennial biomass energy crops such as switchgrass to meet national energy goals. Improved plant materials and improved management practices are needed for both pasture production systems and perennial biomass production systems to optimize productivity and profitability and maintain sustainability. Pasture and perennial biomass production systems have many similar research needs and research efficiencies can be achieved by addressing overlapping plant materials and management practices in an integrated research project. Improved plant materials and management practices are needed for pasture and perennial biomass energy production systems in the Central Great Plains and the Midwest, USA.

Objectives of Research: The objectives will address National Program 205 problem areas in Component II (Pasture Production Systems) and Component III (Herbaceous Bioenergy Production Systems).

<u>Component II. Pasture Production Systems.</u>

Objective 1. Improved plant materials and germplasms for use in pasture systems are lacking in the Central Great Plains and Midwest, USA.

> a. Develop improved cultivars and germplasms of warm-season (big bluestem, indiangrass, and switchgrass) and cool-season (smooth and meadow bromegrass, intermediate, western, and tall wheatgrass) grasses by continuing on-going recurrent breeding and testing cycles (Vogel, Sarath, Mitchell).
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> b. Develop germplasms of native legumes adapted to the Midwest and Central Great Plains for use in breeding programs and management studies (Vogel, Sarath, Mitchell).

Objective 2. The lack of information in the plant-animal interface limits animal production from grazing lands.

a. Quantify effect of improved plant materials adapted to the central Great Plains and Midwest on grazing animal performance and production system economics in grazing trials (Mitchell, Vogel, UNL animal scientists)

b. Quantify effect of modifying sward composition of pastures with multi-species mixtures of improved grasses and legumes on animal performance and production system economics in grazing trials (Mitchell, Vogel, Sarath, UNL animal scientists).

Objective 3. Management strategies are inadequate to economically and sustainably optimize land and water use.

a. Develop improved technologies for establishing grasses and legumes, including native legumes, in pure and mixed stands in the Central Great Plains and Midwest by developing improved methods of quantifying seed quality of warm-season grasses and quantifying the allelopathic effects of small grains residue on grass and legume establishment. (Mitchell, Sarath, Vogel).

b. Develop improved pasture monitoring and management tools that can be easily and reliably used by producers (Mitchell, Vogel, ARS scientists at Cheyenne, WY and Miles City, MT).

Objective 4. Inadequate understanding of physiological, biochemical, and molecular biology mechanisms involved in plant development, and biotic and abiotic stress tolerances limits genetic and management improvements in pasture productivity and sustainability.

a. Develop improved molecular genetics and genomics technology for genetic improvement of pasture grasses with emphasis on switchgrass (Sarath, Vogel, cooperative with ARS scientists at Albany, CA).

b. Determine physiological, biochemical and genetic control processes for seed dormancy and germination of warm-season forage grasses and specific native legumes (Sarath, Mitchell).

c. Determine the biochemical, physiological, and genetic mechanisms of rhizobial N fixation by native legume species when grown with native prairie grasses. (Sarath, Mitchell)

Component III. Herbaceous Bio-energy Crop Production Systems

Objective 1. Improved switchgrass cultivars and germplasms are lacking for use in herbaceous biomass production systems in the mid-continent USA and in breeding programs.

a. Develop improved switchgrass germplasms for use in public and private breeding and molecular biology genetic improvement programs (Vogel, Sarath, Mitchell).

b. Develop improved cultivars using conventional breeding systems and plant materials that can be used to produce hybrid cultivars (Vogel, Sarath, Mitchell).

c. Develop reliable molecular genetic tools including marker systems and maps and gene function characterization for switchgrass (Sarath, Vogel, ARS scientists at Albany, CA)

Objective 2. Determine the effect of genetics, management, and environment on herbaceous biomass composition and their effect on conversion to liquid and gaseous fuel.

a. Effects of gene expression or suppression of genes involved in metabolic pathways governing cell wall synthesis and composition in switchgrass will be determined (Sarath, Vogel, ARS scientists at Peoria, IL, St. Paul, MN, Albany, CA).

b. Effects of pre-and post harvest management practices on feedstock conversion efficiency for both liquid fuel and synthesis gas production will be determined (Mitchell, Sarath, Vogel, ARS scientists at Peoria, IL, St. Paul, MN).

c. Effects of genotypes and genotype x environment interactions on conversion efficiency will be determined (Vogel, Mitchell, Sarath, ARS scientists at Madison, WI, Peoria, IL, St. Paul, MN).

Objective 3. Reduce switchgrass biomass production costs to make bio-fuels produced from biomass more economically feasible and profitable to producers and processors.

a. Develop improved establishment tools and methods that increase switchgrass establishment success, reduce establishment costs, and reduce the time period required to reach full production potential (Mitchell, Sarath, Vogel)

Objective 4. Develop and validate technologies to improve harvest, storage, and transport efficiency and quality for very high-yield bioenergy crops such as switchgrass for use by farmers and biorefineries.

a.   Develop information on the economic cost of different methods of harvesting and storing biomass feedstocks on farms using available and experimental biomass harvesting and handling technology (Mitchell, Vogel, DOE-INL, ARS-Madison, WI, Peoria, IL).

b. Develop information on the effect of harvesting and storage technologies on switchgrass conversion efficiency for the central Great Plains and Midwest (Mitchell, Vogel, DOE-INL, ARS-Madison, WI, Peoria, IL).

Objective 5. Quantify soil carbon sequestration and other environmental benefits of herbaceous biomass crop production systems.

a. Determine the short term (<5 and 10 years) effects of switchgrass grown and managed as a bioenergy crop in the central and northern Great Plains on soil carbon sequestration (Vogel, Mitchell, ARS soil scientists at Lincoln, NE, Ft. Collins, CO, and Mandan, ND).

Lincoln Sorghum Genetics and Pathology Project – 5 year Project 2002-2007

"Genetic improvement of sorghum for enhancing energy yield, nutrient availability, and disease resistance".

Scientists: Jeff Pedersen, Deanna Funnell, Vacant

Problems to be Addressed: Sorghum is the second-most important cereal feed-grain grown in the U.S. Production is economically critical to farms operating in marginal rainfall areas because of sorghum's ability to tolerate drought and heat. Both the livestock and bioenergy industries utilize sorghum as an energy substrate. For the past five years, USDA-ERS analyses have shown reduced average returns to management for sorghum production. During this same period, shifts in production practices and movement of new pathogens into U.S. sorghum-growing regions have accelerated disease risk. Development of sorghum lines with enhanced energy yield, increased nutrient availability, and enhanced disease resistance is crucial for providing a more competitive crop in marginal rainfall areas.

Objectives of Research:

1. Enhance the energy yield and nutrient value of sorghum by modifying structural and storage carbohydrates.
2. Confirm expression of transgenes in existing T1 sorghum lines and develop systems for deployment of transgenic sorghum.
3. Develop molecular tools and technology for efficient and reliable genetic characterization of fungal races and bacterial biotypes pathogenic on sorghum that can be used to expedite detection and identification of pathogens.

Objective 1: Enhance the energy yield and nutrient value of sorghum by modifying structural and storage carbohydrates. Plant genetics procedures used to accomplish this objective will be supported by the following sub-objectives:

a. Identify and describe waxy mutations of sorghum and develop sorghum germplasm with high amylopectin content. (Pedersen, Funnell, ARS Scientists at Manhattan, KS).

b. Optimize screening nursery experimental design, utilize NIRS and IVDMD technologies to identify lines possessing high grain digestibility, low ADF, or high oil content, and introgress those traits into elite grain sorghum germplasm. (Pedersen, UNL scientists, ARS Scientist at Stoneville).

c. Describe the individual brown midrib mutants and their effects and develop brown midrib sorghum germplasm with reduced lignin content. (Pedersen, Funnell, UNL animal scientists, Scientists at W.H. Miner Agricultural Institute, Chazy, NY)

Objective 2: Confirm expression of transgenes in existing T1 sorghum lines and develop systems for deployment. This objective will be supported by the following sub-objectives:

a. Confirm expression of chitinase, snowdrop lectin, and cyanamide hydratase genes in T1 transgenic sorghum lines previously developed by the project via particle bombardment. (Pedersen, ARS Scientist at Stillwater).

b. Develop systems for transgenic sorghum deployment including pollen control methods to prevent or reduce transgene flow to non-transgenic sorghum and weedy relatives of sorghum. [Pedersen, Funnell, ARS Scientists at Stillwater & Gainesville, Scientists at UNL, Purdue, Ohio State, Berkeley, ARC-Roodeplaat (South Africa), EIAR (Ethiopia), and INRAN (Niger)].

Objective 3: Develop molecular tools and technology for efficient and reliable genetic characterization of fungal races and bacterial biotypes pathogenic on sorghum that can be used to expedite detection of pathogens. This objective will be supported by the following sub-objectives:

a. A collection of microorganisms associated with sorghum in the Great Plains and other sorghum growing regions will be established. (Funnell, Pedersen)

b. Morphological and cultural characteristics of collected isolates will be assessed. (Funnell, ARS Scientists at Manhattan)

c. DNA from a subset of isolates from the collection, as well as isolates from species closely related to isolates of interest will be extracted to identify potential molecular markers. (Funnell)

d. In order to screen large quantities of material, using fungal race- or bacterial biotype-specific probes, PCR methods to detect pathogen DNA isolated from infected plants and from field soil will be developed for sorghum. (Funnell, Pedersen, ARS Scientists at College Station)

e. Using results obtained from "b" and "c" above, traits, chromosome polymorphisms, or molecular markers associated with isolates highly virulent on sorghum will be assessed. (Funnell, Pedersen)

Wheat Genetics and Germplasm Enhancement Project
Current Research Project

"Genetic improvement and evaluation of hard winter wheats"

Scientist: Robert Graybosch, Research Geneticist

Problems to be Addressed: The economic system of the arid portion of the western Great Plains has been built upon production of hard red winter wheat. Increased competition from abroad, coupled with low commodity prices, now threaten sustained agricultural production in this region. As agriculture goes, so goes the rest of the rural socioeconomic system and a continuous erosion of rural communities may result. A more diversified agricultural base is being developed to help resolve this situation. New types of wheat for both domestic and import markets will diversify and strengthen the rural economies of the western Great Plains. These new types of wheat, however, will require accepted levels of agronomic performance and disease resistance or their economic benefits will be minimal.

Objectives of Research:
Objective 1. To determine whether increased expression of HMW (high-molecular weight) glutenin genes in wheat endosperm can result in improved baking quality of hard winter wheat, and if such approaches can confer greater environmental stability of quality, and to determine if there are any negative effects of transgenic expression on agronomic properties. This project will result in wheats with gluten strength desired in commercial milling and baking operations, and will provide fundamental knowledge on the agronomic and quality effects of genetic modifications in wheat.

Objective 2. To develop and characterize adapted waxy (amylose-free) and partial waxy wheats, and to exploit the waxy gene system to produce novel wheat starches. The goal of this project is to expand market demand by developing market demand for wheats with novel starches for use in the food and ethanol industries.

Objective 3. To identify and characterize new sources of resistance to preharvest sprouting, and sources of low or nil grain polyphenol oxidase. These components are necessary attributes of any future hard white winter wheat cultivars.

Objective 4. To pyramid available genes for resistance to wheat streak mosaic virus, and combine these resistance genes with genes for white grain color, resistance to preharvest sprouting and low levels of grain polyphenol oxidase. Germplasm will be developed that will be attractive both to producers and to end-users, and will entice wheat growers to continue the change in production from hard red winter wheat to hard white winter wheat. This change is necessary for the U.S. to remain competitive in world wheat export markets.

4. To coordinate the Hard Winter Wheat Improvement Program and supervise the Hard Winter Wheat Regional Performance Nursery Program.

Wheat Virology Project – Proposed New 5 year Project 2007-2012

"Wheat streak mosaic virus interactions with host and vector"

Scientists: Roy French, Drake Stenger

Problems to be Addressed: The long-term goal of this project is to reduce wheat yield losses due to wheat streak mosaic virus (WSMV). Development of novel disease control measures requires increased fundamental knowledge of the role of viral genes in both pathogenicity and vector transmission. WSMV is the type species of the genus Tritimovirus in the family Potyviridae. While work with other potyviruses may shed some light on WSMV biology, several key features of virus life cycle are unique to Tritimoviruses and, when they are better understood, may serve as potential targets for disease control. Potyviral HC-Pro is a well-known suppressor of post transcriptional gene silencing. However, as we have shown that deletion of WSMV HC-Pro has little effect on infectivity, tritimoviruses such as WSMV may encode additional proteins acting to suppress silencing. Very little is known about how mites specifically transmit WSMV. Our previous research has provided definitive molecular genetic evidence that WSMV HC-Pro is required for virus transmission by the wheat curl mite, *Aceria tosichella*. Presumably HC-Pro either directly or indirectly provides a bridge between a component within the mites and virions of WSMV. Transgenic wheat expressing WSMV proteins promises to facilitate the above research and may provide new sources of resistance.

Objectives of Research:
This project contributes to the Action Plan for National Program 303: Component 2A: Pathogen Biology, Virulence Determinants, and Genetics of Pathogens and Component 2B: Plant-Microbe-Vector Interaction. Over the next 5 years we will focus on the following objectives:

Objective 1: Identify and characterize wheat streak mosaic virus determinant(s) of pathogenicity enhancement (disease synergism) and suppression of the host defense RNA silencing pathway. The hypothesis is that like many other plant viruses, WSMV encodes one or more genes specifically involved in suppressing host post transcriptional RNA silencing pathways. A corollary hypothesis is that the same gene(s) are responsible for disease synergism in mixed infections with other viruses.

Objective 2: Identify and characterize wheat streak mosaic virus determinant(s) responsible for semipersistent transmission by the wheat curl mite. The hypothesis is that WSMV encodes one or more genes, which together with HC-Pro, are required for specific semipersistent transmission by its eriophyid mite vector.

Objective 3: Develop and evaluate transgenic wheat expressing WSMV non-structural proteins (P1, HC-Pro, P3, NIa) for gene complementation and pathogen-derived resistance to WSMV. The hypothesis is that transgenic wheat expressing WSMV non-structural proteins can serve as a platform for virus gene complementation studies and may provide novel pathogen-derived resistance.