Research Project: Improved Plants and Production Practices for Grasslands and Biomass Crops in the Mid-Continental USA

Stagegate Review Summary – Ken Vogel, edited by Mark Downing

Objectives of this project are to:

1. Develop perennial cool- and warm-season perennial grasses and legumes and associated management practices for use in establishing or restoring grazed grasslands.

2. Develop perennial grasses, with emphasis on switchgrass, and associated management practices for use in biomass energy crop production systems.

3. Develop basic and applied information on the genetic and physiological mechanisms controlling grass herbage and biomass yield and quality that could be utilized to improve these traits via breeding and management research (Objectives 1 and 2).

Breeding perennial forages is a multi-year, multi-phase process. Process phases include germplasm evaluation, recurrent breeding and mating, regional small plot trials, and grazing trials of advanced strains. Each phase requires 4 to 5 years to complete. Research is in process on specific phases of breeding and management studies for nine perennial grasses and fifteen native legumes.

This research addresses the forage germplasm development and forage, rangeland, and conservation management components of National Program 205, Grazinglands Management (60%), and it also is conducting research to develop switchgrass into a biomass fuel crop which links it to National Program 307, Bioenergy (40%).

Milestones or Indicators of Progress from the Project Plan:

Objective 1. Complete specific phase for each experiment in progress. As a result, the following products or information will be developed. A crested wheatgrass cultivar will be released in 2002. Depending on seed availability, release two big bluestems and a smooth bromegrass cultivar in 2003. Two intermediate wheatgrass strains will be released as cultivars in 2003 or 2004. A Canada wildrye strain will be released in 2002 or 2003. Increase seed of a blue grama strain for potential release in 2003. Switchgrass germplasm composites for Hardiness Zones 4, 5, and 6 will be released in 2002. Big bluestem and indiangrass germplasm composites for the same hardiness zones will be released in 2003 and 2004, respectively. Some of the initial native legume composites may be available for release in 2005 or 2006. A Standardized Establishment Test (SETS) for switchgrass will be evaluated and validated by 2004. SETS will be developed for other species including big bluestem, indiangrass, and other native grasses, and legumes. Sufficient information on the switchgrass toxin will be available to allow the development of management guidelines.

Objective 2. Determine amount of heterosis for biomass yield for F1 hybrids of switchgrass and the change in heterosis, if any, with advance in generation. The Kanlow x Summer hybrid populations may be released as germplasm or as cultivars in 2004 depending on the results of the heterosis study. Initial results on corn and switchgrass yields from the carbon sequestration study will be summarized and reported in 2003. Initial soil carbon results should be available in 2003 and then at three-year intervals. Economic analysis information on ethanol production from corn vs. switchgrass could be available in 2003 or 2004. Summary reports will be developed every three years. This study is the first study that was initiated to compare corn vs. a perennial herbaceous crop as energy crops and the effect of their production on soil carbon and soil quality. The data will likely have a major impact on agricultural

program policy. The economic costs of establishment based on on-farm trials will be available in 2003. Additional economic information will be available in 2006. Soils results will be available in 2006.

Objective 3. Scientist is hired, laboratory is equipped, and laboratory protocols are developed for analyses. Samples from first two years of full switchgrass plant growth have been collected and feedstock differences between lines have been characterized. Switchgrass strains from the different cycles of selection are increased and released as genetic stocks for use by other laboratories (2003). Sorghum lines are increased and biomass is analyzed and characterized. Information and samples are provided to ARS and DOE laboratories conducting conversion research to start collaborative research.

Milestones enumerated specifically for 2004:

Objective 1. Despite extensive drought in the Great Plains and parts of the Midwest in 2001, 2002, and 2003, all of the 100 plus field and laboratory experiments on specific phases of the forage breeding and management studies are on schedule except for two studies which have been delayed one year.

The drought during these three years delayed the release of some cultivars by one or two years because of reduced seed yields in breeder seed fields. Irrigated isolations for breeder seed increase fields were obtained in 2002, 2003, and 2004 to address this problem and all planned releases should be completed during the five-year term of this project.

Bonanza and Goldmine big bluestem cultivars were officially released in May, 2004.

The intermediate wheatgrass cultivars, Beefmaker and Haymaker, scheduled for release in 2003 and 2004, respectively, were released ahead of schedule in 2003.

Canada wildrye cultivars and germplasm releases are in preparation for ARS and cooperating university review for potential release in September, 2004.

Dependent upon agency approval, the blue grama cultivar and switchgrass germplasm composites will be released in 2004. The big bluestem and indiangrass germplasm composites will be released in 2005.

The Standardized Establishment Test (SETS) for switchgrass will be evaluated, validated, and completed on schedule in 2004.

A milestone that was initially planned for the next five year CRIS project was completed. An economic evaluation of the profitability of well managed big bluestem pastures in comparison to non-till, non-irrigated corn was completed using data from the big bluestem grazing trial and the corn component of switchgrass and corn carbon sequestration study. The net return per acre for well managed big bluestem pastures in the western cornbelt seeded to the best available new cultivar (Bonanza) for the three year period, 2000 through 2002, was $120 per acre. The net return per acre for no-till, non-irrigated corn for the same three year period was $49. The net return for the big bluestem pastures included amortized fencing and water costs. These results demonstrate that well managed pastures planted to cultivars with improved forage digestibility can be about two to three times more profitable than corn on marginal croplands.

Objective 2. Determine the extent of heterosis in switchgrass and the potential decline in heterosis with advance in generation. F1 hybrid populations of Kanlow x Summer switchgrass produced 24% higher biomass yield than Kanlow and 50% greater yields than Summer in sward plots in eastern Nebraska in 2002 and 2003 demonstrating the potential of increasing biomass yields by the development of hybrid cultivars. The F1 hybrid populations produced 20 Mg/ha (8.5 US tons/acre) of biomass during years with

below average precipitation. There was a decline in heterosis with advance to the F2 and F3 generations. Research objective was fully achieved.

F3 populations of the Kanlow x Summer will be released in 2005 as germplasms dependent upon agency approval because of their unique genetic background.

Production results for the four year period, 2000, 2001, 2002, and 2003, from the ten-year plus switchgrass vs. no-till corn carbon sequestration study were summarized. The corn plots were split beginning in 2000 and about half the stover was removed with a field flail harvester. Three years previous stover removal significantly reduced corn grain yields 15% in 2003 in comparison to the area of the plots where no stover was removed. These results were consistent over three N fertility rates and averaged about 13 bushel per acre. These results indicate that removal of corn stover for bioenergy can have deleterious effects on grain yields of non-irrigated corn in the western Corn Belt

Estimated ethanol yields per acre comparison from switchgrass biomass and corn for the same period at equivalent fertility rates demonstrated that switchgrass had the potential to produce greater ethanol yields per acre than corn. The ethanol yields for corn included ethanol from both grain and harvested stover. These results demonstrate that for marginal cropland in the western Corn Belt, perennial biomass crops such as switchgrass can potentially produce more ethanol per acre than corn while providing benefits equivalent to the Conservation Reserve Program. Average ethanol yields from switchgrass during the four year period, 2000 to 2003, were 4200 l/ha or 450 gallons/per acre at a conversion rate of 79 gallons/US ton. In three of these years, the area experienced a drought.

The carbon sequestration component of this study is being conducted by Dr. Ronald Follett, USDA-ARS, Ft. Collins, CO (see CRIS# 5402-11000-006, "Land Use, Land Mgmt. and Climate Chg: Interactions of C/n Cycl, Trace Gas Fluxes and Soil Qual. Agroe") and Dr. John Kimble, NRCS National Soils Laboratory. The carbon sequestration research is on schedule.

Objective 3. Scientist is hired, laboratory is equipped, and laboratory protocols are developed for analyses. Milestone completed.

Samples from first two years of full switchgrass plant growth have been collected and feedstock differences between lines have been characterized using conventional biomass analyses. Completed.

Switchgrass strains from the different cycles of selection are increased and released as genetic stocks for use by other laboratories (2003). Release is being delayed. Additional analyses are being conducted on plant material to more fully characterize the germplasm before release. See additional studies listed below.

Sorghum lines are increased and biomass is analyzed and characterized. Research is on schedule. This research is in cooperation with ARS CRIS project 5440-21220-024-00D "Genetic Improvement of Sorghum for Enhancing Energy Yield, Nutrient Availability, and Disease Resistance". This project is providing Near Infrared Reflectance Spectroscopy (NIRS) and other laboratory support to this project. The NIRS scans were completed and prediction equations developed for the entire U.S. photoperiod insensitive sorghum collection (4000 accessions) for oil, starch, protein, fiber, and phosphorous content, total digestible nutrients, net energy available to livestock, and metabolizable energy. Data for these traits were submitted to GRIN for approximately half of the accessions. Data for the remainder of the accessions will be submitted in FY2004. The U.S. photoperiod insensitive sorghum collection represents a large and diverse germplasm pool that can be directly utilized by plant breeders and basic scientists without the need to backcross these lines into backgrounds that will flower in the continental U.S. Characterizing this collection for traits such as starch, protein, and oil content will allow selection of lines

for improved ethanol production and efficiency. The nutritional data will similarly be immediately useful for improving the nutritional characteristics of sorghum grain.

Information and samples are provided to ARS and DOE laboratories conducting conversion research to start collaborative research. Three standard switchgrass samples representing maturity stages that differ in potential conversion to ethanol were collected, processed, and provided to ARS laboratories at Peoria, IL, Wyndmoor, PA, and a laboratory at Michigan State University that are conducting conversion research. Corn stover NIRS scans were provided to the National Renewable Energy Laboratory (NREL) which were used to predict feedstock composition of the corn stover using NREL's prediction equations and models. The data currently being analyzed will be used to determine the effect of environment and fertilization rates on corn stover feedstock composition.

In addition to the research described in the project plan, basic research on warm-season grass tillering, sites of lignification, and molecular mechanisms controlling lignification have been initiated. Initial studies will be completed in 2007. Research on physiological mechanisms of seed germination and dormancy has been initiated.

Molecular mechanisms: Generate initial set of cDNA libraries from switchgrass tissues. Completed. Develop and analyze a marker population of switchgrass in collaboration with RL and Dr. Christian Tobias (USDA-ARS, Albany, CA). Initial crosses completed.

Analyze switchgrass samples for lignification, digestibility and tiller characteristics. Phenolic compounds in cell walls have been studied by HPLC. Potential target compounds have been selected and will be identified by 2007.

Clone and recombinantly express selected enzymes of the lignin biosynthesis pathway from switchgrass and study their enzymatic properties in detail. Initial studies will be completed in 2007.

Initiate proteomic and biochemical analyses of switchgrass germplasm with regard to photosynthesis, carbon partitioning and cell wall composition. Initial studies completed in 2007.

Investigate nitrogen fixation and nodulation in three prairie legumes (Partridge pea, Roundhead lespedeza and Illinois bundleflower). Development baseline physiological information for initiating management research. Expected completion in 2007 of initial studies.

The Single Most Significant Accomplishment during the FY 2004 year.

Two new improved big bluestem cultivars were released. `Bonanza' was developed for use in USDA Plant Hardiness Zone 5 while `Goldmine' was developed for use in USDA Plant Hardiness Zone 6. Both cultivars are best adapted east of 100 degrees W. Long. Bonanza and Goldmine produced 14% and 8% more kg of beef per ha, respectively, than the cultivars they are replacing. Bonanza produced more than 380 kg/ha (340 lbs/acre) of beef per year during the period 2000-2002 in eastern Nebraska during which precipitation was below normal.

Science and/or technologies have been transferred and to whom?
New cultivars are being transferred to the grass seed industry via University Foundation Seed Divisions. Plant Variety Protection is being sought to protect the genetic integrity of the wheatgrass and the bluestem cultivars. Certified seed of the wheatgrasses will be available in 2005. Certified seed of the big bluestems should be available in 2006. Information on the corn and switchgrass research has been provided to the U.S. Department of Energy.