ANNUAL REPORT OF ACCOMPLISHMENTS AND RESULTS

MONTANA STATE UNIVERSITY

COLLEGE OF AGRICULTURE
MONTANA AGRICULTURAL EXPERIMENT STATION

FEDERAL FISCAL YEAR 2006

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Introduction

Preface

The College of Agriculture (six departments and one division) at Montana State University (MSU), headquartered in Bozeman, Montana, is comprised of the Montana Agricultural Experiment Station (MAES) and the College's academic programs (5 departments and one division) in undergraduate and graduate studies. The MAES is a network of eight Agricultural Research Centers, four farms, and two collaborative research programs with USDA-ARS units in Miles City and Sidney. It does not financially include the Montana Extension Service, though Extension Specialists are housed within four departments in the College of Agriculture. The College does not have programs in Family and Consumer Sciences, Food Science, Sociology, or Rural Development. Expanded partnerships include the Montana Extension Service, MSU-Billings, MSU-College of Technology at Great Falls, MSU-Northern at Havre, the 1994 Land Grant tribal colleges, and other state, federal, and private institutions in Montana and the region (e.g., North Dakota State University, South Dakota State University, University of Idaho, University of Wyoming).

The Montana State University Plan of Work consists of programs listed under the primary prevailing goals. Programs are developed on a five-year or longer timeline, although many individual projects have critical short- and medium-term goals. Stakeholder input has been solicited in the strategic planning process and continues throughout, as programs are developed, implemented and changed, and dollars are allocated.

The source of funds shown in the Key Themes does not represent all of the funding sources that contribute to the research conducted by MAES faculty. Other sources include, but are not limited to: Montana crop and animal agricultural groups, conservation and wildlife groups, Montana Department of Agriculture, Montana Board of Research and Commercialization Technology, Montana Wheat and Barley Committee, Montana Fertilizer Advisory Committee, Montana Noxious Weed Trust Fund, National Institute of Health, National Science Foundation, NRCS, NASA, BIA, USFS, BLM, private industry, private donations, other states, Canadian Provinces, and the State of Montana.

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Vision

The MSU College of Agriculture (COA)/Montana Agricultural Experiment Station (MAES) provides focused and viable science-based education, research, and extension/outreach programs essential for disseminating and creating new knowledge and leadership in agricultural and natural resource systems to preserve and improve the quality of our lives and our environment, and to create added-value from our resources for Montana and its people in a global economy.

Mission

As a land grant institution, MSU provides education, research, and extension/outreach programs focused to meet the changing needs of Montana. The College of Agriculture and MAES generate and disseminate superior knowledge and technological solutions to increase the competitiveness of Montana's agricultural and natural resources, preserve environmental quality, and improve the quality of life for all our citizens.

Values

- Create a work environment of open communication, trust, honesty, and acceptance
- Develop a community of scholars and learners committed to quality and excellence
- Embrace the highest standards of ethics and citizenship
- Provide visionary and responsive leadership

Program Focus and Overarching Goals and Objectives

COA/MAES creates and disseminate knowledge and provides quality educational and outreach activities. Montana agriculture, Montana students, and Montana citizens are the primary focus of COA/MAES programs, although impacts are also regional, national, and international in scope. COA/MAES goals are to:

1. **Enhance Economically Viable and Sustainable Agricultural Systems**
   - Scientifically develop viable and sustainable plant and animal systems.
   - Improve the fundamental understanding of plant and animal biology.
   - Foster the development of value-added biobased agricultural products.
   - Improve plant and animal health through integrated pest management (IPM) and other sustainable practices.
   - Improve food safety and quality.
   - Contribute to commodity and product marketing and economic development.
   - Create programs that comprehensively address plant and animal systems.

2. **Improve Natural Resource Management and Enhance Environmental Quality**
   - Provide a scientific basis for developing land and water use policies and practices.
   - Enhance environmental quality and sustainability of natural resource systems.

- Create educational programs that address natural resource use.
- Develop ecosystem improvement programs that promote sustainable management practices consistent with enhanced biodiversity.
- Enhance our understanding of rural, urban, and disturbed landscapes.

3. **Strengthen the Quality of Life for Montana and Its People**
   - Facilitate the development of educational programs and new delivery systems.
   - Improve recruitment and retention of students.
   - Develop partnerships to enhance business and community development.
   - Emphasize leadership development programs.
   - Enable research to enhance agriculture and natural resources sustainability and development

MAES Key Themes

GOAL 1: An agricultural system that is highly competitive in the global economy.

Overview

Montana is a state with limited crop and livestock diversity due to semi-arid conditions, a short growing season, and the potential for severe winters. Cattle and sheep are the primary livestock enterprises; small grains, forages, and short season specialty crops make up the bulk of the cropping activity. With limited livestock and crop diversity, researchers at MSU are able to delve deeper into understanding each entity from production and management studies to plant and animal genomics. Agricultural cash receipts in Montana total nearly $3.0 billion annually and are made up of roughly a 45:55 mix of crops and livestock. Montana is world-renowned for the quality of its wheat and the robust beef cattle that it supplies to the Great Plains and Midwest. Montana exports approximately 85% of its raw commodity products. It is increasingly important to add value to raw agricultural commodities and processed food products before they leave the state. The revitalization of agriculture and rural communities in Montana is essential for the state's economic sustainability and competitiveness in the global marketplace.

Research programs in the COA/MAES range from research, such as economics, genetics, and biotechnology to practical applications in rangeland, forest, crop, and livestock management. Often the direct impacts of the research are difficult to measure; but the research meets long term strategies designed to make Montana agricultural products more desirable in U.S. and world markets.

Projects in **Goal 1** are designed to address production and marketing issues that will ensure that Montana agricultural products maintain their competitiveness and quality in a global market place.

A coordinated research strategy has been implemented to attain the goal of sustainable cropping systems for Montana producers. Research continues into developing alternative crops in Montana. Camelina, canola, chickpeas, fenugreek, lentils, winter peas, and assorted herbs (calendula, lavender, oregano, safflower, sage, specialty mints, thyme, and yarrow) have been evaluated for their potential in emerging value-

added markets that include cosmetics, nutraceuticals, and natural rubber production. Pulse crop (chickpea, winter peas, and lentil) acreage in Montana increased dramatically to 350,000 acres in 2005, due in part to the contributions made from crop diversification research. Camelina, canola, and safflower are being evaluated as biolubricants that could add substantially to the market for these crops produced in Montana, the northern Great Plains, and the Pacific Northwest.

Researchers continue to evaluate systems that will produce higher quality wheat and barley to meet increasing world demands. An aggressive plant breeding program at MSU ensures development of higher yielding, pest-resistant cultivars. A major effort is underway to characterize and evaluate wheat and barley germplasm and to increase the utilization of world germplasm collections. A barley cultivar with increased levels of beta-glucans has been developed that aids in the reduction of viral livestock diseases and could increase demand for specialty barleys. Forage research has resulted in the release of new alfalfa cultivars, new annual borages, new grass cultivars, and a new sainfoin cultivar that should help Montana hay and seed producers grow well-adapted, high-yielding, and winter-hardy forage cultivars. New oilseed varieties are being developed for nutraceuticals and biofuels.

Research into alternative pest control measures using plant and insect natural enemies continues to provide novel approaches for controlling difficult pests in Montana crops. New, environmentally benign strategies to control fungal diseases are being investigated. A field study has been initiated on the ectomycorrhizal fungi of whitebark pine in the Greater Yellowstone Ecosystem (GYE) to sustain a key food source for grizzly bears.

A grass identification manual, “Grasses of Montana,” is serving as a handy resource for those interested in grass taxonomy and ecology, especially in Montana. The manual is constantly updated with new records of grasses in Montana and is continuing to be distributed free of charge. An effort is underway to determine the opportunities for establishing “native” landscaping and utilizing native grasses and forbs in urban landscapes.

The Montana Sheep Institute has assisted land managers in developing grazing plans and is increasing the competitiveness of U.S. lamb and wool in the world market. Promoting and maintaining animal health (cattle, sheep, and wildlife) is a large undertaking at MSU. By understanding immune systems and parasite development in livestock, and by developing novel genes and new biochemical routes of activity for drugs and vaccines, economically important diseases such as coccidiosis, shipping fever, and brucellosis may be managed more efficiently.

Improving feed efficiency, managing stress during the winter, lowering production costs, and improving beef genetics continue to be primary objectives in animal research programs. Studies demonstrating the effects of winter stress on cattle productivity may lead to a change of livestock management practices to prevent losses. Grazing studies continue to show promise in reducing invasive plant species, especially spotted knapweed.

To maintain the agricultural competitiveness and profitability of Montana commodities, research models have been established that create valuable marketing and economic information for producers and government policy makers. MSU is a leader in the

development of biobased products and the use of biotechnology in the development of highly desirable agricultural products. The Biobased Products Institute currently supports 14 biobased research projects and has developed several high-value biobased products. With the direction of the board, The Biobased Products Institute is continuing to work to expand development and production of value-added crops and products in Montana and to support risk assessment education, research, and extension efforts. Additional initiatives will provide new insights into meat and food safety and risk assessment, the use of vegetable oils as feedstock for fuel cells, development of new wheat varieties, and the optimization of ethanol production from various feedstocks, non-corrosive biobased de-icers, and the impact of plant omega-3 oils on human health.

Studies in precision agriculture have led to the development of a tool for a rapid nondestructive characterization of soils for a variety of environmental and agricultural applications and could dramatically increase the availability of soil data for monitoring carbon sequestration in agricultural lands.

Total Goal 1 Funding: $14,110,009 FTE: 141.5

Following are descriptions of selected projects currently funded and in progress at Montana State University.

Key Theme – Adding Value to New and Old Agricultural Products

a. Wool Research

Description of Activity: International and domestic marketing and sales of wool are based on objective measurements of wool traits. In order to maximize grower income and obtain a more uniform wool clip for the wool industry, Optical Fiber Diameter Analysis (OFDA) technology is used in many countries at all stages of the wool-processing pipeline. In addition to measuring fibers from sheep, it is used to measure, alpaca, cashmere, mohair, and synthetic fibers. The OFDA2000 is a lightweight, fully portable measuring system that can provide rapid (25 seconds), accurate, and precise diameter measurement along the length of greasy wool staples. The OFDA2000 technology provides producers an opportunity to test wool inexpensively and is giving them an edge for marketing their wool clips.

The objectives of this project are: (1) to evaluate the effectiveness of the OFDA2000 compared to core testing and grab; (2) to evaluate and implement OFDA2000 measurements to improve the accuracy and precision for selecting various wool traits in the wool clip; (3) to examine the OFDA2000 in-field use for identifying LDP wool characteristics prior to market sampling; and (4) to evaluate the effectiveness of a portable automated grab-sampling unit to the standard manual grab sampling and core methods.

Fleece samples were obtained from 6,055 Rambouillet sheep at shearing. Four staples were randomly selected from each fleece immediately after being shorn and were measured with the OFDA2000 for fiber diameter, length, and comfort factor. Each animal's ID was recorded and a log was taken to identify which set of fleeces corresponded with each bale of wool. After a sample was measured on the OFDA2000, the fleece was sorted according to micron size. One hundred-fourteen bales were

weighed and cored according to American Society for Testing and Materials (ASTM) procedures. The core samples were then shipped to Yocum-McColl Testing Laboratories (Denver, CO) for yield, fiber diameter, standard deviation, and coefficient of variation. Core test results were compared to the OFDA2000 results for each classing line.

Impact/Accomplishment: Comparisons of OFDA2000 in-field sampling and core samples analyzed at the testing laboratories demonstrated that the OFDA2000 sampling was consistently 0.30 microns finer than the measurements from core samples. Having access to portable measuring systems for measuring wool samples provides producers the opportunity to immediately know the quality of the product they are marketing. The results of this research will improve the tools and technology available for improving the quality, marketing efficiency and international competitiveness of U.S. wool.

Source of Funding: Special Grant, State of Montana

Scope of Impact: National

Key Theme – Agriculture Competitiveness

a. Agricultural Policy

Description of Activity: Farm and ranch incomes in Montana are affected by many domestic and international government programs. This project examines the economic effect that agricultural policies have on rural communities in Montana and throughout the U.S. The project provides important insights into the effect that farm programs have on incomes, community well-being, consumers, and up-stream and downstream agribusinesses. The project provides information that will enable farmers, rural community business leaders, and policy makers to increase their knowledge base and the quality of their business and policy decisions. The objectives of the project are to model and estimate the economic effects of domestic and international trade, agricultural commodity programs, disaster and crop insurance programs, commodity and livestock marketing systems, natural resource use and policies, and agricultural science and social science research policies.

A particular focus examines the degree to which Canada and the U.S. have integrated wheat and barley markets. The effects of foreign grain and livestock policies, state trading enterprises, and economic integration among Western Hemisphere countries on U.S. agricultural commodity prices are being investigated.

Several program areas in the Northern Great Plains are being analyzed including commodity programs, crop insurance, cropping decisions (including specialty and organic crops), disaster payments, soil erosion, and chemical use. A new review of the impact of government management practices, natural resource policies, recreational asset policies, timber and forest products concerns, and investment decisions has been initiated. Other projects include the impact of agricultural science policy, livestock regulations, forest management policies, and an evaluation of the economic effects of a landmark court decision on tribal and non-tribal fishing practices in the Pacific Northwest.

Areas of research also include food labeling policy, timber markets, China's domestic wheat policies, U.S. crop insurance programs, animal and human disease policy, and

federal agricultural policy. Research has been initiated on trade policy and incentives for biotechnology adoption, potential federal animal ID programs, the effects of trade policy responses to Bovine Spongiform Encephalopathy (BSE) events on cattle prices, the use of contracts in marketing alternative crops, and the effects of red-lining credit in rural areas.

Impact/Accomplishment: Under this project three refereed journal articles, three masters theses, a book on the economics of agricultural policies, and 16 outreach publications were produced and made available to rural community leaders. Over 2,000 farmers, agricultural business leaders, and policy makers in Montana and other Northern Great Plains and Rocky Mountain states have received and used information from this project. Approximately 60 outreach programs have been conducted that used the results to provide direction to researchers and producers. In addition, policy makers requested results from several research projects to provide background information for making decisions about proposed federal legislation.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Animal Genomics

a. Genetic Analysis of Production Traits in Beef Cattle and Sheep

Description of Activity: The beef and sheep industries are important agricultural enterprises in Montana. Decreasing input costs and increasing production revenues will help producers achieve higher quality products, generate more income, and maintain Montana's position in the world livestock market. Using molecular and quantitative genetics, methods are being developed to identify genes that are important to production efficiency and provide better ways of performing genetic evaluations.

This program’s objectives are: (1) to evaluate the effect of the selection for decreased mature weight and increased weaning weight on the efficiency of the cow herd; (2) to determine the direct response of selection for scrotal circumference; (3) to determine what effect selection for other traits has on female fertility; (4) to determine what effect selection for reproductive efficiency has on other important traits; (5) to determine if there are specific differentiating quantitative traits in two lines of Rambouillet sheep selected for increased and decreased litter size; and (6) to determine the proper endpoints for genetic evaluation of carcass traits.

Impact/Accomplishment: Reproduction and carcass traits are two of the most important considerations for livestock producers to enhance market competitiveness and market access. The acquisition of cattle for the mature weight/weaning weight selection lines was completed. Bred females calved and their heifer calves were retained as replacement females. Females purchased were bred in June to calve in the following spring. Data continues to be analyzed from the scrotal circumference selection study and has resulted in three abstracts and three proceedings papers.

The effect of this selection on female fertility is being analyzed, as data on reproducing females is collected. The first calves from the carcass selection lines were born and

second year matings were performed. The first group of heifers born in the project was bred in 2006 for calves to be born in 2007. Since this project focuses on the reproductive efficiency of the second-calf heifers, it will take several more years of data to determine if there is a difference in the two lines. Early data analyses from this project resulted in one abstract and one proceedings paper. Final analyses of the Simmental data to determine the proper endpoint to adjust carcass data is completed with the submission of three peer-reviewed journal articles.

Providing producers the information needed to produce animals with the highest profit potential is essential to maintaining or exceeding Montana's current ranking in the national cattle and sheep industry.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

b. Homologous Gene Targeting of Primary Embryonic Bovine Fibroblast Cells

Description of Activity: Gene targeting in cattle is potentially of great value to agricultural producers; however it is highly inefficient. The purpose of this study is to identify and test the parameters limiting the efficacy of gene targeting in bovine cells, so that the process efficiency can be increased. Targeted mutagenesis can be used to create genetically modified animals; however, in species other than mice, there are very few reported successes. Increasing the efficiency of targeted mutagenesis in bovine cells could in turn be used to create animals by cloning.

Bovine cell lines were produced from pure-bred dairy cattle (American Holstein) and from free-range beef cattle from Montana. DNA from the Holstein cells has been used to produce vectors for targeted mutagenesis. Mutations were introduced into the targeted vector and efficiency was measured in the two cell lines. As the first systematic study was to analyze parameters affecting targeted mutagenesis in bovine cells, a line of bovine embryonic fibroblast (BEF) cells was produced from a single 40 day-old bovine fetus that was harvested from a "pure-bred" American Holstein heifer inseminated with pure American Holstein semen. The rationale for this breed choice was to minimize heterozygosity in the resultant fetus.

From the same fetus, a genomic DNA library in lambda phage was developed. The BEF cell line was expanded to second passage, and several hundred vials of these early-passage cells were frozen in liquid nitrogen to provide an essentially permanent stock of BEFs that genetically match the genomic library. From this library, five pure clones of the bovine tbp gene were isolated forming the target for the studies. Large numbers of clones of BEFs bearing this targeting vector have now been transfected and isolated. The research will continue to produce clones, and each clone will be analyzed for the presence of targeted vs. arbitrary vector insertions.

An additional line of BEF cells have been produced from a 40 day-old Holstein fetus, a second line from an outbred free-range Montana beef fetus, and a genomic DNA library in lambda phage was produced. Using several vectors, targeting of the matched Holstein cells was initiated and found that the locus could be effectively targeted. Transfection efficiency has been vastly improved in the past year by switching from electroporation of the cells (which gave only a small percentage of the cells transfected in analyses based

on green fluorescent protein expression) to using the Amaxa Nucleofector II electro-transformation system. This modification, has increased transfection efficiency by roughly 10-fold.

Impact/Accomplishment: Our goal is to measure how sequence identity parameters affect the efficiency of targeted mutagenesis in bovine cells. If targeted mutagenesis were to become tractable in cattle, it could both increase the value of existing cattle-based commodities and allow creation of many more valuable cattle-based products. The end results may be the production of particularly disease resistant herds or herds exhibiting increased milk production or enhanced beef characteristics. It could also help create cattle lines custom fit to particular environments by altering their ability to use different feed sources, altering salt tolerance, or changing reproductive cycles.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Animal Health

a. Regulation of Growth and Development in *Toxoplasma gondii*

Description of Activity: The cost of coccidiosis to livestock producers is in the hundreds of million dollars annually from weight loss and death of young animals. Coccidiosis is a parasitic disease of the intestinal tract that can spread from one animal to another by contact with infected feces. It is most severe in young or weak animals. There is also a risk to human populations through food contamination. This research explores the molecular correlates of the *Toxoplasma* cell cycle that are relevant to parasite development through the application of functional genomic and forward-genetic strategies. Changes in gene expression that occur across the developmental pathway and the mechanisms controlling the parasite cell cycle are being examined.

In order to understand the molecular control of coccidian parasite growth and development, genetic strategies to dissect the *Toxoplasma* cell cycle are being developed. Functional genomics are being applied to understand gene expression during *Toxoplasma* development in the intermediate host life-cycle.

Impact/Accomplishment: Progress has continued in the characterization of a new method to synchronize *Toxoplasma* growth using the drug pyrolidine dithiocarbamate (PDTC). This new synchrony model provides the tools needed to complete a comprehensive study of cell cycle gene expression. *Toxoplasma* genome-based microarrays were constructed at Affymetrixs (Santa Clara, CA). About 30,000 chemical mutants and a total of 50 temperature sensitive mutants with generally recognized defects in cell cycle mechanisms have been generated. Complementation experiments are now underway in selected ts-mutants, using a novel complementation cosmid library resource. Five out of five ts-mutants have been complemented using the cosmid library. The construction and sequencing of serial-analysis-of-gene-expression (SAGE) libraries from Type III-VEG strain populations were completed. SAGE tags offer a broad view of gene expression in *Toxoplasma* and tag frequencies in specific libraries define baseline changes in the developmental transcriptome of this parasite. The 300,000 SAGE tags generated in this project represent an estimated 6,000 mRNA transcripts expressed

during the *Toxoplasma* intermediate life cycle. The comprehensive analysis of gene expression across the developmental continuum in *Toxoplasma* development will have a significant impact on the identification of new drug and vaccine targets for disease control in U.S livestock.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

b. Brucellosis Vaccine

Description of Activity: Brucellosis caused substantial losses to farmers in the U.S. over the last century both from direct losses and in the cost of efforts to eliminate the disease. Brucellosis in cattle and bison causes abortions, infertility, and lowered milk production, and is transmissible to humans as undulant fever. There has been awareness of the presence of brucellosis in the Yellowstone National Park (YNP) bison herd for many years. However until bison started leaving the park boundaries in recent years, there was little concern by Montana cattle producers. There are no efficacious vaccines for brucellosis in bison; current vaccines are only 50–60% effective in cattle. This research is designed to develop new subunit and live vaccines that will effectively protect bison and cattle against brucellosis.

Impact/Accomplishment: Sixty-five potential brucellosis vaccines have been identified and are being screened to generate a workable number for development. To refine the vaccine formulation, a murine *Brucella melitensis* model and a caprine *B. abortus* model are being used to determine which DNA vaccines demonstrate protection. In addition, live, attenuated *B. abortus* mutants have been identified as vaccine candidates. These will be further developed to test their efficacy in mice and goats. Finally, the studies are designed to develop a peptide mimitope for *B. abortus* LPS and will incorporate testing for its protective properties. From these collective studies, a subunit brucellosis vaccine for bison can be developed that will be potentially useful for livestock and humans.

Our collective results from the bison and mouse vaccination studies reveal that protective efficacy can be obtained with various live and subunit vaccines. Thus, the development of effective brucellosis vaccines for brucellosis appears to be feasible once the studies have been completed.

Source of Funding: Special Grant, State of Montana

Scope of Impact: National

c. Oral Prion Neuroinvasion Via Cranial Nerves

Description of Activity: Prion diseases are fatal neurodegenerative diseases of animals and humans. Prions are novel pathogens that contain modified host proteins lacking a nucleic acid genome. The prion agent can replicate in the lymphoreticular and nervous systems, but neurological symptoms and degeneration in the brain are primary features of these diseases. In livestock, prion diseases include scrapie in sheep and goats and bovine spongiform encephalopathy (BSE) in cattle. In free-ranging and farmed cervids (deer and elk), prion-caused chronic wasting disease (CWD) is a growing

concern. The goal of this research is to define the route(s) of neuroinvasion following oral prion infection.

The transmission of animal prion diseases is most often associated with ingestion of the prion agent, and initial prion infection is found in the lymphoid tissues of the gastrointestinal tract prior to its spread to the central nervous system. In this study, the ability of prions to infect the nervous system in the oral cavity as an alternate route of entry into the host is examined. These studies can improve our understanding of how prions enter into a host and spread to the brain and peripheral tissues. The specific aims of this project are: (1) to identify potential routes of prion infection in the oral cavity; (2) to determine the ability of prions to infect tissues in the oral cavity that are used in food, such as the tongue; and (3) to investigate oral cavity tissues that could be used for prion detection in an antemortem diagnostic test for animal prion diseases

Impact/Accomplishment: In the past year we focused on two areas: (1) to investigate prion infection in the tongue and nasal cavity of sheep, deer, elk, and cattle experimentally infected with prions, and (2) to determine if prion neuroinvasion from the oral cavity was dependent on replication in secondary lymphoid tissues or whether it can bypass this requirement and invade the brain strictly via nerve fibers. Our collaborators at the National Animal Disease Center have collected tongue and nasal turbinates from sheep, deer, elk, and cattle that have been experimentally infected with scrapie, chronic wasting disease (CWD), or transmissible mink encephalopathy (TME).

Studies in hamsters revealed that the prion agent can spread directly to the brainstem from the tongue via the hypoglossal cranial nerve in only one to two weeks. Since these tissues have a mucosal surface, it may be possible that the prion agent is shed from the tongue or nasal cavity. Our studies suggest that this may only apply to scrapie and CWD but not to BSE. Studies of neuroinvasion in rodents indicate that prior agent infection in secondary lymphoid tissue is not an absolute requirement for prion neuroinvasion from the oral cavity. This suggests that there can be alternate routes of neuroinvasion following prion ingestion.

Studies indicate that the prion agent can spread away from the brain along motor and sensory fibers into the tongue. This finding has implications for public health since livestock tongue is used in food products and could be a potential source of human prion infection. To protect animal and human health from foodborne exposure to BSE and scrapie, specified risk materials (SRM) that are known, or suspected, to contain the prion agent are excluded from the food chain. The current SRM includes tissues from the brain, spinal column, eyes, trigeminal ganglion, tonsils, and small intestine. In most cases, the tongue is excluded from the list of risk materials; but research indicates that prion infection is prevalent in the tongues of sheep and elk that are experimentally infected with scrapie and CWD, respectively. Therefore, it is possible that prion-infected ruminant tongue can enter the food supply and could represent a high risk for BSE transmission to humans, if the BSE agent is present in the tongue or tongue by-products.

Source of Funding: USDA, State of Montana, NRI Competitive Grant

Scope of Impact: National

d. Local Immunity to Bovine Viral Respiratory Infection

Description of Activity: Bovine respiratory disease (BRD), also known as "shipping fever," is the most common, and costly, disease of feedlot cattle. According to the USDA, shipping fever in 2004 cost the U.S. cattle industry over $1 billion for direct costs of treatment, loss of production, and livestock deaths. Shipping fever viral pneumonia is associated with large groups of calves from diverse geographic, nutritional, and genetic backgrounds that have been collected in feedlots. The disease is typically seen in feeder calves 7–10 days after assembly in a feedlot. Up to 35% of the calves may become diseased with a subsequent death rate of 5–10%. Shipping fever and other respiratory diseases also represented 9.4% of the total non-predatory losses of sheep. Consequently, there is a need to develop effective vaccines for viral pneumonias.

The goal of this project is to better understand how immune responses to bovine viruses are induced and expressed in the upper and lower respiratory tracts. An understanding of these mechanisms can then be used for the rational development of efficient immunotherapies against respiratory viruses. Accomplishing the project goals would result in decreased loss of cattle due to respiratory viruses and therefore greater profit margins for producers**.**

Impact/Accomplishment: Shipping fever is normally initiated by a respiratory virus infection which then predisposes the calf to a secondary bacterial infection, such as bovine viral diarrhea virus (BVDV). This virus causes diarrhea and also can induce pneumonia in calves. Research indicates that resistance to BVDV is due primarily to an antibody response and is not dependent on a cellular immune response. In order to develop a more effective vaccine against BVDV, the mechanisms of natural immunity need to be understood. Vaccines then can be developed that would enhance the natural immune mechanism. Studies have been completed and published on the primary and secondary immune response to respiratory infection of calves with BVDV. We found that clearance of a primary response is the result of a cell-mediated response, and that resistance to a secondary challenge with BVDV is mediated by both cellular and humoral immune responses. Most pulmonary virus immunity research has focused on T cell responses in the lungs. However, bovine viruses normally first infect the nasal mucosa, and then spread progressively to the trachea and to the pulmonary airways. Thus, to rationally develop effective vaccines to pulmonary viral infections in cattle, it will be necessary to understand immune responses to these pathogens in both the upper and lower respiratory tract. The most effective pulmonary vaccines would induce immunity that would stop an infection at the upper airways before it could spread to the lung.

Viral pneumonias cause substantial morbidity and mortality in the cattle industry. The development of effective vaccines is critical to ensure the profitability of shipping cattle, especially from a state like Montana that is dependant on profits from feeder calves shipped to feedlots in the Great Plains and Midwestern states.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Animal Production Efficiency

a. Management Practices Related to the Enhancement of Artificial Insemination (AI)

Description of Activity: There is a correlation between transportation stress and early embryonic mortality, especially during critical periods of gestation in cattle. This research study investigates the use of flunixin meglumine, a non-steroidal anti-inflammatory drug (NSAID) and cyclo-oxygenase inhibitor. NSAIDs work by inhibiting the body's production of prostaglandins and other chemicals that stimulate the body's inflammatory response. Flunixin meglumine has several different veterinary uses, including treatments in pregnant and open cattle. Flunixin meglumine can lengthen the life of the corpus luteum through reduction of prostaglandin production. It can also mimic a situation of maternal recognition of pregnancy and can reduce uterine activity.

The objectives of the research project are: (1) to evaluate the pregnancy rates of beef heifers following transportation stress or no stress following administration of flunixin meglumine; (2) to characterize the mechanism by which flunixin meglumine might improve pregnancy recognition and maintenance in beef cattle; (3) to compare the artificial insemination (AI) pregnancy rates of heifers that receive flunixin meglumine and the control heifers that receive no treatment approximately 14 days after AI; and (4) to determine the level of flunixin megulamine necessary to reduce prostaglandin F2a production in stressed beef females.

This research project directly compares pregnancy rates of heifers that are synchronized and artificially inseminated and received either no additional animal handling or a single injection of flunixin meglumine approximately 14 days after AI (during the critical period of maternal recognition of pregnancy). In addition, this research evaluates the ability of a single injection of flunixin meglumine to improve conception rates to AI in a large field trial involving 1,000 beef heifers.

Impact/Accomplishment: Data collected in this study includes birth weight, gestation length, and percent assisted births of calving ease in Simmental cattle and low birth weight Angus sires over a 2-year period (2005–2006). Angus yearling heifers were bred in 2005 and Angus yearling heifers in 2006 at four locations by AI using semen collected from Simmental and Angus sires. Birth weights, gestation lengths, and calving ease scores of approximately 1,100 calvings were analyzed to determine sire breed effect. Calving ease scores are recorded so that the percentage of assisted births can be calculated. The statistical model includes the fixed effects of year of birth, sire breed, calf sex, ranch, two-way, and three-way interaction.

The results of this study could provide information for the production of calves with heavier weaning weights, yearling weights, and greater rates of gain, which would benefit commercial beef producers. Advancement of sexed semen technology will allow for the breeding of yearling replacement heifers to further decrease the incidence of dystocia (abnormal or difficult labor).

Source of Funding: Hatch, State of Montana

Scope of Impact: National

b. Molecular Mechanisms Regulating Skeletal Muscle Growth and Differentiation

Description of Activity: Muscle growth rate and tenderness are important characteristics in the production of meat. Producers demand rapid growth of animals, while the consuming public judges meat quality by the tenderness of the cut of meat. This project seeks to determine if changes in the molecular activities of muscles creates a change in the genetic potential and subsequently changes in the resulting finished product. Information from these studies may help explain some of the variation seen in tenderness in the U.S. meat supply.

The objectives of this research project are to: (1) characterize the signal transduction pathways that regulate skeletal muscle growth and differentiation; (2) determine molecular mechanisms that control gene expression in skeletal muscle; and (3) characterize mechanisms of cytoskeletal protein assembly and degradation in skeletal muscle.

The study compares the relationship and response of satellite cells of different genetic potential to growth factors. Research strives to clarify mechanisms of muscle growth to determine if changes in growth rate or the genetic potential for growth has any impact on the tenderness of meat produced. The initial study evaluates callipyge and non-callipyge satellite cells.

It has been well documented that meat from sheep carrying the callipyge gene is much tougher than meat from sheep not carrying the callipyge mutation. Satellite cells have been isolated from sheep and are being grown, treated with growth factors, and evaluated for the rate of proliferation and markers of differentiation. In addition, the appearance of calpain and calpastatin in the fusing satellite cells is being evaluated. Satellite cells have been isolated from callipyge and normal sheep and from fast- and slow-growing cattle of similar genetic background. These cells are currently being evaluated for their response to growth compounds.

Impact/Accomplishment: The combination of the satellite cell and adipocyte cell approach and the more applied approach to tenderness (Warner-Bratzler shear measures) should allow us to determine what compounds are affecting specific cellular responses, and these responses can be related back to the eating quality of the meat. Information from this study could be used to change implants, if one specific compound causes a greater impact than another. It will also help to determine if changes in genetics can be creating some of the tenderness variation that is being seen in the marketplace.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

c. Montana Sheep Institute

Description of Activity: Most land managers agree that the spread of non-native invasive plants is the primary environmental threat to western wild lands. Many large blocks of rangeland in the West are infested with noxious weeds (leafy spurge, spotted knapweed) to the extent that the land will not support grazing by traditional livestock and wildlife. Encroachment of these non-native noxious weeds is not just an agricultural issue, it's a societal issue. Noxious weed invasion reduces the ecological integrity of land and waters, alters ecosystems, impacts wildlife habitat and threatens survival of native

plants. In many cases, the cost of traditional weed control methods (primarily herbicides) actually exceeds the value of the land. Currently, sheep grazing represents the only economically and environmentally sound alternative to address large infestations of invasive plants. Sheep can be used to manage these weed infestations providing a benefit to the sheep owner while reducing noxious weeds. This project focuses on: (1) the use of sheep grazing as a tool in natural resource management; (2) developing and implementing the selection, nutritional and marketing management strategies for maximizing sheep production; and (3) implementing the development of non-traditional lamb and wool marketing strategies.

Nontraditional adjustment strategies need to be developed and implemented to increase the competitiveness of Montana and U.S. lamb and wool in world markets. Objectives of this project include: (1) to develop, implement, evaluate and conduct educational programs on controlled sheep grazing strategies for managing large infestations of leafy spurge and spotted knapweed; (2) to determine the effects of feeding diets with increasing levels and increasing days on feed of safflower oil to feedlot lambs on animal performance, carcass characteristics, color stability, CLA and tocopherol content of lamb muscle tissue; (3) to plan and implement a project designed to educate producers about the national animal identification and disease trace-back program, issue premise identification numbers and tag individual animals, and collect intrastate and interstate movement data that will be used to test a 48-hour trace-back system; (4) to evaluate ewe lamb weight gain performance and cost of gain comparisons when fed forage of experimental and traditionally grown cereal forages; and (5) to develop and evaluate a system for grab sampling wool for length and strength testing.

Impact/Accomplishment: Initially, seven sites were located across Montana, sheep management and grazing plans developed, monitoring sites established, and initial plant composition data collected. Currently there are 22 active projects at 31 Montana sites involving 1,000 landowners, 31 sheep producers, 30,000 ewes and lambs, and over 100,000 acres of weed infested areas. Initial results clearly demonstrate that as these non-native weeds invade the landscape, the forb component is eliminated. Forbs are a critical component of a healthy wildlife habitat. In our studies, we were able to achieve 60–70% utilization of the leafy spurge or spotted knapweed and limit the utilization of the grass to 30–40%. Over time, this type of grazing should favor the reestablishment of grass and forb components of the landscape. Photo plot data from eight sites with at least two years of sheep grazing indicated leafy spurge composition decreased by 9% per year of grazing while the grass component increased by 10%. Sheep grazing provides an economically feasible and ecologically sound tool to restore landscapes heavily infested with noxious weeds to a level that will support traditional livestock and wildlife grazing.

Source of Funding: Special Grant, State of Montana

Scope of Impact: National

Key Theme – Biobased Products

a. Biobased Products Institute (BPI)

Description of Activity: The future of Montana's agricultural economy depends on maximizing net returns per acre or per animal unit with the most efficient use of our resources. The BPI is continuing to work to expand development and production of value-added crops and products, and to support biolubricant and biofuel development, risk assessment education, research, and extension efforts in Montana. The BPI provides expertise to growers, researchers, and agricultural businesses, and assists in development of safe, nutritious, value-added products, risk assessment procedures, and marketing. A biobased economy will provide manufacturing, product development, rural development, and jobs for the citizens of Montana and the Pacific Northwest.

The goal of the BPI is to provide an infrastructure that encourages collaborative programs addressing issues such as biobased products, value-added alternative crops, value-added meats, and food risk assessment. The BPI has funded 51 research projects; ongoing research is currently being conducted on 30 biobased projects. The initial competitive selection and progress of each project is determined on an annual basis by the Board of Directors. The Board of Directors can choose to continue funding, terminate funding, or alter the amount of funding awarded. Research projects with a potential to enhance agriculture through production of new high-value crops or development of value-added agricultural products and projects with nearer term commercialization potential are high priorities.

The Biobased Products Institute funds cutting edge research that is innovative and responsive to the developing needs of the region by: (1) developing value-added end-use products with a competitive edge; (2) enhancing agricultural production through innovative approaches; (3) developing systems for food safety and agricultural security; (4) establishing biobased product and food science education and research; (6) enhancing partnerships across the region; and (7) conducting outreach activities related to biobased products and food science for producer, agribusiness, and others.

Impact/Accomplishment: The BPI has been instrumental in identifying potential oilseed crops suitable for production in Montana and developing culinary oils, biolubricants, omega-3 oils, feeds and biodiesel and energy products and applications. Several products are being produced and marketed by private industry or grower cooperatives including PrOatina gluten-free oats to the celiac community and beta-glucan to the nutraceutical industry. Fenugreek, an annual legume, shows promise as a nutraceutical feed for geriatric and athletic horses. Teff is being developed as gluten-free flour for production in eastern Montana. Camelina is emerging as a profitable, alternative crop for production of biofuel and omega-3 foods and feeds; new varieties are being developed. Bioproducts made from canola oil (chain oil, penetrating oil, and dust suppressant) are being produced and marketed. Scale-up is in progress for biobased motor oil and hydraulic fluid. Technology transfer collaborative relationships have been developed with the Montana Ag Innovation Center, MSU TechRanch and MSU TechLink. Collaborators have expertise in incubating new products and businesses and assisting existing businesses.

Source of Funding: **Special Grant, State of Montana**

Scope of Impact: Montana

Key Theme – Biotechnology

a. A Biorational Approach to Discovering Novel Bioactive Molecules in Rainforest Endophytes

Description of Activity: The associations and interactions of microbes with higher plants can lead to the discovery of novel products. The discovery of new natural products that have biological activity is of economic and environmental importance. Objectives of this project are to: (1) isolate and characterize endophytic microorganisms (endophytes) that make volatile antibiotics and determine the usefulness and application of the antibiotics; (2) isolate and characterize endophytes that make novel natural products and determine the structure and usefulness of these compounds; and (3) develop novel approaches that can be used to better characterize compounds of interest. We shall approach these problems by visiting areas of the earth, especially rainforests, that have wide ranging biodiversity and by taking plant samples (with approval) for eventual isolation of endophytes. These organisms are then taxonomically identified and their products isolated and characterized. The goals of this program will be met with cooperation and funding from private companies and other governmental agencies.

Impact/Accomplishment: All of the new compounds that we have discovered to date are patented and licensed to U.S. companies. Soils of all types and locations have generally served as the major sources of *streptomyceteous* bacteria. These organisms supply about eighty percent of the antibiotics in the world. We have determined that *Streptomyces spp*. can exist as endophytes within the interstices of some higher plants. The snakevine (*Kennedia nigriscans)* of the Northern Territory of Australia has yielded at least 39 endophytic *streptomycetes*. Most of these isolates possessed no detectable antibiotic properties, while at least seven had impressive antibacterial and antifungal activities.

Fungi belonging to the *Muscodor* genus regularly appear in tropical rainforests throughout the world and these isolates have chemical, biological, and structural characteristics that make them potentially useful in medicine, agricultural and industrial applications. A new isolate of *M. albus* has been obtained from a small, unidentified vine generally used by the indigenous people of the Tesso Nilo region in Central Sumatra, Indonesia to treat snakebites. This unique organism produces a number of volatile antibiotics not previously observed in other *M. albus* isolates including tetrohydofuran, 2-methyl furan; 2-butanone; aciphyllene, and large amounts of an unusual azulene derivative. The DNA partial sequence data showed 99 identities to the original *M. albus* strain.

One strain of *M. albus* has been patented and licensed to AgraQuest of Davis, CA. A petition to the EPA was granted to AgraQuest for the registration of the *M. albus* strain QST 20799 as an agricultural product. It is used to decontaminate cut flowers, fruit, and vegetables during shipment and storage. Another product that was first offered for sale in 2006 uses a strain of *M. albus* to treat fruits and vegetables in shipment and storage. The EPA has also approved this organism as a soil treatment that has the potential to replace some of the uses for methyl bromide, a highly toxic soil fumigant. A new patent on waste treatment using *M. albus* for human and animal wastes was also.

New patented antibiotics have been isolated from endophytic *Streptomycetes spp.* and they are soon to be licensed. A film entitled “Jewels of the Jungle” was released and shown on public TV around the country; this film detailed our efforts on the discovery and isolation of endophytic microorganisms. Since the biggest diversity of microbes is to be found in the world’s rainforests, the film was made in forests in Australia, Peru, and Bolivia. This film was sponsored in part by the National Science Foundation and the EPSCOR program at Montana State University.

Source of Funding: Hatch, State of Montana, Special Grant

Scope of Impact: National

b. Plant Viruses as Templates for Nanomaterials Synthesis

Description of Activity: This project develops the use of plant viruses as biotemplates for the fabrication of nanomaterials with applications in agriculture, medicine, and material sciences. Nanotechnology is a term that covers many areas of research dealing with objects that are measured in nanometers (one billionth of a meter). Plant viruses are used as protein cage architectures for the synthesis of nanomaterials. The goal is to move toward direct applications of this technology in medicine, catalysis, and electronics. A detailed understanding of the chemistry of nanostructures and the ability to control materials on the nanometer scale will ensure the development of new and more efficient catalysts.

Impact/Accomplishment: The discovery that plant viruses devoid of their nucleic acid can be used as containers for nanomaterials synthesis has provided a new route for developing antiviral agents in plants and new therapeutic treatments in humans. The advances made have demonstrated that it is possible to modify plant viruses and other protein cage architectures to impart novel function. These discoveries significantly contribute to Montana's and the nation's efforts in the development of innovative solutions for biomedical applications.

The research demonstrated that we can modify plant viruses and other protein cage architectures to impart novel functions. This greatly expands the utility of cage-like architectures for use as nanotemplates for the fabrication of nanomaterials with applications in nanotechnology (including biomedicine, catalysis, and electronics). We have made significant advancements in demonstrating the practical applications of this science in drug delivery and magnetic resonance imaging (MRI), as well as a new method for hydrogen production.

Source of Funding: Hatch, State of Montana

Scope of Impact: Regional

c. Cereal Quality and Biochemistry

Description of Activity: Most of the protein nitrogen (N) present in mature cereal kernels is derived from N present in the vegetative plant parts prior to anthesis. This N is remobilized and retranslocated from senescing organs during the period between anthesis and plant maturity. Methods to improve the desirable attributes of products made from wheat are being researched. A large fraction of the N present in mature

cereal kernels is remobilized and recycled from senescing plant parts (mostly leaves) during flowering and plant maturity. The cellular and molecular mechanisms underlying this process are not well understood. A combination of genetic, molecular, and biochemical tools is being used to improve the understanding of N recycling, with the long-term goal of improving N use efficiency.

Polyphenol oxidases (PPOs) have been implicated in wheat product quality problems, including the undesirable darkening of Asian noodles. Breeders are actively trying to lower PPO levels in mature wheat seeds; however, not much is known about the molecular biology and biochemistry of wheat PPOs. Based on preliminary data, the biological basis for variation in this important trait is being established. This should facilitate the development of low-PPO germplasm. To identify the PPO gene(s) responsible for wheat quality problems, a gene-specific quantitative real-time RT-PCR system has been developed allowing the separate assessment of expression levels of all PPO genes in developing wheat kernels. A long-term goal of this project is the development of low-PPO germplasm with higher commercial value.

Impact/Accomplishment: Major progress has been made in the characterization of wheat kernel PPOs associated with the wheat darkening. One PPO isoenzyme was partially purified from the bran of a high-PPO MSU developed variety, Rampart. The study confirmed that the corresponding gene and other members of the same gene cluster were expressed during kernel development in hexaploid wheat varieties. Expression was undetectable in durum wheat.

Our understanding of the physiology and molecular biology of N remobilization from senescing cereal leaves has been improved. Our data demonstrate that high protein levels in mature grains are correlated with high amino acid levels during the rapid phase of grain filling, and with low amino acid levels in the main source tissues (flag leaves) during the same period. We have identified a number of candidate genes (proteases), which may be functionally involved in the degradation of major proteins prior to the retranslocation of resulting amino acids at the onset of leaf senescence. The development of molecular markers for high and low PPO activity in wheat constitutes a directly applicable result. These data allow, for the first time, the selection of desirable low-PPO germplasm at the seedling stage, as opposed to the previously used activity assays that relied on mature kernels. Increased understanding of the molecular biology and biochemistry of cereal grains will lead to the development of products more suited to the requirements of important world markets.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Diversified/Alternative Agriculture

a. Using Diversified, No-till Cropping Systems to Increase Agricultural Sustainability in the Northern Great Plains

Description of Activity: Traditional wheat and barley cropping systems that dominate dryland crop production in Montana are widely held to be economically and environmentally unsustainable. Surveys at Montana farm conferences indicated a strong

interest in expanding diversified crop rotations. This research investigates the value of diversifying dryland cropping systems to include oilseed and pulse crops in sequence with cereal crops in Montana and the northern Great Plains. A sustained and coordinated research strategy has been implemented to attain the goal of sustainable cropping systems. The five primary objectives for this project are: (1) to investigate cultivar differences and best management practices for chickpea production in the U.S. northern Great Plains; (2) to test adaptation strategies for winter pea and lentil related to stubble height management in direct-seeding systems; (3) to quantify relationships of forage yield and quality from winter and spring pea with soil effects on water and N; and (4) to investigate the role of crop diversity in increasing resource-use-efficiency in advanced no-till and organic cropping systems; and (5) to investigate potential for adding value to Montana farming systems through greenhouse gas mitigation strategies. We utilized no-till management throughout this work as it is a key step toward sustainable agriculture in the semiarid northern Great Plains.

Impact/Accomplishment: A multi-state project investigating best management practices (seeding date and rate, cultivar, and cropping sequence responses) for chickpea production is underway. Four chickpea cultivars, representing the full range of commercial grain classes from large kabuli to small desi types, were sown over five dates in chemfallow and wheat stubble scenarios. One kabuli-type chickpea was sown over five seeding dates and at five seeding rates. After three years of tests, the effect of delayed seeding has resulted in a decrease in chickpea yield, though at a slower rate than for dry peas or spring wheat. To develop adaptive cropping strategies, the effect of stubble height and seeding date on the productivity of winter and spring types of pea and lentil is being examined. This project leads an overall study on winter pulse production with four locations, including two in Montana and one each in Idaho and Washington.

The crop diversity rotation study compared organic and no-till management for continuous cereal-broadleaf rotations. Barley, canola, corn, lentil, mustard, pea (spring and winter), sunflower, triticale (spring and winter), and wheat (spring and winter) were sown in one or more rotations. Soil water extraction showed that sunflower consistently extracted the greatest amount of water and peas the least. The organic rotation performed well, with high winter wheat yields and high grain test weights. Wild oat densities were lower in the organic and highly diverse no-till rotations.

Research at MSU on pulse crops (especially lentils and peas) has led to producers instituting a 1% check-off program and increasing production acres in Montana. Research on carbon sequestration funded by this project has led to other project funding at MSU for investigating CO_2 emissions. During the past year, a cropping sequence study was continued; a 6th year was completed for the crop diversity rotation study; and the 3rd year of a greenhouse gas rotation study was completed. A new line of research investigating winter canola was initiated. Pulse crop (pea, lentil, chickpea) acreage in Montana jumped dramatically to 350,000 acres in 2005, due in part to the contributions of this research project. This has meant an important new and diversified source of income for Montana farmers.

Source of Funding: Hatch, State of Montana

Scope of Impact: Regional

b. Specialty Crop Evaluation and Product Development

Description of Activity: Traditional agricultural crops in Montana often provide insufficient rural income to be a sustainable industry. This project's goals are to evaluate markets for crops and products in the Pacific Northwest and Montana, develop specialty crops, and develop value-added products. The project assists rural communities in evaluating and developing community-based businesses, using local agricultural resources. Current research is focused on food and non-food products, including biobased lubricants and fuels, gluten-free cereal products, and equine care products.

Impact/Accomplishment: Timothy has been identified as a promising gluten-free cereal with flavor properties similar to wheat and containing less detectable gluten than Indian ricegrass. Several germplasm accessions of timothy have been tested for suitability as turfgrass. Fenugreek (*Trigonella foenum-graecum*) has been evaluated for acceptance by the equine industry and has proven to be valuable as a supplement for athletic and geriatric horses. Fenugreek research is expanding to evaluate its use in human nutrition, particularly for diabetes control. There is considerable commercial interest in breeding and growing fenugreek cultivars in the U.S. Over 220 fenugreek germplasm accessions have been evaluated for their potential in Montana agriculture.

Interest in the identification and production of nutraceuticals from crops is growing in U.S. and world markets. Herbs, including calendula, lavender, oregano, sage, specialty mints, thyme, and yarrow, have been evaluated for potential in value-added markets, such as for nutraceutical and cosmetic applications. Many plant species are particularly adapted to our semiarid conditions. The technologies developed in the research of alternative crops are being transferred to rural communities in Montana.

Development of specialty crops for natural rubber production and bio-energy were a focus over the last year. New crops and bioproducts included for development were dwarf lawn grass species and cultivar selection, native ornamental flowers, and new essential oils. A natural rubber project has been initiated to develop a male sterile system of hybrids for Russian dandelion. An increased focus on geranium, thyme, and sage were made for transitioning from peppermint oil production to other essential oils. The world demand for peppermint oil continues to be low creating substantial unsold product. Infrastructure for essential oils requires replacement for peppermint oil as imports affect domestic production.

Source of Funding: Hatch, State of Montana

Scope of Impact: Montana

Key Theme – Grazing

a. Prescribed Livestock Browsing for Controlling Conifer Encroachment on Foothill Rangeland

Description of Activity: Analyses of historical photographs confirm that conifers have encroached upon vast acreages of Montana rangeland. This trend is continuing today throughout the West and may have accelerated in recent years. Conifer encroachment reduces forage production for both livestock and wildlife, decreases the flow of water from springs and creeks, thus degrading fish habitat and riparian ecosystems. Cost-

effective strategies are needed for controlling conifer encroachment. Several species of conifers are currently invading grasslands and shrub steppe across Montana, including ponderosa pine, Douglas fir, Rocky Mountain juniper, and lodgepole pine. Prescribed livestock browsing is a promising tool for suppressing conifer encroachment, but more information is needed to develop effective prescriptions.

Impact/Accomplishment: This research project will evaluate opportunities for using prescribed browsing by sheep or goats to control encroachment. Specific objectives are: (1) to determine whether a low-cost nutritional supplement can increase goat browsing of ponderosa pine in winter; and (2) to determine whether sheep or goat browsing of felled trees in late fall can reduce fuel loading and the potential for forest fires. Twelve 2½ acre paddocks were constructed on a private ranch in west-central Montana in preparation for the first year of the grazing trial. The information will help refine browsing prescriptions and better enable range and livestock managers to use prescribed browsing as a tool for suppressing conifer encroachment.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

b. Winter Grazing in Montana

Description of Activity: Livestock grazing practices are receiving increasing attention because of their perceived negative impacts on soils, biodiversity, and water quality. Across the landscape, point sources of water pollution are often associated with livestock confined to certain areas while being fed hay during winter. Feeding hay represents the greatest percent of variable costs for producers in cold climates. The purposes of this project are to: (1) refine our recently developed thermal balance model; (2) identify whether cattle have strong seasonal differences in heart rates, as an indicator of metabolic rates and requirements; and (3) identify whether cattle fed hay in Montana have higher heart rates during winter than those grazing native range. Our goal is to use certain behavioral (activity patterns, position, orientation) and physiological (heart rate, back fat, weight, body condition) measures to determine how free-ranging beef cattle tolerate winter conditions without affecting reproductive performance

Cattle may graze foothill rangelands in northern latitudes as an alternative to feeding hay. However, winter winds and extreme temperatures may increase weight loss and lower body condition scores. We refined a simple thermal balance equation to model heat exchange of free-ranging cattle during winter. Model simulations indicated that behaviors, such as lying down and orientation to the sun, mitigate the effects of extreme weather. For many combinations of winter weather variables, metabolic requirements increased only slightly due to cold exposure of mature beef cattle in a near maintenance state. Our model indicates that solar radiation contributes strongly to the thermal balance of a cow. This thermal balance model will provide insight into metabolic requirements of beef cattle during winter.

Impact/Accomplishment: The thermal balance model may be used to predict metabolic requirements of beef cattle based on behavioral adjustments. Although the model was developed for cattle grazing winter range, it may apply whenever results from controlled environments are extrapolated to a natural environment setting. The model predicted metabolic requirements in winter similar to those measured in three empirical studies.

Predicted requirements increase only slightly when mature beef cattle in a maintenance state are exposed to cold. For many combinations of winter weather, predicted requirements were close to or lower than known basal metabolic rate. Thus, previous work may overestimate requirements for cattle acclimated to grazing winter range. Solar radiation lowers metabolic requirements, especially on cold, clear days. Our model emphasizes the contribution of the irradiative environment to a cow's ability to conserve energy in winter, and illustrates the benefits of considering solar radiation when selecting winter pastures or husbandry practices. Understanding the requirements of cattle during winter months will help producers plan feeding schedules and adjust protection requirements to weather conditions.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Ornamentals/ Green Agriculture

a. Commercializing Production of Native Montana Plant Species

Description of Activity: There are many benefits to having turfgrass in the landscape including functional, recreational, and aesthetic benefits. Yet for all these benefits, most turfgrasses, particularly Kentucky bluegrass, require high amounts of water to maintain their appearance and growth. Many consider this excessive water usage a waste of natural resources. There is an increased interest in “native” landscaping; however native trees, shrubs, and perennial forbs planted with non-native grasses do not fit in a totally native landscape. In order to reap the benefits of both turfgrass (temperature moderation, safe playing surface, and erosion control) and natives (water and energy conservation, natural landscaping, and sense of place) the use of native grasses in turfgrass applications needs to be explored. The objectives of this project are to learn which native and adapted grasses are suitable for turfgrass applications, their water and mowing requirements, their potential to form a sod, and their ability to establish and/or restore a landscape. Additional projects investigate the seed germination requirements of native forbs that can be used in Montana landscapes.

This research consists of three large-scale line source irrigation experiments established in Montana (2) and Utah (1). Twelve mixtures of native species have been chosen based on their drought tolerance, adaptability to the Intermountain West, more natural landscape color, anecdotal turfgrass qualities, and commercial availability of seed. Species for the mixtures are based on photosynthesis mode and growth habit.

Impact/Accomplishment: Germination protocols have been established and tested for the commercial production of native forbs, including *Penstemon spp*., *Phacelia spp*., and *Sphaeralcea spp*. Results were presented at the 2004 annual meeting of the American Society for Horticultural Sciences. Germination and photoperiod results for several projects underway will be published.

The results of these studies have been made available to native plant providers in Montana; we expect that greenhouses and nurseries will begin to offer plants that are more suited for establishment in Montana habitats. By establishing germination protocols for native Montana species, we will aid seed testing labs with testing procedures, and

continue to help Montana greenhouse growers meet the increasing demand for native Montana plant species.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Plant Genomics

a. Winter Wheat Breeding and Genetics

Description of Activity: Several biotic and abiotic stresses hinder hard red and hard white winter wheat production in Montana and the Northern Great Plains. This research project will develop germplasm with excellent end-use qualities including improved resistance to environmental stresses. Primary breeding objectives include increased yield potential, winter hardiness, wheat stem sawfly resistance, imidazolinone herbicide tolerance, and enhanced dual-purpose end-use quality.

The primary goal is to provide improved hard red and hard white winter wheat cultivars that are adapted to Montana conditions and suitable for both domestic and export markets. A combination of field, greenhouse, and laboratory selection protocols are being used. The Asian noodle market is an important business opportunity for Montana growers. The quality of noodles made from different wheat samples is evaluated on entries from the advanced and intrastate nurseries.

Impact/Accomplishment: Approximately 2,500 selected lines were bulk harvested and evaluated in observation nurseries. A sawfly observation nursery containing solid-stem germplasm and nurseries containing hollow-stem germplasm were grown in selected locations. Based on disease and quality screening results, winter survival, and agronomic performance at individual locations and across locations, about 150 lines have been selected for entry into preliminary yield testing. Selected lines from the three preliminary trials were moved into advanced trials and subsequently into the intrastate nursery. In addition to development and release of superior cultivars, genetic, agronomic, and production research is conducted to maximize production and quality consistency of wheat in Montana.

A new winter solid stem wheat cultivar, Genou, was released to Montana seed growers. The cultivar has improved yield potential and is targeted toward wheat stem sawfly-infested winter wheat areas of Montana that are currently planted to the cultivar Rampart. Rampart was the leading winter wheat cultivar in Montana over the last three years, being planted on approximately 500,000 acres each year. Genou is 7–8% higher yielding than Rampart representing an increase of over four bushels and a return of $11.60 more per acre, based on 2004 state averages (59 bu/a; $2.85/bu). Genou is winter hardy and has a solid stem. The cultivar will withstand invasion by wheat stem sawfly, thereby significantly reducing field losses. In six environments with differential cutting by wheat stem sawfly, average stem cutting in Genou was equivalent to the solid stem check (Rampart or Vanguard), less than Neeley, and less than Morgan. Yellowstone, an improved winter wheat cultivar with very high yield potential, cold tolerance, and stem solidness, was released to Montana seed growers. Experimental

data from Montana over the last four years indicates Yellowstone yielded 16%, 21%, and 17% more than leading winter wheat varieties Neeley, Tiber, and Morgan, respectively.

Based on average planted acreage and prices, development of an improved winter wheat cultivar which produces an additional one bushel per acre either by enhanced yield or reduced yield loss to disease, insects, or environmental stresses, potentially impacts the Montana economy by $5–$6 million, annually.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

b. The Grasses of Montana, Analysis of Airborne Pollen in Southwestern Montana, and Phylogenetics and Crop Species

Description of Activity: The manual entitled "The Grass Flora of Montana" is a continuation of a project that started six years ago and fills a need for a modern comprehensive identification manual for grass species occurring in Montana. The taxonomic treatment in the “Grasses of Montana” was roughed out during the first grant period and is being updated with new and additional relevant information.

The “Grasses of Montana” is available as hard copy, and on the Internet as dynamically retrievable information, including habitat data, geographical distribution, and close-up photographs of all or most of the grass species in Montana. Recent taxonomic changes in certain widespread and well known grass groups, such as the needle-and-thread and Indian rice grasses (*Stipeae*) and wheatgrasses (*Triticeae*) are integrated into the “Grasses of Montana.”

Detailed descriptions and distribution maps will be continually updated for the estimated 244 grass species occurring in Montana. For each grass species, information is provided that aids identification and gives an understanding of habitat, geographical distribution, and any economic importance. The grass identification manual, “Grasses of Montana” (by M. Lavin and C. Seibert) has been updated from the 2003 version, and is now available at http://gemini.oscs.montana.edu/~mlavin/herb/mtgrass.pdf.

A second part of this research project relates to phylogenetics and crop species. Phylogenetics is the study of evolutionary relatedness among various groups of organisms. This project seeks to translate gene pool hypotheses that direct plant breeding programs into hypotheses of phylogenetic relationships. It will serve to illustrate the interface of phylogenetics and the concerns of plant breeders by addressing questions on genetic bottlenecks, direction of gene flow among cultivated species and their wild relatives, the degree of relatedness among cultivated species and their wild relatives, and the identity of gene pools that exist at levels above the population.

Impact/Accomplishment: “Grasses of Montana” is serving as a valuable public resource for grass taxonomy and ecology especially in Montana. The grass identification manual is providing access for students and other individuals to the basics of grass identification and ecology in Montana. It is constantly updated with new records of grasses in Montana and is continuing to be distributed free of charge.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

c. Mycology in Montana

Description of Activity: Over 90% of plants have symbiotic fungi on their roots which promote plant health and survival, and improve soil properties. Little is known of these fungi in Montana and the Rocky Mountain region. Knowledge of the ecology and diversity of the symbiotic fungi of woody plants benefit basic research in high elevation ecology, reclamation, and reforestation. This project focuses on the diversity and distribution of mycorrhizal fungi in three diverse ecosystems: whitebark pine forests in the Greater Yellowstone Ecosystem (GYE); aspen growing on smelter-impacted sites, such as the Anaconda, MT superfund site; alpine tundra (willows, *Dryas spp.)* of the Rocky Mountains. Information on the ecology and diversity of fungi in each of these systems will be initiated with a general survey and database of distribution data. Identification of fungi will be through classical taxonomic methods and molecular methods such as sequencing of the ITS region of the genome. Selected fungal species will be cultivated and screened for their potential use in reclamation and reforestation.

Whitebark pine forests are in serious decline (40–100% in some areas) due to blister rust and mountain pine beetles, and their decline will likely affect bear populations that depend on pine nuts for food. Mycorrhizal fungi are crucial to sustainability of these forests, yet we know nothing of the fungi associated with this tree species. Our work will lead to applications/inoculation of nursery grown stock with appropriate native fungi that will prevent further decline and begin to reestablish forested areas. A survey is being conducted to discover the diversity of alpine fungi in the Rocky Mountains. Research on the use of native ectomycorrhizal fungi for aspen regeneration in heavy metal soils will primarily consist of greenhouse studies to first develop a method for mycorrhization of aspen in regard to fertilization regimes. Fungi and seeds will be from smelter impacted sites and should improve the knowledge of fungal species valuable in reclamation of smelter-impacted sites.

Impact/Accomplishment: A field study has been initiated on the ectomycorrhizal fungi of whitebark pine forests in grizzly bear habitat. A project which delineates the fungi crucial for whitebark pine in the Greater Yellowstone Ecosystem (GYE) has been completed with the discovery of over 44 species in the GYE, and one new to science. The fungi discovered on whitebark pine will be an important resource for revegetation of these trees in the GYE. Regeneration of these trees is now the overall plan for YNP, and native ectomycorrhizal fungi for seedling regeneration will be a valuable asset.

To date we have catalogued over 200 species of alpine agarics, about 5% are new to science, and many are ectomycorrhizal (mutualistic) with alpine plants. A method for mycorrhization of aspen in the greenhouse was developed. Some native ectomycorrhizal fungi can prevent the uptake of heavy metals (particularly copper) from smelter impacted sites. The research on aspen mycorrhizae has benefits for reclamation/reforestation of high-elevation areas, particularly smelter-impacted sites.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

d. Alfalfa Breeding

Description of Activity: Alfalfa is the most important forage legume grown in Montana. Proprietary companies are generally doing a good job developing varieties that perform well under irrigated conditions, but are not working on dryland cultivars. The primary purpose of the project is to develop multiple pest-resistant dryland cultivars with good agronomic traits for Montana. There are several germplasms being considered that were initially developed for irrigated conditions. These germplasms are being tested statewide and will be released if they can be effectively cultivated. Phenotypic and genotypic recurrent selections are used to develop improved germplasm and new cultivars. Recurrent selection involves systematically evaluating individual plants within a population, selecting the most desirable plants, and crossing the selected plants to obtain seed for an "improved" population. This seed can be tested for possible release or serve as an improved germplasm for the next selection cycle. A selection cycle is completed every time desirable plants are crossed to form an improved seed source (seed to seed). These techniques are used to improve pest resistance and drought resistance in alfalfa.

Impact/Accomplishment: Previously established uniform intrastate alfalfa yield trials were continued. Recurrent selection has been used to improve *Phytophthora* root rot and *Verticillium* wilt resistance in alfalfa. Over the past several years several cultivars (Shaw, Cooper, Melton) and have been released and shipped to producers and seed companies for planting.

Cultivars have been obtained from many out-of-state sources that may have potential for use in dryland conditions. Over 200 plants from a drought stressed nursery in Oregon were received and may have the potential to ultimately be a good dryland variety. In addition to alfalfa projects, efforts have been made to assist in the development of new grass varieties for Montana. Willow Creek was released as a forage type winter wheat. We also tested a new sainfoin, Shoshone, from Wyoming and shared in its release. Sainfoin is a deep-rooted and very drought-resistant plant commonly grown in England. There are limitations with sainfoin winterhardiness that will need to be investigated.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

e. Barley Breeding and Genetics

Description of Activity: Most Montana farmers are dependent on barley and wheat for their livelihoods. Our barley varieties must make the greatest possible economic use of our scarce rainfall. Providing the germplasm needed to fit developing markets is our most important task. The purpose of this project is to develop and disseminate barley varieties that provide the highest possible economic production from Montana's scarce resources.

The MSU barley improvement program uses field research technologies, extensive on-station and on-farm trialing, and state-or-the-art genomics tools to develop well-adapted, high yielding, improved quality barley varieties. Our “Feed Barley for Rangeland Cattle” project includes the world's most extensive and effective varietal testing program of its kind. We disseminate our research products to farmers, colleagues, and stakeholders

through technical and non-technical publications and through the release of germplasm and new genomics tools and techniques.

Impact/Accomplishment: Project members generate new genetic diversity by making more than one hundred targeted crosses per year between lines carrying genes conferring improved quality traits or stress tolerance and well-adapted, high yielding barley varieties. Our understanding of the genetic control of traits like winter hardiness, feed quality, malting quality, and drought tolerance has been developed and extended through these experiments. Once we understand which genes control variation for specific economic traits of interest, we move those genes into our adapted barley varietal base through crossing and marker-assisted selection.

Three malting barley lines are now in plant scale test with the malting and brewing industries. The lines are likely to result in a near 50% improvement in dryland farmer success, due to their drought tolerance advantages over Harrington. We expect this to result in $10 million per year in increased Montana farming revenues.

Source of Funding: Hatch, State of Montana, Special Grant

Scope of Impact: National

Key Theme – Plant Health

a. Control of Fungal Diseases of Cereals

Description of Activity: Fungal diseases cause widespread damage to crops worldwide. New, environmentally benign strategies to control these diseases are needed. This project examines the use of two novel strategies for the control of fungal diseases: mating inhibition to prevent disease in the smut and bunt fungi, and the use of anti-fungal puroindoline proteins to inhibit diseases. The objectives of this project are to: (1) determine the mechanisms by which different pheromone analogs interfere with mating of the fungal pathogen *Ustilago hordei* and teliospore germination of the pathogen *Tilletia spp.*, and (2) determine the structural moieties of the puroindolines that are important for anti-fungal activity.

Biochemical and molecular approaches are being used to determine the effect of mating inhibitors on the activity of farnesyltransferase and methyltransferase enzymes from cell extracts of *Ustilago hordei*, *Tilletia tritici*, and *T. indica*. The farnesyltransferase and methyltransferase genes are cloned from these fungi and expression in the presence of the mating inhibitors is determined. The wheat puroindoline genes are expressed in yeast and specific mutations will be made to determine the active, anti-fungal moieties of these proteins.

Impact/Accomplishment: Since smuts and bunts are non-pathogenic until sporidia mate to form a dikaryon, an analysis of the mating system of *U. hordei* (the cause of barley covered smut) is being conducted. We have shown that the enzyme farnesyltransferase, that adds a farnesyl group to the CAAX motif located at the end the pheromone preprotein, is directly inhibited by several pheromone analogs, presumably by competing with substrate. The farnesyltransferase gene has been cloned by PCR from *U. hordei* and expression confirmed by RT-PCR and western blotting.

Puroindolines are found in the wheat seed endosperm, play a role in seed hardness, and also have antifungal activity. A vector containing pinA, the gene for puroindoline A, has been transformed into *Pichia pastoris*. Expression has been confirmed by western blots using antibody to the puroindoline protein. Four mutations have been constructed to date and one mutation has been transformed into *P. pastoris*. Protocols for detecting the puroindoline genes in transgenic wheat have also been developed and optimized. Putative wheat transformants have been backcrossed with the wild type parent to reduce potential mutations that may have risen during the transformation process. Progeny are being screened for the presence of the herbicide selectable marker and the pin gene.

The spores that are formed during the sexual cycle are important for many fungi for long-term survival, disease spread, genetic variability, and (in the case of smut and bunt fungi) is required for pathogenicity. Disruption of the sexual cycle using pheromone analogs is a new and potentially significant approach to controlling fungal plant diseases. The use of anti-fungal proteins incorporated into transgenic plants is another promising approach to limiting fungal diseases of cereals. This has a very large financial impact on our cereal grain industry.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Precision Agriculture

a. The Application of Diffuse Reflectance Spectroscopy to Soil Carbon (C) Measurement in North Central Montana

Description of Activity: Standard soil characterization techniques are time-consuming and expensive. Statistically rigorous soil mapping, precision agriculture, and soil carbon (C) monitoring and measurement for C sequestration all require a more rapid and inexpensive method of soil characterization. The purpose of this study is to develop and refine predictive soil characterization models based on visible and near visible infra-red (VNIR) diffuse reflectance and to determine the feasibility of making *in situ* soil C determinations using Diffuse Reflectance Spectroscopy (DRS). DRS has been used successfully to quantify soil organic carbon (SOC) and other soil properties important for land management, such as texture and mineralogy. To gain access to carbon credits for soil carbon (C) sequestration, farmers need: (1) a large amount of soil C data to better calibrate cropping system models, and/or (2) a quick and inexpensive means to verify C accumulation in agricultural soils. DRS has the potential to meet both these needs.

While research has demonstrated the ability of DRS to provide nondestructive rapid prediction of soil properties in the lab (dried, crushed, and sieved), there is little information on the precision of calibrations derived from *in situ* DRS applied to heterogeneous, moist soil.

For the “Golden Triangle” wheat area of northcentral Montana, DRS scans have been acquired for: (1) *in situ* moist soil cores; (2) *in situ* dry soil cores; (3) dried, crushed and sieved (< 2 mm) soil samples; and (4) dried, crushed, sieved and fine-milled soil samples. By determining the analytical precision of each scenario, an informed cost-

benefit analysis can be made of the best way to proceed with future research and applications.

Impact/Accomplishment: Research shows that the spatial structure of calibration and validation sample sets can have a dramatic impact on model construction and the validity of statistical results. To construct robust soil C models, a larger number of calibration samples are required than previously thought. Accordingly, a global soil visible and near-infrared (NIR) spectral library of over 4,000 samples has been constructed in collaboration with the USDA-NRCS Soil Survey program.

All soil coring, VNIR scans, laboratory analyses, and partial least squares (PLS) regression modeling have been completed. Research is continuing on: (1) analysis of replicate cores; (2) mapping of SOC absorption features for the VNIR range by comparing reflectance patterns with and without soil organic matter (SOM) removal; and (3) examination of ways to enhance regional predictions using a global soil-spectral library.

DSR provides a tool for rapid, nondestructive, inexpensive, *in situ* soil characterization for a variety of applications including site-specific management, watershed hydrologic modeling, and the monitoring of C sequestration in agricultural lands. The results of this research could dramatically increase the availability of soil data for environmental modeling. Statistical models will be produced that relate soil organic and inorganic C to diffuse reflectance for soils for *in situ* and laboratory-based analyses.

Source of Funding: State of Montana, Special Grant

Scope of Impact: National

Key Theme – Rangeland/Pasture Management

a. Remote Sensing for Montana Land Resources

Description of Activity: Managers of rangeland are dependent on accurate information on the type, quantity, and condition of vegetation in order to make sound decisions. The large acreages involved and the rugged and inaccessible Montana and Yellowstone National Park (YNP) terrain pose substantial obstacles for obtaining needed information. Satellite remote sensing holds the promise of providing efficient, cost effective, and in many cases the only practical means, of mapping vegetation quantity, type, and changes over these vast expanses. In spite of the potential of remote sensing, methodologies still have not been developed to use this technology on an operational basis.

This project was established to evaluate remote sensing technologies and addresses three major objectives for Montana range resources: (1) assistance in evaluating rangeland productivity and ecological condition; (2) mapping rangeland vegetation types in a flexible geographic information system; and (3) developing automated methods for regularly updating rangeland vegetation maps. The specific objectives are to: (1) develop and test an automated method for identifying anomalies in rangeland production or ecological health using Landsat satellite imagery; (2) produce an accurate hierarchical map of rangeland vegetation in the northern range of the Greater Yellowstone

Ecosystem (GYE) using Landsat satellite imagery; and (3) develop a method for automatically updating satellite-based rangeland vegetation maps using tasseled cap-based change vector thresholding.

Impact/Accomplishment: This research, using the U.S. Landsat 7 satellite ETM+ combined band values and vegetation index data, and introduced an efficient, remote sensing-directed method for preliminary identification of locations within ecological range sites where soil and site stability, biotic integrity or hydrologic function may be outside an ecologically stable range. This method demonstrated the potential to identify areas of ecologically vulnerable conditions with an overall accuracy level over 90%.

Numerous aspects of the research have been substantially completed, including: (1) assistance in evaluating of rangeland productivity and ecological health; (2) mapping of rangeland vegetation types in a flexible geographic information system; and (3) developing automated methods for updating rangeland vegetation maps on a regular basis. Classifications of rangeland cover types and a change analysis study in YNP were completed. Accuracies ranged from 84% at the coarsest level to 74% at the species level. Analyses revealed that 4% of Yellowstone's northern range had changed vegetation type over the decade of the study period and change accuracies were similar to the initial accuracies.

Results of this study support the use of high-resolution spectral imagery combined with ecological site delineations to enhance efficient rangeland inventory, the effectiveness of rangeland monitoring, and ecologically sustainable management. Rangeland vegetation mapping potentially will result in greater detail for range maps than have been available in the past and allow for automated updating of maps, while potentially reducing manpower by up to 50%. The automated method for identifying anomalies in rangeland production and ecological health using Landsat satellite imagery has been adopted by the National Resources Conservation Service (NRCS) and is being used in their evaluation of rangeland conditions in Montana.

Source of Funding: Hatch, State of Montana

Scope of Impact: Regional

Key Theme – Urban Gardening

a. Naturalization: A New Approach to Landscape Restoration in Urban and Disturbed Sites

Description of Activity: Degradation of native plant communities is partially attributed to urbanization. A shift to landscaping with native plants will help contribute to biological diversity in urban and suburban environments. The purpose of this study is to establish guidelines for growers and nurseries to produce and market native plants, and also to establish design guidelines for the landscape industry and other agencies that plan, authorize, and monitor naturalization projects. This study aims to find alternative approaches through which diverse plant associations are created in harmony with the nature of the site, soils, climate, and related environmental conditions.

This project has two components: (1) to use native plant communities as models for naturalization, and (2) to identify consumer preferences for native plants and ecologically-based landscapes in urban settings.

A computer program is being prepared to facilitate the plant selection process by analyzing a selected plant community and generating a community plant database. Appropriate species are assigned to different locations within a project site. Images of schematic designs are prepared based on pre-defined guidelines and variables. Computer generated 3D views of selected homes and related landscapes are being used. Surveys will be administered at Montana Nursery and Landscape Association Annual Meeting, the MSU web site, and randomly in three different neighborhoods in Bozeman, MT.

Impact/Accomplishment: The on-line survey evaluating consumer preference for the native plants in residential landscapes and the perception of ecologically-based design in urban settings has been concluded. The survey data will be evaluated, analyzed, and prepared for publication. Work on the Garden History Image database is assembled, organized, and catalogued.

The environmental and economic impact of this project will be to create sustainable landscapes, restore biological diversity in disturbed landscapes, and reduce the impact non-native plants have in the environment. As a source of technical assistance and inspiration for scholars, students, and professionals, the Image Database will provide a meaningful view of the garden landscape as it creates healthy and productive human environments.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

GOAL 2: A safe and secure food and fiber system.

Overview

U.S consumers demand adequate quantities of high quality and safe food products at a reasonable cost. They also expect fiber products that are consistent, durable, and economical. The production of food and fiber products in the U.S. requires substantial input costs to ensure quality and safety. Our research is forward-thinking with the consumer in mind and seeks to provide agricultural producers/innovators with tools to increase yields and reduce the costs of production.

The Key Themes in **Goal 2** tie closely to other Goals, especially as they relate to improved plant and animal production practices and health, the development of new plant varieties, and the development of innovations for the marketing and storage of commodities. Flexible markets, price incentives, and business organization structure and behavior are required to maintain a quality food supply. The regulation and monitoring of food supplies and production inputs are also critical to ensure that food supplies are safe.

Research at MSU has added value to Montana commodities by improving plant genetics through yield and quality advancements. Plant breeding accounts for approximately one-

half of the dramatic yield gains in most major crops over the past few decades. Much of this increase is due to the expression of genes for insect and pathogen resistance within the plant. Using genetics and biotechnology as tools that lead to the betterment of our food and trade goods has led to new products and crop quality innovations. These results and consumer demand have led to the development of new barley and wheat varieties for Montana producers.

Montana is well-positioned to become a leader in tracking beef from the source to the meat counter. This requirement was necessitated by increasing concerns about preventing bovine spongiform encephalopathy (BSE) from occurring in the U.S. During 2005, approximately 55,000 calves were certified for age and source verification, in addition to utilizing consumer-driven livestock care practices.

The understanding of the biological and epidemiological causes of foodborne illnesses from contaminated meats will likely lead to improved ways to protect humans from these illnesses. Protecting livestock against diseases through research in immune behavior, and the development of vaccines ensure a supply of quality beef and sheep products from Montana.

Total Goal 2 Funding: $342,841 FTE: 3.83

Following are brief descriptions of selected projects currently funded and in progress at Montana State University.

Key Theme – Food Quality

a. Marketing and Delivery of Quality Cereals and Oilseeds

Description of Activity: Certain agronomic factors and pests affect the quality of cereals and oilseeds. This study is designed to quantify the factors that affect the milling, processing, and marketing of cereals and oilseeds. Postharvest resistance to insects has not been a breeding program objective, but could be a secondary objective provided that milling, baking, noodle quality, and other important properties are not affected. The ability to resist damage by lesser grain borer and Indian meal moth would be advantageous for very long-term storage and thereby would enhance opportunities for producers to take advantage of grain market fluctuations. Several varieties of hard red winter wheat from six Montana production sites, both irrigated and dryland, were evaluated for their resistance to insect damage.

Impact/Accomplishment: Varieties Neeley and NuWest were significantly better at resisting Indian meal moth than Vangard, which was, in turn, significantly better than Tiber, Big Sky, and Rocky. This resistance trait was expressed similarly across all locations and agronomic practices within varieties Big Sky, Tiber, Neeley, and Rocky. All hard red wheat varieties (except Neeley) were significantly more resistant to supporting Indian meal moth than the susceptible variety, Penawawa. Laboratory-induced sequential damage studies of these varieties with kernels degermed by the Indian meal moth demonstrated the most notable finding. The variety McNeal switched from being one of the most resistant varieties to the least resistant, when the pericarp layer was removed, and the outer endosperm exposed to Indian meal moth larvae. From these

results, it can be confirmed that at least one factor conferring resistance in McNeal is located in the pericarp.

This project has already identified strong resistance factors in the bran layer (possibly also the germ and aleurone layers) of McNeal and a marked site-specific or cultural condition-specific resistance in Penawawa. For varieties that will meet current market requirements for certified organic wheat and seed growers, these factors will be important in guiding breeders who service this market and in guiding growers who must maximize non-synthetic chemical protection of their commodity during storage. Wheat breeders will be able to use this information to develop a hard wheat variety appropriate for very long-term storage and thereby enhance opportunities for producers to take advantage of grain market fluctuations.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

GOAL 3: A healthy, well-nourished population.

Overview

Montana produces some of the highest quality plant and animal products in the world. Consumer directed research at MSU ultimately leads to an improvement in food supplies. This is accomplished through improved genetics, a better understanding of livestock diseases, and advances in the control of plant and livestock pests. Many of the projects discussed in **Goal 1**, **2**, **4**, and **5** impact human health.

The Montana Beef Quality Assurance (BQA) program for beef producers uses best management practices to ensure food safety, feeder calf quality, product consistency, and source verification. The program also provides educational materials and workshops for consumers to better understand food safety issues. Creating added value to Montana producers, while ensuring a quality and safe product for consumers, is a primary goal of the BQA program.

The Montana Beef Network (MBN) is a collaborative effort between MSU and the Montana Stockgrowers Association and has been designed to assist Montana livestock producers in receiving added value for their cattle. A major fundraising priority for the MSU College of Agriculture remains the Animal Bioscience Complex. The complex will provide opportunities to unlock the secret to enhancing the efficient production of safe, consistent, high-quality meat products for consumers in the U.S. and the world. In addition, the facilities, in combination with faculty, staff, students, and the industry will help to position the animal and range enterprises in Montana for success in the future.

Total Goal 3 Funding: $700 FTE: 0.0

Following are brief descriptions of selected projects currently funded and in progress at Montana State University.

Key Theme – Human Health

a. The Montana Beef Network: An Integrated Total Quality Management Approach for Source Verified Beef Production

Description of Activity: International and domestic consumers are demanding more information about the beef they purchase, including the age and source of the animal, and the health, nutrition, and handling management. This project is designed to assist producers in meeting these demands through education of best management practices, assistance with carcass data collection (so the producers understand the product they are producing), programs to help producers take advantage of marketing options (source and age verification), and research to address regional specific issues affecting beef production. The objectives of the Montana Beef Network (MBN) include: (1) conducting educational programs aimed at conveying beef quality assurance standards, production, and marketing goals; (2) certification of feeder calves that have met defined health management protocols; and (3) information feedback from the feedlot and packing plant to the cow-calf producer showing that the feeder calves have met industry requirements for quality, consistency, safety, and red meat yield.

Source, age and process verification of Montana feeder calves are offered to interested Montana producers through the MBN. The MBN uses its experience and knowledge to assist Montana producers in the implementation of the National Animal Identification System (NAIS), providing education, assistance with premises registration, research on animal ID, and trace-back.

Educational programs on a variety of topics, such as the NAIS, registering premises, bovine viral diarrhea virus (BVDV) impact, Beef Quality Assurance (BQA) practices, beef cattle marketing, and ranch management issues are being offered throughout the state by one-on-one producer interactions, in local meetings, via interactive television technology, through newsletters and newspaper stories, and through large statewide meetings. Staff members are assisting producers with tag application and data collection for source, age, and process verification through on-site visits or via pre-scanned tags and telephone consultations. The MBN staff is working closely with Montana officials to determine the impact of premises registration, animal ID, and animal movement tracking on the livestock industry in Montana. Trials are being conducted at livestock auction markets, ranches, and feedlots. A long-term tag retention study will evaluate the retention and readability of four different radio frequency tags placed in a large cow herd over several years. Cooperating producers, veterinarians, and extension agents are working with the MBN staff and students to collect ear notch samples for testing for BVDV.

Impact/Accomplishment: As the beef industry becomes more consumer-focused, there has been an increased effort to target quality and consistency issues in all segments of the industry. To meet the customer's needs and return additional revenue to cattle producers, it is recognized that a network must be in place to ensure that a quality and consistent product is produced. The MBN is working toward this goal through educational programs. During 2005 and the first six months of 2006, this educational objective was met through six interactive TV conferences, 20 hands-on demonstrations, and numerous presentations to producers. Production was completed on a video, filmed at two different producers' ranches, for airing on RFD-TV. This video demonstrates the benefit to the producer of participating in the MBN and being able to source and age-verify cattle. It shows the various technologies being used on actual premises by the producer. The demonstration trailer has become an important and popular part of the

educational objective associated with the MBN and is outfitted with several available scanners, scanning panels, radio frequency identification tags, software, computers, and monitors. It allows the producer to discuss the various technologies with knowledgeable individuals and also allows the producer to experiment with these technologies. In the first six months of 2006, over 25,000 cattle were tagged for 76 producers. To date, 175,000 calves have been certified and approximately 1,300 producers are BQA certified. Carcass data was returned on 57% of the cattle enrolled. These data will be made available to Montana producers.

Source of Funding: **Hatch, Special Grant, State of Montana**

Scope of Impact: National

a. Agricultural and Biological Risk Assessment, Plant-Stress Ecophysiology, and Integrated Pest Management

Description of Activity: This project examines the potential human health and environmental risks from transgenic crops. The objectives of this project are: (1) to identify and communicate the best approaches for ecological risk assessment of plant-based biopharmaceuticals; (2) to determine human health and environmental risk from biotechnology crops of importance to Montana; (3) to determine relationships between pest stress, food crops, and food toxicology and nutrition; (4) to determine the best approaches for assessing risk from both invasive weed species and weed control technologies; (5) to incorporate environmental risk into economic decision levels; (6) to determine the physiological mechanisms underlying wheat responses to wheat stem sawfly injury; (7) to determine if wheat responses to wheat stem sawfly are mediated by sawfly parasitism; (8) to determine wheat responses to distinct insect injury types; and (9) to incorporate uncertainty into economic decision levels to improve IPM decision making.

Impact/Accomplishment: Risk assessment activities to date have emphasized pesticides (ecological risk quotient modeling), biotechnology crops (glyphosate-tolerant wheat and plant-based pharmaceuticals), invasive species, and biological controls. Examples of research included human health risk assessments for West Nile virus compared to risks from using mosquito insecticides; comparative risk assessments of pest management technologies; risk assessment approaches for plant-based biopharmaceuticals; invasive weed and biological control environmental risk assessment; and relationships between pest stress and food toxicology and nutrition.

Ecological and human-health risk assessments of emerging infectious diseases and insecticides used to control disease vectors will reveal science-based risks, as well as uncertainty and variability associated with each risk type.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Human Nutrition

a. Value-Added Agriculture in Montana

Description of Activity: Recent advances in health diagnostics and studies of dietary imbalances demonstrate the need for more nutritious foods. Few of our current field crops are selected based on their nutritional value. The goals of this research are to develop new crops targeted to improved nutrition and successfully establish the agricultural production of these crops.

Our approach is to identify consumer nutritional needs based on scientific biochemical and genetic research, as they emerge, and then develop crops to meet these consumer needs. We will continue to survey human and animal nutritional research involving biochemical and genetics, in order to anticipate market demands. Our current approach involves a survey of published advances in analytical techniques at the human genetic level. This survey has indicated the potential for new crops to alleviate obesity (fenugreek and camelina); to aid in the management of diabetes (sugar beet fiber, fenugreek, camelina, and wrinkled pea); to alleviate inflammation and pain from rheumatoid arthritis (camelina); and prevent celiac disease (Indian ricegrass and timothy). These crops are currently being grown; after their agronomic fitness is determined to be acceptable, they will be put into food and feed studies.

Impact/Accomplishment: We have made considerable progress in the development of new crops for Montana and the Northwest U.S. Two grower cooperatives have been formed, and consumer satisfaction with resulting products has been good. Montina (Indian ricegrass) is increasing in acreage in Montana with a grower cooperative of 53 members (the Amazing Grains Cooperative) in Ronan, MT established. The French government has listed Montina as a health subsidy prescription food. Cooperation among MSU, the cooperative, and the Celiac Sprue Association (CSA) has led to use of this cereal grain by gluten-intolerant sufferers. This value-added product is netting growers over $2 per pound, as compared to wheat at $0.08 per pound. A high protein and gluten-free oat variety (Proatina) is entering the consumer market. Also flour from a timothy variety (Timtana) has entered the market. All three cereal grains have been developed with help from CSA.

Source of Funding: Hatch, State of Montana, Private Donations

Scope of Impact: National

GOAL 4: Greater harmony between agriculture and the environment.

Overview

Montanans pride themselves in the high quality of environmental resources in their state. Whether individuals are hiking in the millions of acres of forested lands or fishing and boating on the state's streams, rivers, and lakes, awareness of the fragile nature of these resources is a key to their preservation. A number of diverse ecological systems are located in or border Montana. These systems provide opportunities for extensive research into how they react and evolve to human-induced change.

Research reports on global warming continue to contribute to concerns about long-term changes in our climate coupled with our agricultural competitiveness. Field studies on

soil emissions of N_2O are currently being conducted to quantify the potential release of greenhouse gases under varying cropping scenarios and to develop models that compare land use to greenhouse gas release or sequestration. Several projects over the past years have looked at flora growing in or near the hot springs of Yellowstone National Park. Understanding the mechanisms of growth of these native plants in geothermally-modified soils helps researchers understand the limitations and opportunities that global warming may present on agricultural production.

Integrated pest management (IPM) programs at MSU seek to optimize grower profitability and natural resource sustainability through development, selection, and implementation of appropriate pest management strategies that are economically sound and environmentally acceptable. Increasing public concern related to food quality, natural resource biodiversity, and sustainability of the quality of soil, air, and water are mandating less reliance on traditional pesticides and more on non-chemical pest control options that are economically sound and environmentally acceptable. MSU is a leader in the research of biological control methods for pests of forages, potatoes, small grains, and sugar beets. In addition to new resistant wheat varieties that have been developed, the use of natural enemies and pathogens are being evaluated to stem the effects of wheat stem sawfly infestations. Novel management systems are being investigated to reduce the overall effects of invasive weeds, especially hoary cress, rush skeletonweed, field bindweed, and spotted knapweed that reduce the productivity of Montana crops and rangeland.

In Montana and throughout the U.S., the relationship between economics and the sustainability of ecological systems has become one of the critical issues in modern agricultural and environmental policy. As a headwater's state with multiple land uses, Montana is in a unique position to understand how land management practices impact ecosystems. For example, rangelands comprise 70% of the land area in Montana. The greatest environmental challenge is better grazing management in concert with preservation of riparian habitats, wildlife, and clean water. Characterization and understanding of the complex interactive components will lead to improved soil, plant, and water resources in those ecosystems.

Total Goal 4 Funding: $4,087,318 FTE: 42.83

Following are descriptions of selected projects currently funded and in progress at Montana State University.

Key Theme – Agricultural Waste Management

a. Seasonal, Operational, and Plant Effects on Oxygen Potential and Microbial Responses Influencing Constructed Wetland Performance

Description of Activity: Rural populations need access to cost-effective wastewater treatment. Constructed wetlands (CW) can economically treat water from a variety of sources. This project examines processes that control wetland performance. The research goal is to identify and quantify removal mechanisms and how they are affected by temperature and seasonal variances in cold-temperate climates.

We have developed a screening protocol for relatively rapid assessment of seasonal variation in root zone oxidation by species and its effect on CW performance. We are developing models to predict the seasonal release of oxygen transfer as a function of the specific species adaptation to the hydrologic regime. It is believed that wetland plants modify the environment, thus allowing greater diversity in microbial community structure. Our research indicates that specific plants may mitigate the typical negative effect of temperature on microbes by increasing oxygenation during winter. Recent advancements in microbial techniques offer several methods for analysis of microbial communities and/or shifts in microbial metabolic pathways as modified by plants. These techniques will be employed and refined as needed to determine interactions between plant and microbial communities. Batch hydraulic loading ensures that the entire microbial population will be exposed to decreasing organic C concentrations and a concurrent decrease in oxygen demand.

Impact/Accomplishment: Data collection using columns and flow-through cells were started. In addition, new columns containing 20 different wetland plant species were planted. These columns are less heavily instrumented, but started receiving the same artificial wastewater used in the other experimental wetlands. Rather than a "one-size fits all approach" to the design of wetlands to treat wastewater, design engineers will be able to use our results to optimize a wetland for a specific wastewater composition (e.g., municipal, industrial, agricultural or mine impacted water), and for a specific geographic location (climate). Presently only size is varied, depending on wastewater flow rate and composition. Our results will allow other variables, such as type of water application, species selection and potential rock media to be optimized to either reduce the cost, increase the performance expectation, or determine the climatic regime in which wetlands can be successfully built. As wetlands are among the cheapest alternatives for wastewater treatment, we can expect better water quality at reduced costs as an end result of this research.

Source of Funding: NRI Competitive Grant, State of Montana

Scope of Impact: National

Key Theme – Biodiversity

a. Ecology and Behavior of Rangeland Insects

Description of Activity:
Pollinators, especially bees and predatory insects, play critical roles in natural and agricultural ecosystems. The ecology and behavior of many pollinator species is poorly understood, and populations of these insects may be negatively impacted by certain land and crop management practices designed to solve other problems. The goal of this project is to gain a better understanding of: (1) the value of pollinator and predatory insects in agricultural and natural ecosystems; (2) the effect of land management practices on these insects; and (3) the basic biology of certain understudied groups.

The bulk of this research project is directed at obtaining a better understanding of the diversity, distribution, and activities of pollinators in natural and agricultural ecosystems. The pollinators of interest come from a variety of taxa, especially *Hymenoptera* (bees, wasps, and sawflies). The research is designed to provide information relevant to

agricultural production and land management strategies. The primary goals are to document and quantify: (1) pollinator diversity; (2) plant-pollinator associations; (3) pollinator-pollinator interactions; (4) temporal trends in pollinator populations and communities in relation to habitat modification, agricultural management practices, and plant succession; (5) behavior of bumble bees, solitary cavity nesting pollinators, and predators; and (6) mortality factors of pollinators, particularly those occurring during developmental stages within nests. The research is being conducted in a variety of agricultural and natural habitats, including alfalfa seed farms, cucurbit farms, and seed and plant production farms used for restoration projects, National Forests, National Wildlife Refuges, and grassland and riparian areas of the Gallatin Valley of Montana. A secondary aspect of the research is to study the diversity and biology of predatory solitary wasps that occupy the same nesting habitats as many of the bees.

Impact/Accomplishment: Our work over the past several years has provided important groundwork for this research including the development of a large reference collection of bee and wasp species from several Montana locations and one in New York. We have made substantial progress creating pollen reference collections for several of the sites and have documented the local flowering plant flora at sites where we will be conducting diversity and behavioral studies.

Accomplishments in the past year include: (1) completion of a four-year study of the pollinator communities of the Tenderfoot Creek Experimental Forest (MT, WY, AB) including examination of the impact of shelterwood management on pollinators; (2) initiation of a major project on the effect biopesticides on pollinator, natural enemy, and pest communities in seed alfalfa; (3) continuation of studies of the foraging and reproductive behavior of trap-nesting bees and wasps, including the alfalfa leafcutter bee, *Megachile rotundata*; (4) continuation of a major reference collection of pollinators from natural and agricultural habitats in Montana; and (5) completion of a study of the effect of grazing on black grass bug populations on rangeland.

The importance and financial contribution of natural pollinators to agricultural and natural ecosystems is well documented. This research is aimed at gaining a better understanding of the basic biology of pest, pollinator, and predatory insects in natural and agricultural habitats. Research has specifically addressed rangeland habitats, as well as alfalfa seed fields and managed forests. The results are providing data for assessing the impact of species land management practices (grazing regimes, shelterwood management), pest control practices (grazing, pesticides) and pollinator management practices (use of enhanced alfalfa leafcutter bee populations).

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Biological Control

a. Biological Control in Pest Management Systems of Plants

Description of Activity: Noxious and invasive weeds are a serious problem on Montana's range and forested lands. They have a serious economic impact on the productivity of these lands, and the presence of these invaders compromises the

ecological integrity of all Montana's land. This project investigates the use of biological control agents for the management of several noxious weeds, many of which are newly targeted for biological control in North America or in Montana specifically.

The identification and testing of various arthropods for the biological control of hoary-cress, field bindweed, rush skeletonweed, Russian knapweed, tansy ragwort, and invasive hawkweeds continued at the quarantine facility at MSU and at multiple Montana locations. The project was established to determine the environmental safety of exotic natural enemy candidates prior to their release into the environment. It was also designed to monitor the release, establishment, and redistribution of these natural enemies, and to evaluate natural enemies of target plants.

Impact/Accomplishment: Host specificity testing of the gall wasp, *Aulacidea subterminalis*, is nearly complete. Twenty-one invasive and native hawkweed species and closely related native plants were tested. In all, a total 443 replications of 33 plant species have been tested to date. Galls occurred on four species of hawkweed—all invasive species.

A cold adapted strain of the tansy ragwort flea beetle, *Longitarsus jacobaeae*, has been collected from Switzerland for release in Montana. In the fall, 24 beetle releases (2003–2005) were surveyed and 13 sites had low levels of adult beetles present. A Mediterranean strain of the beetle collected from Oregon was also released in Montana in 1998–2001. Small, but growing, populations were located during surveys conducted in late 2004 and 2005. The impact, interaction, and possible hybridization of these two populations of flea beetles will continue to be monitored. Dormancy (diapause) strategies of the tansy ragwort flea beetle are being investigated to determine the survival of beetles under highly variable environmental conditions, such as those found in Montana. The two strains of the beetle that are established in Montana have different phenologies: the Swiss beetle overwinters as an egg, whereas the Mediterranean beetle generally aestivates during the drier parts of the summer and emerges as an adult to lay eggs in the late autumn.

The rush skeletonweed root moth, *Bradyrrhoa gilveolella*, was again imported from northern Greece for rearing and release. Over 200 viable eggs were obtained and were sent to the Nez Perce Biological Control Center, ID for additional rearing. A small rearing colony has also been established at MSU for biological studies. A habitat specificity study of the root moth on rush skeletonweed is being conducted to better select potential release sites for its establishment. Developmental studies of *B. gilveolella* are also continuing and will develop a degree-day model to better understand its phenology.

The gall mite, *Aceria malherbae*, has been established at several sites in Montana. Redistribution of this mite continues in warmer areas. Several studies on the ecology and biology of biological control agents for several invasive weeds have been initiated.

Biological control has proven to be one of the most effective, environmentally sound, and cost-effective approaches used in pest management. It is compatible with most other weed management strategies, having significant environmental, economic, and social impacts on the quality of agricultural systems, the ecosystem at large, and rural life. These projects will contribute to the selection of potentially new biological control agents for the control of noxious weeds, as well as a general understanding of biological control and its implementation.

Source of Funding: Hatch, State of Montana

Scope of Impact: Multistate

b. Basic and Applied Research for Management of Wheat Stem Sawfly and Stored Grain Insects

Description of Activity: Stored grain insects cause large economic losses for wheat producers. Survey information and monitoring data will be obtained and used to develop a stored grain outreach program for Montana wheat producers. Wheat stem sawfly is a severe pest of wheat production in the northern Great Plains. It cannot be managed using conventional tools or agricultural practices. Chemical signals produced by insects and plants and pathogens are being examined as potential tools to manage the wheat stem sawfly.

Impact/Accomplishment: Research has shown that adult female wheat stem sawflies show considerable preference for certain winter and spring wheat lines, irrespective of wheat developmental stage. A second year of research, using trap strips of attractive winter wheat to protect an interior of unattractive wheat, show infestation levels of 80% in the winter wheat trap with a 15% infestation in the interior spring wheat. The wheat trap is harvested for forage at the termination of the wheat stem sawfly adult flight. The harvested hay is of acceptable quality for marketing, and yields match those reported for similar cropping practices. Detailed spatial characterization indicates a clear edge-effect, with high levels of infestation in field perimeters compared to the interiors. The trap crop approach is an enhancement of this innate pattern.

New research will explore if trap strips can be further enhanced to concentrate oviposition resources in these areas at even higher levels. A sampling plan was developed for determining management approaches for wheat stem sawfly infestation.

Sampling plans developed allow for rapid determination of appropriate management strategies for hidden wheat stem sawfly larvae. Detailed study also shows that trap strips may attenuate a natural tendency for adult female sawflies to disperse further into fields. A field test of an automated dual-beam stored product insect monitoring system showed high levels of accuracy under aerated and unaerated conditions in newly-stored wheat. Automated stored grain insect traps successfully monitored insect population in field trials under both aerated and unaerated conditions. The use of such technology should limit the need to conduct labor intensive sampling to monitor commodity integrity.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

c. Managing Plant Microbe Interactions in Soil to Promote Sustainable Agriculture

Description of Activity: Biological controls are needed for managing diseases of potatoes and sugar beets. The objective of this project is to integrate disease management programs that profitably provide growers biological, chemical, and host plant resistance control options.

The microflora present on potato and sugar beet leaves and roots in the presence and absence of diseases are being characterized. We are identifying microorganisms with high potential for commercial formulation that demonstrate biocontrol of one or more diseases. Selected organisms will be tested for *invitro* antagonism and by inoculating plants or tubers with test organisms. The best appropriate chemical pesticide is used as a control. Seed treatments are used for sugar beet root diseases and tuber inoculation will be used for potato tuber diseases. Foliar applications are used for foliar diseases. Efforts are being made to recover isolates demonstrating control to ascertain their phyllosphere/rhizosphere competence. Systems that increase or selectively support populations of biocontrol agents in soil or on plants will be studied against soilborne and foliar diseases. Agents will be studied for biocontrol optimization and for the induction of systemic resistance.

Impact/Accomplishment: A biorational synthetic mixture of organic components mimicking key antimicrobial gases produced by *Muscodor albus* compared favorably with the use of live *M. albus* for control of seedling diseases of sugar beet caused by Pythium ultimum, *Rhizoctonia solani*, *Aphanomyces cochlioide*s, and for root knot nematode, *Meloidogyne incognita*, on tomato. The biorational mixture provided control of damping-off equal to a starch-based formulation of the live fungus for all three sugar beet pathogens; and the mixture significantly reduced the number of root-knot galls on tomato roots.

M. albus (isolate 620) or synthetic mimics of its natural volatile organic compounds may provide a new means of controlling soilborne diseases of potato and sugar beet and may provide an alternative for methyl bromide fumigation used for soilborne disease control in other crops. MSU 341-16-5 (*Bacillus pumilis*) has demonstrated an average 6.8% yield increase for sugar beet in 26 sites over the last 10 years. Yield increases are measured through improved stands, disease control, and growth promotion.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Global Change and Climate Change

a. Effect of Cropping Systems and Water on N_2O Emission from Soil as Influenced by Fertilization and Crop Residues in the Northern Great Plains

Description of Activity: Concentrations of greenhouse gases in the atmosphere have been found to be increasing over the last 200 years. Although nitrous oxide is considered a trace greenhouse gas, its presence in the atmosphere is particularly important as its atmospheric warming potential (per molecule) is estimated to be 310 times greater than carbon dioxide. The Intergovernmental Panel on Climate Change (IPCC) has identified agriculture as the major source of N_2O emissions accounting for approximately 72% of emissions generated by human activity. There is great uncertainty about the validity of this value as it is applies to agricultural systems in semi-arid regions (e.g., Great Plains). It is the overall goal of this project to address the current lack of data on nitrous oxide emissions from the Northern Great Plains by conducting detailed measurements of nitrous emissions under a variety of cropping system and nutrient

management practices. Current IPCC methodology assumes that 1.25% of all applied nitrogen (N) inputs (fertilizer, manures, crop residues) are lost to the atmosphere as N_2O. The goal of this project is: (1) to learn more about seasonal patterns and cumulative N_2O emissions from agricultural soils in the Northern Great Plains, and (2) to determine whether the current IPCC methodology accurately predicts emission levels of N_2O.

Field studies on soil emissions of N_2O are currently being conducted. The first study integrates the measurement of N_2O emissions with a project on best management practices for soil C sequestration. This study consists of eight cropping systems and one perennial grass system (CRP). The second study examines the levels of N_2O generated from fertilizer N and crop residues under a water gradient.

Impact/Accomplishments: Research has shown that 70–75% of yearly N_2O emissions occur during two periods. The first is during spring thaw when surface soils (0–4 inches) are at, or near saturation (water-filled pore space >90%). Losses during this period are likely attributed to denitrification. The second period follows the application of N and lasts approximately 7–10 weeks. Emissions during this period are believed to result from nitrification of fertilizer N, and increase with higher N application rates. Emissions of N_2O decline during the summer to near ambient levels as soils dry to a water-filled pore space of less than 25%. Annual losses of N_2O are affected by cropping sequences and intensity. No-till (NT) systems showed similar losses to conventional till (CT) systems except during the spring thaw. Losses were greatest for wheat-wheat (NT) crop rotation systems, followed by wheat-pea (NT) which was equal to wheat-fallow (NT) and wheat-fallow (CT). Continuous wheat systems exhibit the highest emissions losses due to higher N fertilizer inputs. Overall, the level of soil N_2O emission activity appears to be modest in the Northern Great Plains. Fertilizer induced emissions of N_2O are equivalent to 0.1–0.5% of applied N amounts. This is well below the IPCC default value of 1.25%, and indicates that regional models should be adjusted to reflect conditions in the Northern Great Plains. Preliminary results suggest that application timing of N fertilizer in accordance with crop demand could be the key to minimizing N_2O emissions. Studies are ongoing to determine whether fertilizer management strategies can be adjusted to mitigate losses of N_2O into the atmosphere.

The results of this study will be used to validate or refute IPCC methodology for estimating nitrous oxide emissions in the Northern Great Plains. The results will also identify cropping systems and fertilizer management practices that minimize nitrous oxide losses to the atmosphere.

Source of Funding: Hatch, State of Montana, NRI Competitive Grant

Scope of Impact: Northern Great Plains

b. Climate Change and Greenhouse Gas Mitigation in Montana and U.S. Agriculture

Description of Activity: Changes in economic conditions, agricultural policy, and trade policy raise questions about the economic future of Montana and Great Plains agriculture. Farm-level production models of land use and management will be developed and linked to existing models, which will assess long-term land use decision making.

Objectives for this project include: (1) to develop more tightly-coupled linkages between the Century model, the DSSAT-Century model, and the Montana econometric process model for the dryland grain production system, and to evaluate soil C sequestration costs and policies; (2) to assess the capability of existing econometric-process models to analyze soil C contracts and policies relative to the existing field-scale model for Montana and other regional and national models being used in CASMGS (Consortium for Agricultural Soils Mitigation of Greenhouse Gases); (3) to test sensitivity of Montana and regional models to yield changes, carbon rates, and parameters in the simulation model; (4) to add nitrous oxide to the Montana analysis of soil C; (5) to develop a C sequestration component for the Nebraska econometric-process model farm/field scale analysis and make comparisons to the Montana model with respect to contract design and efficiency of soil C sequestration; (6) to review the types of policy mechanisms and their suitability for soil C sequestration; and (7) to use the integrated modeling approach to predict changes in C storage and greenhouse gas fluxes based on soil sampling, databases, and coupled ecosystem and econometric-process simulation models.

Impact/Accomplishment: Research is continuing on development of new methods to model impacts of climate change and greenhouse gas mitigation. A model using county-level data was further developed to simulate agricultural land use in the Central U.S. region. Analysis was conducted to investigate various climate change scenarios and their impacts. Another model was developed to simulate C supply curves for the adoption of reduced fallow and conservation tillage practices in the central U.S. The results from this research will enable government and private entities to assess the economic feasibility of agricultural emissions reductions for greenhouse gases.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

c. Studies of Plants Living in Extreme Environments within Yellowstone National Park

Description of Activity: Heat stress in plants can result in significant losses in crop yield. This may become more important with the increased affects from global warming. By the latter half of the 21st century, global climate change, primarily warming, resulting from increasing atmospheric concentrations of CO_2 and other greenhouse gasses could jeopardize agriculture, forestry, and other industries dependent on the natural environment. Although much research has been conducted to evaluate such economic effects of global warming, efforts aimed at practical approaches to improve the adaptability of plants to their temperature environment have only recently begun.

Acidic soils (both natural and as a result of acid precipitation from human activity) reduce soil available nutrients to plants and can lead to increased toxicity from heavy metals in the soil. There is some geological evidence to suggest that Yellowstone National Park (YNP) may have extensive areas where plants are – and long have been – exposed to high levels of CO_2 of volcanic origin. No systematic study of such plant communities in YNP has been conducted to our knowledge. This project examines the possibility that geothermally-modified soils, which are common in YNP, have selected for native plants unusually adapted to heat and to toxic soils. The results of this research have increased our understanding of how fungal symbionts may contribute to heat and drought tolerance

in native plants. The information gained by discovering the precise mechanisms of improved stress tolerance in native plants adapted to extreme environmental conditions may be applied to efforts to improve stress tolerance in crop plants.

Our primary objective is to better understand the cellular mechanisms responsible for thermotolerance in eukaryotes, especially sessile organisms such as plants and fungi, which often cannot avoid extreme heat stress. Secondly, we are interested in determining the degree to which microbes (fungi in particular), contribute to the evolutionary adaptation of vascular plants to stressful environments. Finally, recent scientific interest in the effects of increasing atmospheric CO_2 on plants has motivated us to better understand plant photosynthetic physiology and plant community structure in the high-CO_2 environments of YNP.

Impact/Accomplishment: Using portable CO_2 infrared gas analyzers, we measured the soil-surface CO_2 concentrations at dozens of vegetated geothermal areas within YNP. Many of these sites displayed high CO_2 values, ranging from 450–1500 ppm (with background level equal to 370 ppm). Leaves were collected at both background- and high-CO_2 sites from the predominant plant grass species in geothermal areas, *Dichanthelium lanuginosum*. Using two independent methods for estimating the levels of the enzyme ribulose bisphosphate carboxylase/oxygenase (RuBisCo), we found that leaves from the high-CO_2 sites consistently had less RuBisCo than comparable leaves from the background-CO_2 sites. These findings are consistent with the idea that plants growing in high-CO_2 areas of YNP are chronically exposed to elevated levels of this gas. Thus, YNP may be an extremely valuable resource with regard to investigating important questions involving the long-term (years/decades/centuries) effects of increased atmospheric CO_2 on plants and on plant communities.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Key Theme – Nutrient Management

a. Nutrient Management and Cycling in Montana Soils

Description of Activity: New agronomic and cropping system practices can lead to a more productive and sustainable agriculture in Montana. These practices must be balanced against environmental impacts, including water quality and greenhouse gas emissions. This project examines agronomic and cropping system practices that will promote the health and sustainability of Montana's agriculture while minimizing environmental concerns associated with modern agricultural production.

The objectives of this project are: (1) develop agronomic management practices which provide more efficient utilization of N fertilizer for Montana's crops; (2) improve current databases on N-water interactions on grain yield, quality, and straw production of wheat (and/or other important crops); (3) develop and evaluate new and emerging technologies/practices, including on-the-go protein sensing and precision farming; (4) identify the potential for Montana agricultural soils to sequester C; and (5) identify the effect of tillage practices and diversified cropping sequences on N_2O emissions from Montana soils.

Impact/Accomplishments:
A greenhouse study was conducted using the Neubauer approach to determine what effect drying (50° C) had on plant availability of ammonium-N levels in a cropland soil (surface and sub-surface). Previous research has indicated that drying soil samples prior to analysis will elevate the amount of ammonium extracted with KCl. Soil samples were collected at a field site in northern Montana from two depth layers. Soils (fresh and dried) were transferred to pots where barley was being grown under a sand culture. At the conclusion of the study the plants were harvested, analyzed for N, and soils were separated and analyzed for nitrate and ammonium-N. Results of this study showed that soil drying had no effect on the amount of N absorbed by barley. Ammonium-N levels at the conclusion of the study did not differ significantly between fresh and dried pretreatments. Also, while nitrate-N levels dropped precipitously over the course of this study, ammonium-N levels did not. It was concluded that ammonium-N extracted with KCl is considerably less available than nitrate-N with this same extracting solution.

Analyses of soil samples for N is the single most important nutrient test performed by soil testing labs serving agronomists and the agricultural communities. Knowledge of the effect of soil preparation practices on soil N test levels is critical to understanding and interpreting soil test results from our region

Source of Funding: Hatch, State of Montana

Scope of Impact: Regional

GOAL 5: Enhanced economic opportunity and quality of life for Americans.

Overview

Montana producers are presented with an array of complex governmental programs to ensure that their income is maximized and protected. The development of a set of tools has been completed to address economic problems and risks in farming operations. These tools discuss alternative contractual arrangements, producer incentives, risk management, and governmental policies. Results of the research have been used by federal congressional leaders in formulating agricultural policy and legislation.

The Biobased Products Institute at MSU is working to expand development and production of value-added products in Montana and to support food risk assessment education, research, and extension efforts. Montana's agricultural economy depends on maximizing net returns per crop acre (or per animal unit) with the most efficient use of available resources. Value-added, agriculturally-based end products can provide unique markets and enhanced revenues for Montana producers. Continued education, research, and partnering will enhance the opportunities and awareness of value-added programs. The development of food safety systems for consumers will also add value to Montana's agricultural products.

Effective procedures are needed to establish the priority process for agricultural research in applied science, economic policy, and management. This is needed in order to develop priority setting procedures that enhance agricultural research productivity.

The revitalization of agriculture and rural communities in Montana is essential for the state's economic sustainability and competitiveness in the global marketplace.

Total Goal 5 Funding: $275,786 FTE: 2.41

Following are descriptions of selected projects currently funded and in progress at Montana State University.

Key Theme – Impact of Change on Rural Communities

a. Impact Analysis and Decision Strategies for Agricultural Research

Description of Activity: Effective procedures are needed to establish the priority process for research in applied agricultural science, agricultural economic policy, and agricultural enterprise management. This is needed in order to develop priority setting procedures that enhance agricultural research productivity.

The objectives of this project are: (1) to estimate the expected and actual flow of benefits and costs of research for agriculture, and related areas including the incidence of their distribution; (2) to determine and quantify the relationships between research and other public sector policies and programs for agriculture; (3) to analyze decision strategies for agricultural research funding by different public institutions and private organizations; and (4) to continue the development of procedures for facilitating the priority setting process for agricultural research and to implement them.

Impact/Accomplishment:
The impact of this project has been substantial. Key project findings have been presented to researchers, policy makers, agricultural producers, agricultural commodity group leaders, and Congressional staffers. An important refereed journal article on food labeling policy was published. In addition, a study of the linkages between agricultural chemical markets and biotechnology adoption was initiated.

Source of Funding: Hatch, State of Montana

Scope of Impact: National

Stakeholder Input

The Montana Agricultural Experiment Station (MAES) and College of Agriculture (COA) obtain stakeholder input on research priorities, programs, and direction. As an example, the College Development Board, sustainable agricultural focus groups, MAES Advisory Council, and the Ag Coalition provide input. These expanded upon the historical scope of input into long-term Montana priorities and are aligned with USDA programs. Recent facilities improvements to enhance our field research capacity include: (1) $1.6 million over the 2006–2007 biennium at agricultural research centers; (2) $5 million in biosafety facilities (BSL); and (3) $9 million towards a $12.5 million goal for an animal and range sciences teaching and research facility.

The Ag Coalition consists of representation from the Montana Stockgrowers, Seed Trade, Wool Growers, Agricultural Business Association, Beef Council, Farm Bureau

Federation, Montana Farms Union, Montana Water Users Association, and the Montana Department of Agriculture. It meets quarterly to review program priorities, new initiatives, fundraising efforts, and legislative activities.

The College of Agriculture and MAES have 21 advisory committees and boards with a total of 266 members, in addition to alternates. These include the Animal Biosciences Complex Board, Biobased Product Institute, Center for Invasive Plant Management Board, Center for Invasive Plant Management Science Advisory Council, Central Agricultural Research Center Advisory Committee, Council for Agricultural Research, Extension, and Teaching, Eastern Agricultural Research Center Advisory Committee, Foundation Seed Advisory Committee, Livestock and Range Research Laboratory, MAES State Advisory Council, Mint Committee, Montana Beef Advisory Committee, Montana Beef Council, Montana Beef Network Advisory Committee, Montana Farmers Union, Montana Grain Growers Association, Montana Pulse Growers Association, Montana Seed Growers Association Board, Montana Wool Growers Advisory Committee, Northern Agricultural Research Center Advisory Committee, Northwestern and Western Agricultural Research Centers Advisory Committee, Organic Certification Association of Montana, Potato Certification Board, Southern Agricultural Research Center Advisory Committee, Thermal Biology Institute Scientific Advisory Board, Undaunted Stewardship Guidance Council, Variety Release and Recommendation Committee, and Western Triangle Research Center Advisory Committee.

Members of these committees represent agricultural educators, agricultural organizations, communities, conservation groups, county extension agents, farmers and ranchers, financial organizations, private citizens, scientists, small businesses, and tribal councils. The College of Agriculture and its MAES administration faculty respond to input from these stakeholders and state/national/international trends by evolving their programs. Three regular meetings of the Advisory Council are held each year during the fall, winter, and summer.

Each of the seven research centers hold annual field days for the presentation of research and to collect input on new research directions. We activity participate with USDA-ARS programs. These field days are attended by agricultural clientele and the general public. Nearly 1,200 individuals had direct contact with project leaders in 2005.

MAES responds to stakeholder inputs by integrating their proposals at research planning meetings with advisory groups, administrators, and scientists. As a result of the stakeholder input meetings, MAES received specific suggestions with regard to research. These suggestions were:

1. Adding value to our high quality crop and livestock products
2. Establishing better marketing of applied research
3. Creating new business opportunities for rural communities
4. Developing new alternative crops and end-product uses
5. Increasing the research programs on alternative energy sources
6. Using integrated pest management
7. Integrating new agricultural product and crop research to expand agricultural products and markets

Program Review

Hatch Projects are subject to a rigorous review at the department level, followed by a peer review, with final approval at the Director's level. The MAES Director's Office has oversight of this review process. The peer review committee, selected by the Director after consultation with department heads, includes the principle investigator's department head, MAES administrator, one department peer reviewer, and two additional faculty external to the PI's department. Many external faculty have no affiliation with MAES. Seminars are presented to the review committee and to interested stakeholders. The seminars are announced to the public on the Internet, so the public can attend. Reviewers are requested to provide written recommendations on the following items: relevance and importance of the project; relation of the project to previous research; objectives; approach and methods; scientific and technical quality; resources; environmental, economic, and/or social impacts. The responses are presented to the PI during a subsequent meeting with the MAES administrator and department head. The PI is required to revise the project as recommended by the reviewers and to resubmit the project proposal to the MAES administrator and department head for additional review and semifinal approval. The approved project is submitted to the Director for final approval. Projects that do not meet expectations will not be approved, and subsequent action will be deferred until all of the key elements listed above have been met.

Multistate Research

Montana State University is a participating partner in numerous Multistate projects.

Molecular Mechanisms Regulating Skeletal Muscle Growth and Differentiation [NC-1131]
Muscle growth rate and tenderness are important characteristics in the production of meat. Producers demand rapidly growing animals, while the consuming public judges meat quality by the tenderness of the cut of meat they are enjoying. This project in cooperation with other institutions from ID, MI, MN, and SD, seeks to determine if changes in the molecular activities of muscles create a change in the genetic potential and results in subsequent changes to the finished product. Information from these studies may explain some of the variation seen in tenderness in the U.S. meat supply, and it will help to determine if changes in genetics are creating some of the tenderness variation.

Domestic Surveillance, Diagnosis, and Therapy of Transmissible Spongiform Encephalopathies [NC-1024]
The transmissible spongiform encephalopathies, or prion diseases, are a group of emerging animal diseases that directly impact U.S. agriculture, wildlife disease management, cervid game farming, and recreational hunting. MSU researchers are seeking to determine the transmission routes for chronic wasting disease (CWD). Through collaborative arrangements with researchers at South Dakota State University, Colorado State University, the USDA National Animal Disease Center in Ames, IA, the USDA National Veterinary Service Laboratories in Ames, IA, and the USGS National Wildlife Health Center in Madison, WI, tissues from scrapie-infected sheep and CWD-infected cervids have been obtained for analysis of prion infection at mucosal sites that could be relevant to prion agent shedding and transmission.

Sources, Dispersal, Management of Stable Flies on Grazing Beef and Dairy Cattle [S-1005]
Stable flies are economic pests of grazing beef and dairy cattle. Their presence is responsible for lowered weight gains, reduced milk production, and lowered weaning weights. This project examines development, overwintering, and dispersal of stable flies with the results incorporated into stable fly management strategies. Eleven additional states and ARS scientists across the U.S. in livestock producing areas are working to gather information on developmental biology, overwintering studies, and dispersal studies to ultimately be incorporated into management tactics that will be transferred to producers via outreach. A study was initiated to investigate the overwintering success of stable flies in and around hay bales. Samples obtained this spring will provide evidence relative to the ability of this species to survive winter in Montana and may explain why some cattle producers are experiencing stable fly problems early in the season.

Reproductive Performance in Domestic Ruminants [W-112]
Despite recent advances in reproductive technology, cattle and sheep producers are faced with the persistent problem of low livestock fertility. Recent work indicates that the fertility of domestic ruminants, even under optimal conditions, is only about 50%. The poor fertility of domestic species is reflective of cumulative loss due to poor fertilization efficiency, high embryo mortality, and spontaneous abortion. The knowledge gained will lead to the development and implementation of new management protocols and/or pharmaceutical and nutritional regimens that will increase the fertility of domestic ruminants in the West by increasing conception and reducing embryo and fetal loss. Our collaborative work will result in the development of effective methods of estrous synchronization and, thereby, facilitate the use of artificial insemination in breeding programs of beef cattle and sheep on the Western range.

Exotic Germplasm Conversion and Breeding Common Bean (Paswoulus Vulgaris L.) For Resistance to Abiotic and Biotic Stresses and to Enhance Nutritional Value [W-1150]
Breeding for food quality and other important characteristics is often difficult because they are influenced by multiple genes. The genes controlling the important characters are identified and tags are made with easily scored DNA markers. Cases of conserved gene order will permit prediction of positions of new genes in both pea and common bean without having to perform actual mapping experiments. Our use of intron-targeted markers in pea, lentil, and common bean has revealed that genomic comparisons between cool season and warm season legumes will be of limited value until genomic sequences are available for at least one taxon in each group. We expect to eventually have a set of genes that can be use for mapping in most legume species, permitting map comparison throughout this important family.

Plant Genetic Resource Conservation and Utilization [W-6]
Most commercially grown horticultural and agronomic plant species are not native to the U.S. The evaluation and documentation of plant genetic resources, determination of the extent of genetic variation, and the collection and distribution of information about introduced plant germplasm provides the agricultural community and allied industries with new cultivars of important crops to remain competitive in the world market place. New cultivars depend on a diverse source of genetics. Conserving and evaluating new plant germplasm is an important step in the cultivar development process. Montana scientists (and 12 states with ARS) have participated in plant exploration and collecting

trips. Montana scientists will use molecular markers to investigate taxonomic relationships among cultivated crop species and their wild relatives important to Montana. Montana received 2,599 individual plant accessions during 2004. Eleven of the 16 individuals receiving plant germplasm were associated with MSU. These 11 individuals received 99% of the total accessions.

Managing Plant Microbe Interactions in Soil to Promote Sustainable Agriculture [W-1147]

Soilborne plant pathogens are responsible for many diseases of field crops and are responsible for up to 25–50% of yield losses. Scientists from MT, NE, NY, CA, IL, OR, WA, ID and AZ, are researching biological controls for managing diseases, primarily of potatoes and sugar beets. The objective of this project is to integrate disease management programs that profitably provide growers biological, chemical, and host plant resistance control options. While a number of biocontrol agents are now available commercially, problems with production, storage, delivery, reliability, efficacy, and establishment have prevented most of these products from being mainstreamed. This project has been a major contributor to progress in biological control of plant diseases. Members of this research group endeavor to find environmentally friendly solutions for management of plant pests. *Muscador albus* or synthetic mimics of its natural volatile organic compounds may provide a new means of controlling soilborne diseases of potato and sugar beet and may provide an alternative for methyl bromide fumigation used for soilborne disease control in other crops.

Biological Control in Pest Management Systems of Plants [W-1185]

Noxious and invasive weeds are a serious problem on Montana's range and forested lands and in other producing areas of the U.S. They have a serious economic impact on the productivity of these lands, and the presence of these invaders compromises the ecological integrity of all Montana's land. This project, in cooperation with the ARS and over 20 other states, investigates the use of biological control agents for the management of several noxious weeds. Biological control has proven to be one of the most effective, environmentally sound, and cost-effective approaches used in pest management. It is compatible with most other weed management strategies, having significant environmental, economical, and social impacts on the quality of agricultural systems, the ecosystem at large, and rural life. The identification and testing of various arthropods for the biological control of hoary-cress, field bindweed, rush skeletonweed, Russian knapweed, tansy ragwort, and invasive hawkweeds continued at the quarantine facility at MSU and at multiple Montana locations. These projects will contribute to the selection of potentially new biological control agents for the control of noxious weeds, as well as a general understanding of biological control and its successful implementation.

Characterize Weed Population Dynamics for Improved Long-Term Management Decision Making [NC-1026]

Weed management is a time-consuming and costly expense for crop producers. The use of weed management decision support systems (DSS) is being investigated by institutions from MT, NE, IA, CO, MN, SD, MI, and KS. Successful implementation of a weed management DSS has the potential to greatly reduce the amount of herbicides applied in corn and soybean cropping systems, as well as to improve overall management of weeds. The significance of this research is that it combines information on the biology of northcentral states weeds and the impact of those weeds on corn into a model that assesses the economic risk of management practices. Common sunflower and giant ragweed seeds collected in IL, KS, and MT were planted near Bozeman, MT,

and the emergence rate, seedling survival to maturity and reproduction were measured for each species and each collection site. There were significant differences in all aspects of the biology of these species due to their place of origin. The experiments are ongoing. The expected impact based on preliminary results is to shift weed management decision support system to localized areas to increase certainty in recommendations.

Development of Plant Pathogens as Bioherbicides for Weed Control [S-1001]
Invasive weeds are one of the greatest threats to the improvement and sustainability of agriculture. Plant pests, such as insects and plant pathogens, can be used to control these weeds. However, few plant pathogens have proven effective enough to economically compete with herbicides. This project evaluates strategies to enhance the effectiveness of plant pathogens for control of noxious weeds. Research is coordinated among scientists at ARS locations and in NY, CA, FL, NC, MA, and IN. Research is investigating the virulence of plant pathogens for biocontrol of weeds. We are also evaluating alternate distribution systems, including mycelial formulations and live-seed distribution systems, to economically deliver pathogens to the target weed and throughout the soil profile.

Science and Engineering for a Biobased Industry and Economy [S-1007]
The development of alternative energy sources for the U.S. is a priority to reduce our country's dependence on fossil fuels. Research is established to investigate and provide alternatives to reduce the costs associated with the handling of feedstocks for biofuels, biomaterials, and biochemicals. We are working to develop, evaluate, and optimize integrated processes to convert biomass resources into biomaterials with commercial applications and to expand the scientific knowledge for the development of processes for the production of biobased specialty chemicals from agricultural feedstocks and residues. Current crops targeted in Montana include canola, camelina, and mustard. The development of these crops can significantly reduce the cost of biodiesel manufacturing.

Evaluating the Physical and Biological Availability of Pesticides and Pharmaceuticals in Agricultural Contexts [W-1082]
The ability to predict the fate and transport of organic chemicals in soils is, to a large degree, dependent on the rates of microbial degradation occurring in soils and thereby elucidating the potential for contamination of surface and ground waters. Our role in this project is to identify mechanisms by which pesticides and other organics interact in soils. Our work is focused on factors controlling microbial population dynamics and subsequent degradation of specific compounds present in hydrocarbon contaminated soils. We recently finished a project to identify linkages among temporal microbial and chemical dynamics in soils contaminated with complex hydrocarbon mixtures. Continued work on this project will focus on complimentary chemical analytical and molecular tools to link the degradation of specific constituents present in hydrocarbon mixtures with 16S rDNA and functional gene signatures, especially in the presence of different mixture types.

Impact Analysis and Decision Strategies for Agricultural Research [NC-1003]
MSU is cooperating with over 20 other institutions to establish effective procedures for setting priorities for agricultural research in applied science, economic policy, and management. This is needed in order to develop priority setting procedures that enhance agricultural research productivity. The research is designed to estimate the benefits and costs of research for agriculture, quantify the relationships between research and other public sector policies and programs for agriculture, analyze decision

strategies for agricultural research funding, and continue the development of procedures for establishing priorities for agricultural research.

Integrated Research and Extension Activities

Most MSU College of Agriculture faculty have dual appointments involving two of the three responsibility areas (e.g., research, extension, or teaching). Nearly 10% of the FTE is devoted to integrated research and extension activities. However, most of our MAES and COA faculty have extensive outreach initiatives well beyond the Extension financial support in order to meet the needs of Montana stakeholders and MSU faculty expectations. MAES and the Montana Extension Service are assessing future high priority joint appointments. At this point, the research and extension efforts are on target to reduce input costs, and manage land and water resources effectively and efficiently for crop, range, conservation, federal and state agencies, and the public.

Planned Program Activity Summaries

Epidemiological investigations on arthropod-borne diseases of domestic livestock and wildlife: The bluetongue study has demonstrated that transmission in Montana and Alberta is not an issue and should not be subject to trade regulations. West Nile Virus (WNV) surveillance work has shown that testing mosquito pools for the virus is the most useful prognostic tool for informing residents that transmission activity is occurring. Control of livestock pests will improve animal health and economics. C. sonorensis is, for the most part, an incompetent vector of bluetongue virus in Montana and Alberta. West Nile virus surveillance in Montana has determined that enzootic foci occur along major river drainages in the state including the Milk River, Yellowstone River and Missouri River. The use of mosquito pools and sentinel chickens for virus detection has shown that virus is first detected in mosquitoes before seroconversion occurs in sentinel birds. WNV human cases were reported from western Montana for the first time in 2006. Despite a severe drought in northeast Montana which significantly reduced mosquito production, a WNV epizootic was recorded in juvenile American white pelicans at Medicine Lake National Wildlife Refuge. This outbreak has prompted investigations into non-mosquito WNV transmission among pelicans. Insect pest control studies were conducted on horn flies on cattle and the sheep ked and African blue louse on sheep. Insecticide impregnated ear tags provided about 8 weeks control of horn flies on rangeland cattle which was less than the manufacturers' claim of 4 months control. Horn fly populations reached more than 1,100 flies per animal in the untreated control. Reports on the African blue louse are becoming more frequent in Montana mainly due to the lack of an effective, registered insecticide. Currently, a product is being evaluated for both sheep ked and lice control.

Integrated Pest Management of Montana Field and Forage Crops: Development of reduced (pesticide) risk management alternatives for the key pests of forage alfalfa (alfalfa weevil) and seed alfalfa (lygus bug) are being investigated. The impact of reduced risk management alternatives on insect pollinators and natural enemy populations will result in improved management on new biological tools in the IPM program. The factors that favor soil-inhabiting forage pests which reduce stand longevity are being identified. This will lead to alternative control measures and longer term longevity of stands.

Prescribed Livestock Browsing for Controlling Conifer Encroachment on Foothill Rangeland: This research project is examining cost-effective strategies for using prescribed sheep and goat browsing to suppress conifer encroachment onto foothill rangeland. This information will help refine browsing prescriptions and better enable range and livestock managers to use prescribed browsing as a tool for suppressing conifer encroachment. A 2-year, winter grazing trial was completed on foothill rangeland in west-central Montana that had been invaded by ponderosa pine. Six, 1-ha pastures were grazed at a high stock density with mature female goats. Goats in three of the pastures were supplemented daily with alfalfa pellets to help the goats detoxify secondary compounds (i.e., tannins and terpenes) within ponderosa pine foliage. Goats in the remaining three pastures were provided a self-fed protein supplement (Sheeplix) ad libitum. Results indicate that the botanical composition of goat diets and the amount of browsing damage inflicted by the goats was similar between the two forms of supplement.

Improve the Profitability and Competitiveness of the Montana Sheep Industry: Improvement of the economic status of the sheep industry will benefit Montana producers, as well as rural communities and counties by making family farms more sustainable. In addition an environmentally sensitive tool in the fight against noxious weeds will be investigated. This will play an important role as management strategies are developed to also deal with Montana's recent wild fires. A sustained and profitable sheep industry must exist for this tool to be available to land managers. This project also addresses animal husbandry, breeding and genetics, management, and wool and lamb marketing issues necessary for a healthy and viable sheep industry. The Montana Sheep Institute marketing strategies will assist family farms adjusting to the demands of a global marketplace. We assist sheep producers and private and federal land managers to develop, implement, and evaluate controlled grazing projects to manage large infestations of non-native invasive plants. Results will facilitate the development of grazing guides that can be used as a model for the implementation of controlled grazing throughout the United States. There are currently 21 active projects with 31 monitoring sites involving over 100,000 weed-infested acres. Most projects are in the second year of a five-year of grazing protocol. Sheep grazing protocols and projects involving private landowners, county weed supervisors, and public agencies are currently being developed.

Management Practices Which Influence Morbidity, Feedlot Performance, and Carcass Characteristics of Montana Beef calves: Food safety is an increasingly important issue in the beef industry. It is a top five issue of concern for consumers eating beef. This study allows us to help the cow-calf producers in Montana produce quality, safe beef and at the same time determine how to improve the quality of the beef that is raised. The Montana Beef Network (MBN) has three primary objectives; 1) educational programs aimed at provided research-based information and meeting beef quality assurance standards, 2) certification of feeder calves that have met defined BQA management protocols, and 3) information feedback from the feedlot and packing plant to the cow-calf producer showing if the feeder calves met industry requirements for quality, consistency, and red meat yield. One to two day short courses are held each year, in which issues pertinent to the beef industry are presented. Interactive television short courses aimed at carcass evaluation, genetic management, opportunities for backgrounding calves, BSE update, BQA certification and marketing options have been presented. Seventeen interactive sessions have been presented. Emphasis was placed on demonstrating new technologies for identification and traceability of cattle born in

Montana, but harvested in the Midwest. Presently, producers that desire data on their cattle, work with the MBN to enable the gathering of this information from the cattle buyer and feedlot. The data captured throughout the process is summarized and explained to the producer showing how they might modify their breeding and (or) management practices to improve the quality of their product. This is done by uploading captured data to a data management service and returning data back to the ranch.

Ecology of phyllosphere and rhizosphere and their potential role in biological control of disease: Bacillus mycoides isolate BacJ has shown the ability to induce resistance in a wide range of crop plants both in the glasshouse and in the field with disease control on sugar beet, cantaloupe, cucumber and tomato being equal to commercial products.

Summary of Goal Funding and FTE

Funding Sources	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5	Total
State	7,928,566	88,270	-	2,861,942	150,949	11,029,727
Hatch	1,126,201	21,731	-	191,640	11,415	1,350,986
Multistate	401,966	30,626	-	169,288	41,224	643,104
USDA-CSREES Animal Health	62,973	-	-	-	-	62,973
USDA-Special Grant	3,459,921	53,534	700	368,586	52,484	3,935,226
USDA-CSREES NRI	1,023,343	139,262	-	431,701	-	1,594,306
USDA-CSREES Other Grants	107,039	9,418	-	64,162	19,714	200,333
	14,110,009	342,841	700	4,087,318	275,786	18,816,654
FTE	141.5	3.83	0.0	42.83	2.41	190.57

U.S. Department of Agriculture
Cooperative State Research, Education, and Extension Service
Supplement to the Annual Report of Accomplishments and Results
Actual Expenditures of Federal Funding for Multistate Extension and Integrated Activities
(Attach Brief Summaries)
Fiscal Year: 2006

Select One: **?** **Interim** **X Final**
Institution: Montana State University
State: Montana

	Integrated Activities (Hatch)	Multistate Extension Activities (Smith-Lever)	Integrated Activities (Smith-Lever)
Established Target %	5.80% %	%	%
This FY Allocation (from 1088)	$1,963,234		
This FY Target Amount	$113,868		
Title of Planned Program Activity			
Epidemiological investigations on arthropod-bourne diseases of domestic livestock and wildlife	$19,437		
Integrated pest management of Montana field and forage corps	$29,794		
Prescribed livestock browsing for controlling conifer encroachment on foothill rangeland	$4,115		
Improve the profitability and competitiveness of the Montana sheep industry	$11,802		
Management practices which influence morbidity, feedlot performance and carcass characteristics of Montana beef calves	$19,240		
Ecology of phyllosphere and rhizosphere and their potential role in biological control of disease	$40,036		
Total	$124,423		
Carryover	$10,556		

Certification: I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays represented here accurately reflect allowable expenditures of Federal funds only in satisfying AREERA requirements.

Director **Date**