ANNUAL REPORT OF ACCOMPLISHMENTS AND RESULTS

MONTANA STATE UNIVERSITY

COLLEGE OF AGRICULTURE
MONTANA AGRICULTURAL EXPERIMENT STATION

FEDERAL FISCAL YEAR 2005

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Introduction

Preface

The College of Agriculture (6 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 system 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 4 departments in the College of Agriculture. The College also 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. NDSU, SDSU, ID and WY).

The Montana State University POW consists of programs listed under the primary prevailing goal. 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, Private Industry, National Institute of Health, National Science Foundation, NRCS, NASA, BIA, USFS, private donations, BLM, other states, Canadian Provinces and the State of Montana.

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Vision

The Montana State University 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, 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, Montana State University provides instruction, research, and extension/outreach programs focused to meet the ever-changing needs of Montana and its people. In keeping with this mission, we provide science-based instruction, discover new knowledge, and exercises leadership on agricultural and natural resource issues.

Values

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

Program focus and overarching goals and objectives

- COA/MAES creates and disseminates 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.

<u>Enhance Economically Viable and Sustainable Agricultural Systems</u>

- Scientifically develop viable and sustainable plant and animal systems.
- Improve fundamental understanding of plant and animal biology.
- Foster the development of value-added biobased agricultural products.
- Improve plant and animal health through 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.

<u>Improve Natural Resource Management and Enhance Environmental Quality</u>

- 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.

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.

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 Montana State University are able to delve deeper into understanding each entity from production and management studies as well as plant and animal genomics. Agricultural cash receipts in Montana total over $2.6 billion annually and are made up of roughly a 50:50 mix of crops and livestock. Montana is world-renowned for the quality of wheat grown and the beef cattle produced.

Research programs in the College of Agriculture range from basic research in genetics and biotechnology to practical applications in rangeland, forest, crop, and livestock management. Often the direct impacts of the research are difficult to measure; however the research meets long term strategies designed to make Montana agricultural products more desirable in U.S. and world markets.

Projects in **Goal 1** were designed to address production and marketing issues that will ensure Montana agricultural products maintain their competitiveness and quality in a global market place. The end of a seven year drought in 2005 brought about higher yields for crops and more available livestock feed. It also improved researchers' opportunities to evaluate crops and rangeland under more ideal conditions.

Researchers continue to evaluate systems that will produce higher quality wheat and barley to meet increasing world demands. An aggressive plant breeding

program at Montana State University ensures development of higher yielding, pest-resistant cultivars. Research into alternative pest control measures using plant and insect natural enemies continues to provide novel approaches for controlling difficult pests in Montana crops. Canola and camelina are being evaluated as a biolubricant which could add substantially to the market for this crop produced in Montana, the northern Great Plains, and the Pacific Northwest. A barley variety 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.

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. The Montana Sheep Institute has assisted land managers in developing grazing plans and it's increasing the competitiveness of U.S. lamb and wool in the world market. Research in targeted mutagenesis of cells in cattle will make milk and beef production more efficient.

Promoting and maintaining animal health (cattle, sheep, and wildlife) is a large undertaking at Montana State University. 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 coccidosis, shipping fever, and brucellosis may be managed more efficiently. Researchers continue to investigate protein antigens for prevention of equine strangles in horses. Additional work has been done on the relationship between the biting midge and bluetongue virus in cattle. A significant finding that could lead to additional restrictions in the shipment of beef products is the presence of BSE agents in the tongues of infected cattle. Current laws do not restrict beef tongue or tongue by-products from entering international markets.

Programs in the Montana Sheep Institute are testing new natural oil additives for improving lamb meat characteristics. Understanding the breeding characteristics and activity of bulls and cows has led to more effectively controlling the breeding process. Feeding studies have shown that certain cultivars of barley can be more cost-effective than corn for the Montana producer. Improving feed efficiency, managing stress during the winter, lowering production costs, and improving beef genetics continue to be primary projects in the 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.

Montana State University 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. Montana's wheat products are important in Asian markets where grain hardness and cereal quality are important considerations. Continued genetic research into the expression of undesirable characteristics in grains will help ensure that the grains will maintain their demanding presence in the market. New biological control uses for products isolated from the fungus *Muscoder albus* entered the market in 2005. Research continues into new uses for the volatile isolates of this fungus.

Research continues into developing alternative crops in Montana. Canola, chickpeas, fenugreek, camelina, and assorted herbs have been evaluated for their potential in emerging value-added markets.

A major effort is underway to characterize and evaluate wheat and barley germplasm and to increase the utilization of world germplasm collections. Databases have been made available for researchers to access information on germplasms. A new solid stem winter wheat cultivar, Genou, was released to Montana seed growers. This cultivar has improved yield potential especially in wheat stem sawfly-infested areas of Montana.

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: $14,798,813 FTE: 166.7

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

Key Theme – Animal Health

a. Analysis of Bison Innate Defense Against Microbial Pathogens

Description of Activity: The American bison is a wild ruminant that is susceptible to serious infectious diseases, such as tuberculosis and brucellosis. This project studies the types of antimicrobial processes present in bison neutrophils (white blood cells) and how active they are against several relevant pathogens, especially *Escherichia coli*, *Staphylococcus aureus,* and *Mycobacterium bovis* BCG. A better understanding of these proteins could lead to practical applications for controlling infectious diseases in bison.

Impact/Accomplishment: Bison can become infected with bacteria that linger as intracellular parasites, where they are sheltered from neutrophil defenses. A protein of interest, one of the bison bactenecins, has been

characterized and sequencing/cloning efforts are underway. Bison neutrophil granule extracts were found to have potent killing activity against *E. coli*. Conversely, the neutrophil extracts did not kill *S. aureus* and, in fact, had a permissive effect allowing the bacteria to continue replicating. Analysis of the extracts shows that the granules possess many low molecular weight proteins with masses of about 30 kD [kilodaltons]. Analysis further shows that bovine and bison neutrophil granule proteins appear to have different molecular weights, which may or may not translate to functional differences.

The majority of studies on neutrophil microbiocidal function have been performed on human cells, several laboratory animals, and a few domestic livestock species. Bison neutrophil functions have now been characterized and unique differences found. These findings may allow bison neutrophils to respond to the distinct host defense challenges that bison encounter. Full-length genes have been cloned and sequenced for all five of the bison NADPH oxidase components ($p22^{phox}$, $p40^{phox}$, $p47^{phox}$ and $p67^{phox}$, and $gp91^{phox}$). Overall, these studies show that the bison and bovine NADPH oxidase genes are highly conserved between these two species, despite their divergence from a common ancestor over one million years ago.

Montana is currently a brucellosis-free state and maintaining that status is a high priority, especially as it relates to the export of beef and beef products. These studies give researchers a better understanding of how bison defend themselves against infectious diseases. Knowledge of the mechanism of neutrophil granule proteins could potentially lead to more cost effective and more easily managed tools for controlling infectious disease in bison and other wildlife. This research will lead to the development of better preventative and curative treatments to protect bison and other wildlife against infectious diseases.

Source of Funding: Hatch, Montana

Scope of Impact: National

b. Salmonella Vaccines for Scours

Description of Activity: Newborn calves are susceptible to scours. The rate of gain in young calves affected by scours is reduced, and the calf will not likely catch up with non-affected calves by weaning time. Calves that get scours typically weigh 15–20 lbs less at weaning time than their healthy herd mates. In recent studies at MSU, the total economic loss per scouring calf that survived to weaning varied from $17–$60. The average over the 14 years was $35 loss per calf with scours. There is a need to provide an efficacious vaccine and a novel delivery method to prevent this disease. Current studies are evaluating the efficiency of the use of *Salmonella* vectors and other methods as a means to vaccinate cattle against enteric diseases.

Studies were designed to optimize mucosal and systemic antibody responses in heifers to provide passive immunity to newborn calves. The focus of the studies is to assess the feasibility of attenuated *Salmonella* vectors (e.g. *Salmonella*-K99) as a vaccine delivery vehicle for cows. The goal of these studies is to learn how modifying vaccine formulations mimic how antigens are naturally or unnaturally presented and to identify how these are reflected in host protective responses.

Enterotoxigenic *Escherichia coli* (ETEC) is responsible for approximately 26% of diarrhea cases in calves, representing the second leading cause of diarrhea in calves and the leading diarrheic agent for piglets. Current ETEC vaccines rely on inactivated whole bacteria or purified fimbriae and have been shown to have limited efficacy. Thus, the need for an effective oral vaccine to induce protective secretory IgA antibodies to lower the incidence of this disease is desirable. While there are several colonization factor antigens associated with ETEC for livestock, the expression of K99 (or $F5^+$) fimbriae accounts for nearly all cases of ETEC found in newborn calves. $F5^+$ ETEC is only infectious to calves during the first two days post partum, and by one week of age, ETEC is unable to colonize the small intestine in these calves because of decreased availability of epithelial cell receptors. Therefore, ETEC is only a disease of newborn calves.

Impact/Accomplishment: To date, vaccine development for ruminants consists largely of inactivating the pathogen and its subsequent administration without concern for possible side effects or efficacy. Mucosal vaccine delivery systems using attenuated, *Salmonella* vectors to express the vaccine antigen K99 fimbriae in cattle are being tested. These studies will be helpful in learning bovine mucosal responses for optimal vaccine delivery. The delivery system will provide the basis for future generation ruminant vaccines to learn how cattle respond to vaccine antigens delivered by *Salmonella*, and whether they are effective in providing protection in ETEC challenge studies. The studies suggest that *Salmonella*-K99 vaccine is effective for stimulating long-lasting immunity in heifers for eventual protection of their newborn calves. New livestock vaccines are probable with successful outcomes.

Source of Funding: USDA Animal Health, 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. In livestock, these include scrapie in sheep and goats, and bovine spongiform encephalopathy (BSE) in cattle. Chronic

wasting disease (CWD) is a growing concern in free-ranging and farmed cervids (deer and elk). These diseases are caused by a novel pathogen known as a prion, which is a modified host protein 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.

Transmission of the 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 gastrointestineal tract. 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. The specific aims of this proposal are: (1) to determine the route(s) of prion neuroinvasion following oral infection, and (2) to determine the role of the lymphoreticular system in prion agent neuroinvasion via oral routes of infection.
The findings from this study are important to U.S. agriculture since they will: (1) Identify potential routes of prion infection in the oral cavity; (2) Confirm the ability of prions to infect tissues in the oral cavity; and (3) Identify sites of prion infection at the oral mucosa that could play a role in prion agent shedding.

Impact/Accomplishment: The study conducted in hamsters demonstrated that tongue infection is a more efficient route of prion neuroinvasion than ingestion. The prion agent can spread directly to the brainstem from the tongue via the hypoglossal cranial nerve in only one to two weeks, which is the shortest time to neuroinvasion following extraneural infection that has been reported. This finding, and the results that show that a superficial lesion on the tongue can predispose a host to prion disease, suggests that exposed nerve endings in the oral cavity can be an alternate route of prion neuroinvasion following oral exposure.

The research demonstrated that prion agents also spread to the tongue following the intracerebral inoculation of six different hamster-adapted prion strains. The localization of the prion agent in the tongue of rodents revealed infection of nerve fibers, skeletal muscle cells, and taste buds. The prion agent also was found in tongues of sheep infected with scrapie and deer with CWD. These 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. The presence of the prion agent at the tongue mucosa may also be important in prion agent shedding into saliva.

On December 23, 2003 the USDA announced the first confirmed case of BSE in the U.S. Within a week the export markets for U.S. beef products were closed. Even though the BSE-infected cow was imported from Canada in

2001, this single case of BSE resulted in a 10% loss in market share for the U.S. beef industry, or approximately $3.7 billion annually.

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 SRM; 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, Montana

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. 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%. 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 bovine 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.

Additional research was conduced on beta glucans, a form of natural soluble dietary fiber found in feeds, including barley, oats, and corn bran. Mice fed a diet of barley containing a high content of beta glucan recovered from respiratory virus infection (influenza) much more quickly and with less weight loss than mice fed a normal mouse diet. Beta glucans are a potent stimulant of macrophages which, in turn, are important in tissue repair, including airway epithelial cells damaged by viruses.

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. Researchers expect to show that calves fed a high beta glucan diet will recover faster from shipping fever and will lose less weight. Such a finding would indicate that the adverse effects of shipping fever could be minimized by conditioning calves with a high beta glucan diet before they are shipped. If the addition of beta glucan proves to aid in the prevention of shipping fever, a significant cost savings to shippers and livestock producers could be realized. Additionally, an increased market for Montana crops, especially specialty barleys, could be realized.

Source of Funding: Hatch, Montana

Scope of Impact: National

Key Theme – Animal Production Efficiency

a. Feed Barley for Rangeland Cattle

Description of Activity: Barley varieties with improved feed quality could provide sustainable seed and grain markets for regional grain producers and provide marketing advantages to beef producers. Limited comparisons are available evaluating differences between the feed value of corn and barley. This project identifies and evaluates factors that leads to the development of barley varieties with improved feed quality and compares feed values between corn and barley. Variation in barley digestibility and milling characteristics, variation in forage quality, nitrate accumulation potential, and variation in feed quality were evaluated.

Impact/Accomplishment: There were no differences between corn and barley diets for average daily gain (ADG), feed efficiency (FE), dry matter intake (DMI), or starch digestibility. Fat thickness was greatest for steers fed corn and least for steers fed H3 and Valier barley varieties. Steers fed corn had higher yield grades than steers fed barley; however, there were no significant differences detected for any other carcass characteristic. Barley had net energy for maintenance (NEm) values and net energy for gain (NEg) values comparable to corn.

While there are inherent differences between corn and barley in nutrient composition and digestibility, lack of differences in animal performance indicate that barley and corn have similar feeding values in high concentrate diets. National Research Council (NRC) feed standards for barley appear to be underestimated. There is a significant impact on the barley and livestock industries in Montana and Idaho if 10% or more of the barley production were used for feed. A stronger market could also lead to higher prices for barley grown in the region. Corn transportation costs are increasing due to higher energy costs. The use of locally grown barley for feed is more cost-effective for the livestock producer and also benefits local economies.

Source of Funding: USDA, Montana

Scope of Impact: Regional

Key Theme – Biobased Products

a. Biobased Products Institute

Description of Activity: The Biobased Products Institute 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. The primary objective of the Institute is to develop a sustainable entity, which is innovative and responsive to the developing needs of Montana, the Pacific Northwest, and Northern High Plains regions

Value-added, agriculturally-based end products can provide unique markets and enhanced revenues for Montana producers. The development of food safety systems for consumers will also add value to Montana's agricultural products. Continued education, research, and partnering will enhance the opportunities and awareness of value-added programs in Montana.

Impact/Accomplishment: The Biobased Products Institute currently supports fourteen projects and has developed several high-value biobased products that will contribute to the long-term economic viability and sustainability of Montana's economy. Field tests with nine oilseed crops at six Montana locations provided evidence that at least one species, camelina, has high production potential with low input costs. Over 90 germplasm accessions of camelina have been evaluated for adaptability, yield potential, and fatty acid content. Camelina production could significantly reduce the cost of biodiesel from a typical $2.45/gallon to an expected $1.05/gallon. The same crop produces omega-3 oil, which is being evaluated for human health consumption.

In addition, gluten-free and wheat-free cereals have been grown and developed as bread mixes, cereals, and pastas. Equine nutrition research indicates a preference for feeds made with fenugreek and additional work is continuing evaluating natural plant pathogen potential. Several production cooperatives have been established in the gluten-free cereal industry and in the production of bio-lubricants and biodiesel from oilseeds. Three new products are now available from processed meats, and a new cuticle cream and hand lotion have been developed. Additional new products have been developed, including shampoo and body washes that use wheat protein, canola oil, fenugreek, herbal teas, and essential oils for fragrance.

Source of Funding: USDA, 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. Isolates of the volatile emissions of the fungus *Muscodor albus* have been shown to act as a pesticide against certain soil organisms that cause plant diseases in crops.

Impact/Accomplishment: Techniques and methods have been established using proton transfer mass spectroscopy for the detection of volatile emissions from *Muscodor albus.* A petition to the EPA was granted for the registration of the *M. albus* strain QST 20799 as an agricultural product. It will be used to decontaminate cut flowers, fruit, and vegetables during shipment and storage. Volatiles (nontoxic to humans) emitted from small packets enclosed with each box of fruit or vegetables will kill microbes that would otherwise cause decay during shipment and storage. The product has the potential to replace some of the uses for methyl bromide, a highly toxic soil fumigant that has been linked to ozone depletion.

Other potential applications for volatile organic compounds of *M. albus* and other endophytes are currently being investigated. A company in Montana has licensed *M. albus* for the company's commercial line of portable toilets. The toilets, which are used by the American military, FEMA, national parks, and in a variety of emergency situations, are now equipped with waste collection bags containing deactivated fungus. When moisture enters the bag, the fungus produces volatile chemicals that neutralize odor and kill a host of dangerous bacteria, including *E. coli*. The technology holds promise for the

developing world, where intestinal diseases resulting from poor sanitary conditions are among the major causes of death.

Source of Funding: Hatch, Montana

Scope of Impact: National

b. Mechanisms of Plant Virus Transmission and Assembly

Description of Activity: The aim of this project is to develop 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 the 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 for industry.

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 the Montana's and the nation's effort in nanotechnology.

Source of Funding: Hatch, Montana

Scope of Impact: Regional

c. Cereal Quality and Biochemistry

Description of Activity: Two approaches to improve the desirable attributes of products made from wheat are being researched. In the first, a large fraction of the protein nitrogen (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 are being used to improve the understanding of N recycling, with the long-term goal of improving N use efficiency.

In the second approach, 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 on the biochemistry and molecular biology of wheat PPOs, the biological basis for variation in this important trait will be established. To identify the PPO gene(s) responsible for wheat quality problems, a gene-specific quantitative real-time RT-PCR system will be developed allowing the separate assessment of expression levels of all PPO genes in developing wheat kernels.

Impact/Accomplishment: During 2005, “gene chip” technology was used to identify the coding of barley genes for proteolytic enzymes. The enzymes are upregulated at the onset of leaf senescence and may be involved in the remobilization of leaf protein N to developing kernels.

A limited number (~5) of genes identified will be subjected to detailed biochemical and molecular analysis. Additionally, the physiology of leaf N remobilization was studied using a number of new near-isogenic barley lines isolating a high-grain protein locus on chromosome-6 in a low-protein background, and vice versa. These studies have indicated that high protein content in mature barley kernels is associated with enhanced amino acid levels during grain filling and also with decreased amino acids in senescing flag leaves. The application of gene chips to this novel germplasm will help identify protease and other genes controlling grain protein accumulation.

Major progress has been made in the characterization of wheat kernel PPOs associated with the undesirable darkening of wheat products during food processing. One PPO isoenzyme was partially purified from the bran of a high-PPO variety, Rampart. The study confirmed that the corresponding gene (GenBank accession AY596268) and other members of the same gene cluster (AY596269 and AY596270) were expressed during kernel development in hexaploid wheat varieties, but quantitatively AY596268 was most important. Expression was undetectable in durum wheat.

At present, the function of several additional wheat PPOs (grouped in a different phylogenetic cluster) is unknown, but they do not appear to be involved in food biochemistry and product quality. Based on the research efforts, other labs have developed a molecular marker for AY596268, which should be useful in marker-assisted breeding/selection of low-PPO germplasm.

Source of Funding: Hatch, 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: Surveys at Montana farm conferences indicated a strong interest in diversified crop rotations. This research investigates agronomic practices to ensure greater success in producing alternative crops. Rotation studies address long-term questions related to water use efficiency and soil quality. Traditional cropping systems (e.g. wheat and barley) are widely considered economically and environmentally unsustainable in Montana. This research investigates the value of diversifying dryland cropping systems to include oilseed and pulse crops in rotation sequences with small grains.

Impact/Accomplishment: The agronomic study compared the influence of seeding dates on chickpea growth, productivity, and grain quality. 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 five seeding rates to explore the influence of stand density on crop development and yield. 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. A range of plant populations from 48,500 to 307,500 plants per acre were studied; only the lowest plant population had reduced yields.

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. Yields of pea and winter wheat, one and two years following sunflower, respectively, were reduced compared to those following wheat. During this transition period, 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 Montana State University on pulse crops (especially lentils and peas) has led to producers instituting a 1% check-off program and increasing production acres in the state. Research on carbon sequestration funded by this project has led to other project funding at Montana State University for investigating CO_2 emissions.

Source of Funding: Montana

Scope of Impact: Regional

b. Chickpea: Economic Diversification Opportunity for Northern Plains Cropping Systems

Description of Activity: Chickpea is a promising high-value crop for increasing dryland farm profitability in the deep, semi-arid soils of the Northern Plains. Chickpea (*Cicer arietinum*) is an annual grain legume or "pulse" crop sold for human consumption. In 2001, six countries (India, Turkey, Canada, Pakistan, Australia and Mexico) accounted for 90% of world chickpea production with India alone accounting for 60%. There are major production and market risks which must be solved before adoption of chickpeas as a viable crop option is realized. Of 46,500 acres seeded in Montana and North Dakota in 2001, only 30,000 acres were harvested; the rest were lost to diseases or environmental factors. The aim of this project is to increase farm profitability and efficiency by incorporating chickpea into crop rotations. Chickpea production in the Northern Plains could result in a new crop industry with an annual value of $30–40 million.

Impact/Accomplishment: Economic issues for chickpea production have been explored and world supply and demand patterns examined to determine the best opportunities for U.S. farmers. Crop insurance vehicles were detailed to enable new chickpea producers to minimize financial risk. Excellent progress has been made in disease and weed management, especially in the control of A*scochyta* blight and damping off diseases. Disease interactions with cultivar and crop seeding dates have been explored and provide the basis for risk assessment of different cultivars. Cropping systems research has been completed with protocols common to sites in Montana and North Dakota. Seeding date and rate studies provide critical information for the Risk Management Agency (RMA), charged with insuring chickpea production. Cold soil tolerance has been documented and optimal plant population goals have been determined. Chickpea-spring wheat sequences averaged 12% greater wheat yields and 0.5–1.5% higher protein when compared with continuous wheat.

Chickpea is agronomically suited for production in the semi-arid northern Great Plains and some producers have generated impressive net returns from this crop. However compared to current small grain crops, producers must accept greater production risk and variable market opportunities. Studies continue to investigate seeding parameters, market opportunities, and disease management thus providing Montana and northern Great Plains producers better management options for profitably producing chickpeas. *Ascochyta* blight can now be managed, with much lower risk, due to improved cultivars and fungicide options, and is no longer a major barrier to the adoption of chickpeas as a viable crop in Montana.

Source of Funding: USDA, Montana

Scope of Impact: Regional

c. Specialty Crop Evaluation and Product Development

Description of Activity: Agriculture typically provides insufficient rural income to be a sustainable industry in Montana. Rural development will require additional training and the development of new opportunities to maximize agricultural potential. This project assists rural communities in evaluating and developing community-based businesses using local agricultural resources. One such business is the community-based "Peaks and Prairies" oilseed crushing plant in Malta, MT. 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 are being 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 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. In 2005 over 220 fenugreek germplasm accessions were evaluated for their potential in Montana agriculture.

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

Source of Funding: Hatch, Montana

Scope of Impact: Montana

Key Theme – Grazing

a. Montana Sheep Institute

Description of Activity: 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. Sheep can be used to manage these weed infestations providing a benefit to the sheep owner while reducing noxious weeds. This project focuses on the use of sheep grazing as a tool in natural resource management; develops and implements the selection, nutritional and marketing management strategies for maximizing sheep production; and implements the development of non-traditional lamb and wool marketing strategies.

Impact/Accomplishment: Initially, seven sites were located across Montana, sheep management and grazing plans developed, monitoring sites established, and initial plant composition data collected. In 2004, there were 22 projects in 31 Montana sites involving 31 sheep producers with 30,000 ewes and lambs. Grazing projects involved 1,000 landowners and over 100,000 acres of weed infested areas. Additional sites were added in 2005.

Sheep grazing provides the only 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. 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%. Utilization data from 22 sites throughout Montana demonstrated 50%–70% utilization of noxious weeds and only 30%–40 % utilization of grasses. Over time, this type of grazing should favor the re-establishment of grasses and forbs into the landscape.

Source of Funding: USDA, Montana

Scope of Impact: Montana

Key Theme – Plant Genomics

a. Genetically Engineering Plant Light Responses and Plant Reproductive Development

Description of Activity: The basic patterns of growth and development of crop plants are critical determinants of their suitability and success in production agriculture. Plants respond developmentally to light intensity and quality throughout their growth cycles. Responses to shading and crowding, sensed by plants as changes in available light, often lead to reduced crop yields. This project examines the structures and mechanisms of plant phytochrome photoreceptors and the effectiveness of phytochrome transgenes in modifying the productivity of plants under dense growth and shading conditions. In addition, the project investigates the genetic pathways involved in specification of the architecture of the plant inflorescence.

The ratio of red to far-red light (R:FR) is monitored continuously by plants

through phytochrome photoreceptors. These molecules absorb red and far-red light and trigger changes in growth, including responses to shading and crowding, induction of seed germination, flowering time, and photosynthesis. Studies on wheat, barley, potato, and tobacco have shown that this R:FR light ratio controls agronomically important traits such as plant height, flowering time, seed set, and harvest index. In this project, the model plant Arabidopsis was used to investigate the individual roles of each of the five phytochrome receptors present in this plant. It is the expectation that, by understanding the basic biology of these molecules, R:FR responses can be modified in targeted ways to increase crop productivity and quality.

Impact/Accomplishment: The research has focused on the analysis of binding interactions among the Arabidopsis light-stable phytochromes. Heterodimeric phytochrome forms present in plant extracts were identified and characterized for the first time. This finding significantly increases the understanding of the complexity of the plant's R:FR light-sensing array. The levels of various heterodimer forms and their individual biochemical properties and functions are currently being assessed. The genetic determinants of plant structure and plant responses to environmental cues are very important research targets in the search for new and effective ways to sustain and improve crop performance. This research has redefined the configuration of the phytochrome photoreceptor family, and the efforts to engineer altered forms of these receptor molecules are uncovering novel ways to genetically modify plant light responses.

Source of Funding: Hatch, Montana

Scope of Impact: National

b. Winter Wheat Breeding and Genetics

Description of Activity: Several biotic and abiotic stresses hinder hard red and hard white winter wheat production in the Northern Great Plains. This research will develop germplasm with excellent end-use qualities and with 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.

Impact/Accomplishment: The goal is to continue to provide improved wheat cultivars that will help Montana producers stay competitive through the development of improved cultivars adapted to Montana climatic conditions and cropping systems. A combination of field, greenhouse, and laboratory selection protocols are used.

Based on average planted acreage and prices, the 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, impacts the Montana economy by $4–$5 million per year. Cultivars must exhibit superior on-farm performance, while meeting stringent standards for end-use quality. In addition to the development and release of superior cultivars, research is conducted to maximize production and quality consistency.

Approximately 2,500 selected lines were bulk harvested and evaluated in nonreplicated observation nurseries. A sawfly observation nursery containing solid-stem germplasm and nurseries containing hollow-stem germplasm are 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 are selected for entry into preliminary yield testing. Selected lines from the three preliminary trials move into advanced trials and subsequently into the intrastate nursery. Noodle quality is evaluated on entries from the advanced and intrastate nurseries. Seed multiplication and purification begins when a line enters the intrastate trial.

A new winter solid stem wheat cultivar, Genou, was released to Montana seed growers in the fall of 2004. 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 4 bushels and a return of $11.60 more per acre, based on 2004 state averages (59 bu/A; $2.85 per bu). Genou is winter hardy and has a solid stem. Stem solidness of Genou (19.6) was lower than the stem solidness of Rampart (21.5), but higher than hollow-stemmed checks, Morgan (7.0) and Neeley (6.5).

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 producers in Fall, 2005. Experimental data from Montana over the last four years indicates Yellowstone yielded 116%, 121%, and 117% more than leading winter wheat varieties Neeley, Tiber, and Morgan, respectively.

Source of Funding: Hatch, Montana

Scope of Impact: National

Key Theme – Precision Agriculture

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

Description of Activity: Diffuse Reflectance Spectroscopy (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 belt of northern 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. The purpose of this project is to determine the feasibility of making *in situ* soil C determinations using DRS.

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 U.S. 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: USDA, Montana

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 about the type, quantity, and condition of vegetation to make sound decisions. The large acreages involved and the rugged and inaccessible Montana terrain pose substantial obstacles for obtaining needed information. Remote sensing allows rangeland mapping to be more efficient, less costly, repeatable, and makes it easier to track changes. Detection of areas that are dramatically different from other areas within range site types makes range evaluation more efficient.

This project was established to evaluate remote sensing technologies to address 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.

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%.

Impact/Accomplishment: 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. Incorporating remotely-sensed imagery in rangeland can potentially reduce on-ground evaluation efforts by 50% or more by identifying locations similar in condition to those visited by ground crews. 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 saving substantial manpower. 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.

Classifications of rangeland cover types and a change analysis study in Yellowstone National Park 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. An accurate hierarchical map of rangeland vegetation in the northern range of the Greater Yellowstone ecosystem and a method for automatically updating satellite-based rangeland vegetation maps using tasseled cap-based change vector thresholding have been delivered to Yellowstone National Park and incorporated into their database.

Source of Funding: Hatch, Montana

Scope of Impact: Regional

Key Theme – Home Lawn and 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. Landscaping with native plants will contribute to biological diversity. The purpose of this study is to produce guidelines for growers and nurseries for production and marketing of native plants, and establish design guidelines for the landscape industry and other agencies that plan, authorize, and monitor naturalization projects.

Impact/Accomplishment: A survey was conducted at the Bozeman (MT) Home & Garden Show in 2004 to determine consumers' preferences for native plants. The survey is now being administered on-line through a Montana State University's web site and consumer preferences are accumulating. The study will continue until a minimum of 500 usable responses are collected. Native plant communities are being investigated across southwest Montana and Yellowstone National Park to use as models for planting designs. As part of the development of a creative and usable design for homeowners, a comprehensive landscape plan was prepared and presented to the nationally reknown Museum of the Rockies. A "Garden History Image Database" is also in progress with over 1000 images collected. Landscaping with native plants will help conserve nature, create sustainable landscapes, and restore biological diversity in disturbed landscapes. As a source of technical assistance and inspiration for scholars, students, and professionals, the Image Database will provide a meaningful view of gardens

and landscapes and their role in creating healthy and productive human environments.

Source of Funding: Hatch, Montana

Scope of Impact: Regional

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 always 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 those in other Goals, especially as they relate to improved plant and animal production 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 Montana State University has added value to Montana commodities by improving plant genetics. 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 has led to new products and crop quality innovations. These results 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 bovine spongiform encephalopathy (BSE) in the U.S. During 2005, approximately 55,000 calves were certified for age and source verification.

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 ensures a supply of quality beef and sheep products from Montana.

Total Goal 2 **Funding: $281,907** **FTE: 2.7**

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

Key Theme – Food Safety

a. Gene Expression in Toxoplasma-infected Murine Astrocytes and Microglial Cells

Description of Activity: *Toxoplasma gondii* infects 1,500,000 people in the U.S. with toxoplasmosis each year; approximately 750,000 of these infections occur via the consumption of contaminated meat products. At least one third of the world's population may have contracted a toxoplasmosis infection in their lifetime, but the parasite rarely causes symptoms in healthy adults. However, those with a weakened immune system are particularly susceptible.

T. gondii is a pathogen of the central nervous system, though the pathology of the resulting disease in distinct brain cell types is not fully understood. The purpose of this study is to evaluate gene expression in tachyzoite-infected murine astrocytes and microglia and identify regulated parasite- and host cell-specific mRNAs most relevant to the development of this brain infection.

Impact/Accomplishment: Results have shown that a class of trisubstituted pyrroles, including some structural analogs, will affect human fibroblasts and endothelial cells, as well as murine astrocytes and microglia, to induce tachyzoites to undergo bradyzoite differentiation within 48 hours post-infection. A systematic analysis of host cell gene expression in these cell types demonstrates that various pyrroles modulate host mRNA levels in concert with the observed induction of parasite development. Eighty distinct mRNAs, whose expression is coincident with induced bradyzoite development, have been isolated.

Early analyses of these mRNAs indicate that many can be directly or indirectly associated with growth regulatory pathways and the proliferative state of the host cell. The research shows that the trisubstituted pyrrole designated Compound 1 induces parasite tissue cyst development by modulating host cell transcription, and that new transcription events ultimately signal the parasite to establish a permanent infection. The ability to experimentally alter the host cell so that invading tachyzoites are induced to initiate bradyzoite development, provides new experimental strategies to study this phenomenon. Proteins encoded by these mRNAs help to define the molecular features of a specific host environment that is more (or less) conducive to bradyzoite differentiation. Researchers are using RNAi technology to evaluate the effects of selected mRNA levels on parasite development. Studies of the effects of the human cell division autoantigen 1

mRNA (CDA1) demonstrate that modulation of a single host gene can dramatically affect the outcome of parasite development.

Source of Funding: USDA, Montana

Scope of Impact: National

Key Theme – Food Quality

a. Marketing and Delivery of Quality Cereals and Oilseeds

Description of Activity: This study is designed to quantify the factors that affect milling, processing and marketing of cereals and oilseeds. 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. 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 in 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 supporting Indian meal moth than Vangard, which was, in turn, significantly better able to support the insect than Tiber, Big Sky, and Rocky. This resistance trait was expressed similarly (no significant differences) 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.

Source of Funding: Hatch, 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**, 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 are primary goals of the BQA program.

Total Goal 3 **Funding: $97,888** **FTE: 1.2**

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

Key Theme – Human Health

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

Description of Activity: The Montana Beef Network (MBN) was established to return additional revenue to cattle producers and meet consumer needs in Montana. An integrated network is in place to ensure that a quality and consistent beef product is being produced and to enable the tracking of calves from Montana ranches to feedlots and packing plants in other states.

Goals of the project are: (1) To develop, implement and evaluate a Montana Beef Quality Assurance (BQA) program for beef producers using best management practices to ensure food safety, feeder calf quality and consistency and source verification; (2) To implement a feeder calf certification program and establish training for producers to enhance calf health; (3) To implement an electronic identification/tracking system to follow calves through various production channels; (4) To conduct educational courses focused on food safety and financial, genetic, nutritional, reproductive and marketing management; (5) To provide Montana beef producers with the tools and information necessary to maximize profits through the integration of workshops, marketing clubs and on-line market information; and (6) To identify, create, and market “value” within the MBN.

Impact/Accomplishment: BQA education and certification of Montana producers is an ongoing project for the MBN. Approximately 4,000 producers have been trained and over 1,200 producers certified. Over 24,600 animals were enrolled in the beef feeder calf certification program in 2004 with nearly 18,500 animals tracked for performance and carcass characteristics. During 2005, approximately 55,000 calves were certified for age and source verification.

Producer education has been a focus of the project. Over 15 interactive television short courses, four “Montana Livestock Forums and Nutrition Conferences,” three “Gate to Plate” seminars and “Montana Beef University” sessions, and numerous statewide producer meetings were presented. Five issues per year of the “Beef: Questions and Answers” newsletter and the development of a website (www.mbn.montana.edu) added to the educational efforts.

Efforts have focused on the challenges faced by Montana's cow-calf producers, including disease control, nutrition, and calf weaning options. The Montana MarketManager® (MMM) program (www.montanamarketmanager.org) has improved the resources available to Montana agricultural producers. MMM has been instrumental in establishing over 25 marketing clubs around the state ensuring that producers will have the opportunity to sell livestock more profitably.

Results from a 2003 producer survey indicated that producers who were enrolled in the MBN received approximately $9 more per head for their calves at sale. In 2005, producers received $30 more per head than those who weren’t enrolled. Two years of research showed that less than 3% of calves were shedding *E. coli* O157:H7 indicating that this is more of a feedlot segment problem than a cow-calf segment problem for the beef industry. Through efforts of the MBN, a weaning program protocol was developed which included nutrition vaccines and backgrounding for 45 days. This program was shown to reduce calf sickness by 50% and has been used on over 150,000 weaned calves in Montana. Results of collecting five years of carcass data showed that 62% of Montana calves graded choice (national average is 52%) and 35% were able to be enrolled in the Certified Angus Beef program (national average is 16%). To qualify for the label, "Product of the U.S.," meat must originate from animals born, raised, and slaughtered in the U.S. With the MBN in place, it will be relatively easy for Montana producers to adapt to mandatory country of origin labeling (COOL) and national animal identification programs.

Source of Funding: USDA, Montana

Scope of Impact: National

GOAL 4: Greater harmony between agriculture and the environment.

Overview

Montanans pride themselves in the high quality of environmental resources available. Whether individuals are hiking in the millions of acres of forested lands or fishing and boating on the states streams, rivers, and lakes, awareness of the fragile nature of these resources is a key to their preservation. A number of diverse ecological systems either border or are located in Montana. These systems provide opportunities for extensive research into how they behave under the climatic conditions of Montana.

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 will help researchers understand the limitations and opportunities that global warming may present on agricultural production. Microbial populations in these environments have shown the capability of either oxidizing or reducing arsenic; this finding can be an important step in the development of products for decontaminating sites containing arsenic and other hazardous elements/compounds.

Integrated pest management programs 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. Montana producers are continually challenged by multiple pests to produce crops and livestock efficiently and economically. Many of these competitive pests require traditional pesticides to economically reduce their direct impact on food and fiber production. 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.

Biological controls for insects, weeds, and diseases are becoming more important as traditional chemical control methods are under scrutiny or cancelled. MSU is a leader in the research of biological control methods for pests of forages, potatoes, small grains, and sugar beets. One colonizing *Bacillus* spp. isolate, Bac J., is being commercially developed as a biological control product by a Montana firm for pests of cucumbers and sugar beets. The wheat stem sawfly continues to limit yields in Montana wheat. In addition to new wheat varieties that have been developed, the use of natural enemies and pathogens are being evaluated to stem the effects of sawfly infestations. Several invasive

weeds reduce crop and rangeland productivity. The use of novel management systems is being investigated to reduce the overall effects of these weeds, especially hoary cress, rush skeletonweed, field bindweed, and spotted knapweed.

Global warming continues to contribute to concerns about long-term changes in our climate coupled with our agricultural competitiveness. Current models estimate that agricultural production contributes greatly to the release of nitrous oxide (N_2O) into the environment. Studies are quantifying N_2O gas release under several different cropping and tillage systems and are finding that releases are less than previously thought.

Cattle and wildlife often compete for the same forage throughout the year, especially in rangeland areas. Results of a study revealed that competition with elk in spring rangeland can contribute to substantial losses to cattle producers. While deer may be more plentiful, their effect throughout the year is not severe enough to take preemptive measures. 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: $3,894,293** **FTE: 36.4**

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

Key Theme – Biological Control

a. Biological Control in Pest Management Systems of Plants

Description of Activity: Noxious and invasive weeds are a continuous problem in the world seriously affecting the productivity of cropland, rangeland, and forests. 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 in 2005 in the

quarantine facility at Montana State University and in 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 the target plants.

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.

Impact/Accomplishment: Host specificity testing of a gall wasp was nearly completed in 2005. A total of 443 replications of 33 plant species have been tested to date, including 21 invasive and native hawkweed species and other closely related native plants. Galls are only inducted on four hawkweed species. The wasp appears to be sufficiently host specific; however, additional plant species will be tested before release.

A cold-adapted strain of the tansy ragwort flea beetle has been collected from Switzerland in recent years for release in Montana. Approximately 16,435 eggs, and 1,787 adults were reared in the containment lab and released in northwestern Montana. In autumn 2005, 24 beetle releases (2003–2005) were surveyed and 13 sites showed low levels of adult beetles present. A Mediterranean strain of the beetle collected from Oregon was also released in Montana in 1998–2001. Small, growing populations have been 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. The rush skeletonweed root moth was imported from northern Greece for rearing and release in Montana. Over 200 viable eggs were obtained and sent to the Nez Percé Biological Control Center in Idaho for additional rearing. A habitat specificity study of the rush skeletonweed root moth on rush skeletonweed is being conducted to better select potential release sites for the insect's establishment. Developmental studies of the moth are also continuing, and a degree-day model will be developed to better understand the moth's phenology in the field. Diapause strategies of the tansy ragwort flea beetle are being investigated to determine the beetle's survival under Montana's highly variable environmental conditions. A host utilization study of the gall wasp (*Aulacidea subterminalis*) has been initiated for several host hawkweed species to determine which species may be a more suitable host and which may be impacted more severely by the wasp.

Source of Funding: Hatch, Montana

Scope of Impact: Multistate

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: Atmospheric nitrous oxide (N_2O) contributes to global warming and destruction of the ozone layer. 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. 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. These studies are nearing completion of their second year and are projected to continue through 2007.

Impact/Accomplishments:
Research has shown that 70%–75% of yearly N_2O emissions occurs 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 to 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.

Source of Funding: USDA, Montana

Scope of Impact: Northern Great Plains

Key Theme – Hazardous Materials

a. Fate and Transport of Chemicals in Soils: Linking Chemical Transformations with Microbial Population Biology

Description of Activity: There is a growing concern in the U.S. regarding soils and natural waters (oceans, lakes, ponds and streams) that are contaminated by arsenic (As) and hydrocarbons. This project examines the importance, behavior, and toxicity of microbial populations that serve to degrade these solutes in the environment. The ability to predict the degradation and transport of organic solutes and arsenic in soils is dependent on the activities of specific microbial populations. This research will define the microbial populations and functional pathways responsible for As(III) oxidation and As(V) reduction in contaminated soils and in the geothermal environments of Yellowstone National Park.
The distribution of arsenic detoxification pathways in soil/water microorganisms and their role in arsenic transformations in natural systems are being evaluated. Specific chemical transformations occurring in soils are being investigated, especially soils contaminated with complex mixtures such as crude-oil, diesel fuel, and creosote. The research focuses on the distribution of arsenic-transforming microorganisms in soils, their interactions in soils of differing characteristics, and their expression in detoxification. Of particular interest is the potential widespread occurrence of arsenite oxidase genes in soil microorganisms. This research will design a variety of functional gene primers to amplify these genes and to show genetic expression in the presence of arsenic.

Impact/Accomplishments: Several projects focusing on arsenic cycling in soils and natural waters have been completed. This research clearly shows that numerous microorganisms in soils and thermal environments are capable of either oxidizing or reducing arsenic. In many cases, the primary mechanism of microbial oxidation/reduction appears consistent with currently established genetic regulatory pathways.

Experiments are being completed that identify functional expression of alkane and aromatic ring degradation in soils contaminated with complex hydrocarbon mixtures. Specifically, an exhaustive set of primers based on the

diversity of functional alkane and polyaromatic hydrocarbon degradation genes have been developed and tested in hydrocarbon-contaminated soils. Future work on this project will focus on complimentary analytical and molecular tools to link the degradation of specific constituents present in hydrocarbon mixtures with 16S rDNA and functional gene signatures. Understanding how microbial populations in geothermal areas reduce and/or oxidize arsenic may lead to practical methods for the decontamination of water or soils.

Source of Funding: Hatch, Montana

Scope of Impact: National

Key Theme – Integrated Pest Management

a. Integrating Marigold (*Tagetes minuta)* into Nematode and Insect Management in Sugar Beets.

Description of Activity: Sugarbeet root maggots, disease-causing fungi, and parasitic nematodes occur together in many high value U.S. cropping systems. This project seeks to answer fundamental questions in the management of nematodes and root maggots using two biointesive strategies – non-horticultural (Mexican) marigold and the microbial biocontrol agent *Beauveria bassiana*. The research evaluated the ability of mulched shoots and essential oils of *T. minuta* to reduce infestations of sugarbeets by the sugarbeet root maggot (SBRM) and the sugarbeet cyst nematode (SBCN). Interactions of these marigold components with the microbial biocontrol agents were determined.

Impact/Accomplishment: Mortality and developmental arrest bioassays were conducted to determine the effectiveness of the fungi *Metarhizium anisopliae* (MA 1200) and a lead fungal candidate, TM28, in the presence of the essential oil of marigold shoots in combating SBRM in controlled laboratory studies. The combination of shoot mulch and essential oils of *T. minuta* reduced infestations of sugarbeets by SBRM and SBCN. For post-diapausing, non-feeding, 12-month old, third instar SBRM larvae, a concentration of 3,100 ppm of the oil mixture was sufficient to prevent pupation without mortality. Increasing the concentration to 4,610 ppm resulted in 94% mortality.

The results of this research will provide some basic information necessary to develop a package of IPM technologies. These technologies may allow sugarbeet producers to omit rotational crops, to have alternatives to the pesticide "standbys" that are being cancelled by EPA, and to have an opportunity to pursue certified organic markets. Equipment used to harvest and prepare marigold shoots for application would not differ from the mowing

and shredding equipment used for sugarbeet tops removed from the field prior to harvesting the sugarbeets. Applications to the fields would be made immediately after sugarbeet harvest during tillage.

Source of Funding: USDA, Montana

Scope of Impact: Regional

Key Theme – Natural Resources Management

a. New Thermodielectric Method to Determine Soil Specific Surface Area and Bound Water

Description of Activity: Mapping soil water content for site-specific management of farm fields is commonly achieved through grid soil sampling. This effort requires intensive soil coring, which is often destructive and time consuming. If sampling techniques are improved and made cost-effective, precision farming and agricultural research can be more productive.

Soil water measurements with time domain reflectometry (TDR) are extensively used in agricultural research and management. Temperature can affect the accuracy of TDR soil water measurements and other commonly-used electromagnetic sensors. Contradictory dielectric behavior of wet soils was explained with a new physical model that considers relationships between competing dielectric responses of bulk and bound soil water to changes in temperature. In order to obtain accurate soil water information, compensations must be made for thermodielectric sensitivity. The expression of these processes in TDR waveforms is being investigated both theoretically and experimentally.

Impact/Accomplishment: Preliminary results show that the thermodielectric phenomenon might be used to obtain measurements of the wettable specific surface area of soils and other porous media. Specific surface area is critical to the behavior of water, agricultural chemicals, and many soil microbial processes; however the data is seldom used due to the lack of simple and accurate measurement methods. The study objectives are to understand the phenomenon and to improve the accuracy of a model to address dielectric responses of bound water. This information then will lead to the development of simple correction factors for water content measurements using TDR, capacitance and related electromagnetic methods.

Extensive lab trials using six different soils and multiple sand-clay mixtures have been completed. This detailed experimental study included TDR measurements in coaxial cells, measurements using a network analyzer equipped with dielectric probe, and measurements using an impedance analyzer. A new frequency domain approach to measure the static dielectric

constant was developed, which will facilitate measurements with very small TDR probes. This should greatly enhance the practical and commercial utility of the study and provide opportunities not previously available. The TDR method is generally not susceptible to fragmentation polarization which can lead to incorrect measurements. This finding is critical to scientists and land managers. Evaluation of conventional methods for measuring specific surface area is complete and will be compared to the new thermodielectric technique when the physical model is updated.

TDR is an established and reliable means to measure volume water content in soils. Advantages relative to other methods include high accuracy and precision, nondestructive nature of the measurements, and lack of calibration requirement. The development of a dielectric mixing model that considers frequency dependence, phase configuration, and interfacial polarization processes is underway. Improved understanding of interfacial polarization processes and temperature impacts on TDR measurements will provide a stronger measurement tool for scientists and practitioners. When this research is complete, investigators will be much closer to routine estimation of specific surface area in soils for environmental and agricultural applications with lower costs and improved efficiency.

Source of Funding: USDA, Montana

Scope of Impact: National

b. Sustaining Wildlife Habitat on Western Ranches

Description of Activity: Interest in the relationships among ungulates, specifically beef cattle, Rocky Mountain mule deer, and elk, is fueled by the animals being vital components of the economy and heritage of the Rocky Mountain West. This research has focused on gaining a better understanding of how elk and cattle interact on habitats and how these interactions impact the sustainability of beef cattle enterprises.

Impact/Accomplishment: Kulcynznski's similarity index was used to calculate dietary and feeding habitat overlap among deer, elk, and cattle across four seasons in both Northwestern Wyoming and Southwestern Montana. The two indices were multiplied together to estimate foraging niche overlap.

In all seasons, elk and cattle diets were grass-dominated, elk diets were more diverse. Mule deer consumed more forbs and shrubs than either elk or cattle. The foraging niche overlap was high (45%) between mule deer and elk in the spring. Cattle use in summer and fall had > 60% foraging niche overlap with elk in spring, indicating that in the spring elk foraged in many of the same places (largely sagebrush grassland) and ate diets botanically similar to what

cattle did during summer and fall, principally Idaho fescue, and grass species in the genera *Stipa* and *Agropyron*. Foraging niche overlap also was high (41–51%) between elk in winter and cattle in summer and fall. Results suggested the potential for competition between deer and cattle was modest to small, whereas potential for competition between cattle and elk was larger. Habitats used by elk in spring represent the highest potential for competition with cattle.

Researchers were unable to validate an existing model for elk feeding site selection and an existing model of cattle feeding site selection using data from the National Land Cover Dataset and GIS-referenced feeding site locations from aerial surveys. Predictive abilities for both models are not acceptable for use in management settings. Logistic regression models of elk feeding site selection (fall, winter, spring) show that elk preferentially selected feeding sites where forage residue was reduced by summer cattle grazing and avoided ungrazed sites in all three seasons.

Cattle habitat use models developed and validated show promise in predicting forage utilization using GIS-based data. Using aerial surveys on five ranches, and taking into account dietary and spatial overlap, a prediction was made that elk consumed from 100 to over 1,100 animal unit months (AUM) of forage that could have been consumed by beef cattle. Computer simulations of these beef enterprises suggest that the value of this forage ranged from $0 to over $24,000 per year ($23 per AUM or $33 per cow-calf pair) on the five ranches. The cost of providing forage to elk tends to be greater for ranches that have lower production costs. Data collected from animal exclosures suggest that wildlife (deer and elk) consumed from 0–12 tons of forage per year on vulnerable hayfields which was valued at up to $900 per year per field. Model predictions suggest that ranches could save up to $3,700 per year by protecting critical spring cattle pastures from wildlife grazing.

A user-friendly, spreadsheet-based tool was developed to assist ranchers and management personnel in evaluating the economic consequences of changes in cattle/elk management. Self-contained instructional modules are near completion and will be distributed to regional universities. Results of the work are currently being communicated to stakeholders in the region via workshops.

Source of Funding: USDA, Montana

Scope of Impact: Regional

Key Theme – Nutrient Management

a. Nutrient Management and Cycling in Montana Soils

Description of Activity: Knowledge of the effect of soil preparation practices on soil nitrogen (N) test levels is critical to understanding and interpreting soil test results. In Montana, plant available-N is estimated from tests of residual inorganic-N in the soil. This test is performed by extracting dried (air or oven) and ground soil samples with potassium chloride. The extract is then analyzed for nitrate-N and ammonium-N. Soil preparation, in particular drying, is a first step in the chemical analyses of most soils and the procedures affect soil N test results.

A study was completed to determine what effect drying (air and oven-drying to 50° C) had on nitrate-N and ammonium-N levels in several Montana soils. Soil samples were collected in the spring and fall from field sites with varying soil type and cropping histories. Soil cores were collected from multiple locations within each field to provide a range of landscape positions. Air-drying and oven-drying (50° C) of soil samples prior to chemical analysis resulted in a small (~12%), but significant, decrease in potassium chloride extractable soil nitrate-N levels versus samples that were analyzed fresh, or at field moisture content. Conversely, drying samples prior to chemical analyses resulted in significant increases in extractable ammonium-N levels. Soil ammonium-N test levels differed by as much as 7.1 µg N /gm between fresh and oven-dried samples. In a follow-up study, soils from one location were used in a pot study to perform a test of availability of extractable nitrate-N and ammonium-N to plants. Results indicate that ammonium-N extracted with potassium chloride from air-dried soils was not as plant-available as was nitrate-N. This suggests that ammonium-N analyses of soils should be conducted on fresh (non-dried) soils samples.

Impact/Accomplishments: Soil N analysis is the most important nutrient test performed by soil testing labs. Sample preparation practices can have a profound affect on reported soil N test levels. Soil testing protocols for characterizing plant available N pools typically use air-dried soil samples. This study indicates these analyses would be better performed on fresh, non-dried soils if soil ammonium-N analyses are included in the testing protocol. Fertilizer inputs represent an increasing cost for producers as the price for the production of basic N increases. Over-fertilizing leads to wasted resources and to potential air quality issues with the release of N_2O. Under-fertilizing reduces the maximum yield potential for the crop and higher profits.

Source of Funding: Hatch, 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.

Farm families face pressures and situations that are unique to rural populations; however, many families face the same obstacles that confront their city counterparts. When divorce, separation, or death creates a single parent household in farm families, extra demands occur in managing the business and tending to family needs. A recently completed study identifies the effects of community structure on families at risk and their businesses, and estimates the economic and social contributions of family businesses to communities over time.

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: $354,945 FTE: 2.2

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

Key Theme – Children, Youth, and Families at Risk

a. Family and Work Identities During Times of Transition

Description of Activity: Parents are faced with the challenge of juggling multiple roles as they balance work and family responsibilities. This can be

even more difficult for families of divorce, especially for nonresidential parents as they try to cope with the changing roles and identities brought on by this family transition. This study seeks to examine the work and family role identities of nonresidential parents and how work and family transitions affect their overall well-being. While this research is directed at farm families, the results are applicable to all families facing similar situations.

Female ranchers and farmers, professionals, and immigrants may find themselves in new economic roles, new household structures, and even new communities. Lacking family and friends that have experienced such roles, and being underserved in programming and services, these women must seek out alternative sources of information and guidance. The purposes of this project are to: (1) Identify the questions, issues, and needs of female ranchers and farmers, professionals, and immigrants; (2) Determine the media messages that they receive in the areas of work, family, and healthy lifestyles; and to (3) Assess the extent to which these messages help or hurt in the struggle to achieve healthy work, family, and personal lives.

Impact/Accomplishment: The use of focus interview groups and the identification of those areas of specific need have allowed MSU publications to reach thousands of interested or affected individuals. Over 4,300 people have accessed the Montana State University extension publication, “Work and Family: Balancing and Weaving.” Additional individuals have gained information on how to handle stress, deal with grief, balance work and family time, and how to manage family meals while dealing with busy schedules.

Source of Funding: Hatch, Montana

Scope of Impact: National

Stakeholder Input

The Montana Agricultural Experiment Station (MAES) and College of Agriculture (COA) obtain stakeholder input on research priorities and programs. New stakeholder committees, including the College Development Board, Precision Ag Research Association (PARA), sustainable ag focus group, MAES Advisory Council and the Ag Coalition, were formed. These expanded upon the historical scope of input into priorities and alignment with national USDA program goals. Facilities improvement to enhance our field research capacity is of utmost priority. For example: 1) Seven Research Centers $1 million dollar match (state provided $1 million and a non-state match of $1 million was to be secured in early 2005) to renovate, build and repair facilities on five of the seven Research Centers throughout Montana, 2) the Montana legislature appropriated $1.6 million for facilities improvement and 3) Animal Bioscience Complex, a new endeavor that will require $12.5 million in private funds ($6 million raised) and approximately $20 million in funds from USDA-ARS for their facility. This

Complex will enhance the teaching and research mission of the Department of Animal and Range Sciences and other departments and foster new research partnerships.

PARA is external to MAES, charges its own dues, and conducts quarterly meetings throughout Montana with members and selected professionals. MAES scientists routinely participate with this group and NRCS to provide training and expertise in GPS, GIS, and remote sensing with geospatial applications. PARA and MSU have secured a number of USDA, NASA and industry grants to initiate collaborative projects on their property as part of the MSU originated “Learning Groups” concept. 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 Department of Agriculture. It meets quarterly to review program priorities, new initiatives, fundraising efforts, and legislative activities.

The Montana Wheat and Barley Committee provide about $500,000 in competitive financial support to MAES scientists annually. This financial support helps direct research programs in spring/winter wheat, barley, cereal grain quality, IPM practices, and interactions in small grains and crop rotations. The Montana Noxious Weed Trust Fund provides about $300,000 to $400,000 annually for community watershed cooperatives and for competitive education and research funds for COA/MAES scientists. Summary of survey information from the Montana Weed Coordinators have identified critical local research needs on invasive plant management on private, public and agency lands. This has led to new state funding initiatives and alignment with the Montana Weed Management Plan.

In addition, the College of Agriculture and MAES have 21 advisory committees and boards with a total of 266 members. These include the MAES State Advisory Council, Biobased Product Institute, Northwest and Western Agricultural Research Centers Advisory Committee, Montana Agricultural Innovation Center Board, Mint Committee, Southern Agricultural Research Center Advisory Committee, Center for Invasive Plant Management Board, Center for Invasive Plant Management Science Advisory Council, Northern Agricultural Research Center Advisory Committee, Montana Wool Growers Advisory Committee, Montana Beef Advisory Committee, Central Agricultural Research Center Advisory Committee, Eastern Agricultural Research Center Advisory Committee, Animal Biosciences Complex board, Western Triangle Advisory Committee, Foundation Seed Advisory Committee, Undaunted Stewardship Guidance Council, Montana Seed Growers Association Board, Thermal Biology Institute Scientific Advisory Board, Variety Release and Recommendation Committee, Potato Certification Board, and Montana Beef Network Advisory Committee. Members of these committees represent farmers and ranchers, tribal councils, county extension agents, financial organizations, communities, scientists, agricultural educators, private citizens, small businesses, conservation groups,

reservation groups, and agricultural organizations. The College of Agriculture, along with its MAES faculty, responds to input from these stakeholders and state/national/international trends by evolving their programs.

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.

Stakeholder input during 2005 was collected in county- and reservation agent-sponsored stakeholder input meetings, listening sessions and a Farm Bill Forum. These meetings were held on all reservations and in the 56 counties. The meetings were organized by county and reservation extension agents under the direction of the Director of Extension. Meetings were advertised via news releases, newsletters, individual letters and announcements at group meetings. Extension agents were instructed to use county profile information to make sure that the people invited to the sessions would reflect the diversity of the area. The advertising and meeting invitations included the statement “Extension agents will also collect input on the research conducted through the Montana Agricultural Experiment Station.”

As a result of the stakeholder input meetings, MAES received specific suggestions with regard to research. These were:

1. Need higher yielding solid stem winter wheat
2. Enhance the development of agronomically sound white wheats
3. Better marketing of applied research
4. Increase the research programs on alternative energy sources
5. New ag product and crop research to expand ag products and markets
6. Create new business opportunities for rural communities
7. Add value to our high quality crop and livestock products
8. Test plots for winter and hull-less barley varieties
9. Explore alternative crops
10. Develop new crops

MAES responds to stakeholder inputs by considering their proposals at research planning meetings with scientists, advisory groups, and administrators. Many of these activities are underway, but remain unknown to these stakeholders. This is an ongoing effort.

A survey of stakeholders was completed in 2001 (annually updated) and results from that stakeholder input are still shaping MAES direction and priorities. The purpose of the survey was to collect input from a representative group of stakeholders in Montana. Questions in the survey were based upon the areas of emphasis in the strategic plans of the College of Agriculture/Agricultural Experiment Station and the Extension Service. Other areas of research that received responses in the high priority rating were natural resources, livestock

production and management, crop production and management, range production and management, noxious weed management, animal and livestock diseases, and nutrition and health. These results will likely continue to influence MAES research priority areas into the next decade.

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. Seminars are presented to the review committee and to interested stakeholders. The seminars are announced to the public on the web so any interested citizen could attend. Reviewers are requested to provide written recommendations are 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 action upon them will be deferred until all of the key elements listed above have been met.

Multistate Research

The Multistate Research Program meets the multi-institution, -state, and -discipline requirement. Montana State University is a participating partner in numerous Multistate projects.

Work carried out as part of W-1185-- Biological control in pest management systems of plants-- provided valuable theoretical and applied knowledge to help incorporate biological control into integrated pest management systems in agricultural, urban and natural settings throughout the western United States. Research led to a deeper understanding of the roles and interactions of a wide array of beneficial and pest organisms in a variety of ecosystems. Unraveling complex ecological relationships is central to understanding pest management systems and implementing biological control as a part of those systems. Research continues to address both the economic feasibility and environmental impact of biological control. Economic and environmental data will continue to be essential to produce realistic biologically-based pest management programs for stakeholders. These will incorporate both target and non-target organisms.

In conjunction with Alaska, CA-Berkley, CA-Davis, CA-Riverside, New Mexico, and Oregon, MAES faculty participated in W-1147-- Managing Plant Microbe Interactions in Soil to Promote Sustainable Agriculture. Soilborne plant pathogens are responsible for many acute and chronic diseases of crop plants that result in severe revenue losses. Economic losses to soilborne pathogens may decrease yields by 25% - 50%. Yield failures resulting from acute diseases such as vascular wilts, take-all of cereals, Phymatotrichum root rot, Verticillium, and Phytophthora may be even more severe and have destroyed entire agricultural industries. About 90% of the major diseases of the principle crops in the United States are caused by soilborne plant pathogens. Monetary losses to soilborne diseases are estimated to be in excess of $4 billion/year. While a number of biocontrol agents are now available commercially, problems with production, storage, delivery, reliability, efficacy, and establishment, and with understanding the mechanisms of action have prevented most of these products from being mainstreamed. This project has been a major contributor to the tremendous progress in biological control of plant disease. Members of this research group endeavor to find environmentally friendly solutions for management of plant pests.

Sustainability of wildlife habitat on ranches is becoming very important. Research is being conducted on elk and cattle habitat use patterns in Montana and Wyoming. Interest in the relationships between beef cattle and elk is fueled by an appreciation of the fact that both beef cattle and elk are vital components of the economy and heritage of the Rocky Mountain West. Because ranching enterprises make major contributions to wildlife habitat, the economic viability of ranching enterprises is important to the preservation of elk and elk habitat. Foraging niche overlap among Rocky Mountain elk, Rocky Mountain mule deer and cattle was studied for 2 years on 37,000 ha of non-forested foothill and mountain habitat. Cattle use in summer and fall had > 60% foraging niche overlap with elk in spring, indicating that, in spring, elk foraged in many of the same places (largely sagebrush grassland) and ate diets similar in botanical composition to what cattle did during summer and fall. Foraging niche overlap also was high (41-51%) between elk in winter and cattle in summer and fall. Therefore, if competitive or complementary relationships existed between elk and cattle, these interactions most likely occurred on sagebrush grasslands where cattle use in summer-fall was followed by elk use in winter-spring.

An evaluation of the effectiveness of livestock distribution practices on grazed watersheds was a part of a three-state project that included Montana State University, University of California (Davis), and Oregon State University, and the USDA-ARS, Burns, OR. Ongoing research from this project has shown the potential to manipulate cattle grazing patterns to protect and improve fishery and wildlife habitat. Preliminary research from Montana suggests that herding can be a very effective approach to protect riparian areas. The combination of herding and strategic supplement placement can potentially focus cattle grazing on

upland areas that typically receive little use. Focused grazing could be used to increase forage quality for elk and other big game.

High-value and alternative crop production for Eastern Montana involves close collaboration between research and extension faculty at the MSU Eastern Agricultural Research Center in Sidney, MT and the NDSU Williston Research And Education Center in Williston, ND. Approximately 42,500 acres of sugarbeets were grown in the MonDak region area in 2000. A conservative value of $900 per acre generated more than $38 million in sugarbeet payments to this region's economy. Additionally, the local Holly Sugar Corporation processing plant has 400 employees with an annual payroll of $4 million. The sugarbeet processing plant also spends annually $5.3 million in commodity purchases, $4 million in freight expenditures, and $3.6 million in fuel expenditures. Sugarbeets are the high value cash row crop now grown in eastern Montana and the industry provides many production, processing, refinement, and marketing jobs to the area. A new malt barley (high value rotational crop) grain storage facility has been built and is increasing this industry due to disease pressure in eastern North Dakota and Minnesota. The Lower Yellowstone River Valley consistently produces the highest quality sugarbeets in the United States.

Despite recent advances in reproductive technology, cattle and sheep producers are still faced with the persistent problem of low fertility. Recent work indicates that the fertility of domestic ruminants, even under optimal conditions, is about 50%. Only one of every two natural or artificial inseminations results in the birth of a healthy calf or lamb. 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 through W-12 Reproductive Performance in Domestic Ruminants, 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 Western region by increasing conception and reducing embryo and fetal loss. We expect that 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.

MAES researchers collaborated to develop a functional genomics program to study bovine immune cells. This effort was capped off by the acquisition of a large functional genomics grant from the USDA IFAFS program. This is the only functional genomics program in the northwest region that is focused on cattle. This program involves participation of investigators from the University of Minnesota and Washington State University. Ongoing vaccine trials are now underway with Texas A&M researchers to study brucellosis in bison. Research is continuing in collaborations with researchers at the University of Montana and the NIH Rocky Mountain Lab to form a center for studying emerging infectious diseases related to wildlife and livestock diseases.

Predictions of winter wheat yield loss from weeds based on a minimum data set concept were evaluated from experiments conducted in CO, ID, KS, MT, NE, WA, and WY. Thirty data sets were utilized to evaluate different bioeconomic models to predict yield decreases from weed pressure. One model provided the best statistical fit to the data, but another model provided the best management tool by fulfilling the bioeconomic model damage function objective of optimizing jointed goatgrass management in winter wheat.

New technologies have emerged that allow for the precise acquisition of data to be manipulated and then acted upon in a precise manner. Precision agriculture components continue to be taught to farmers and schoolteachers in workshops in Montana, Idaho, Utah and Wyoming. This NASA sponsored effort builds upon the leadership in this department and collaboration of scientists in MT, WY, ID, ND, and SD.

Integrated Research and Extension Activities

Most Montana State University College of Agriculture faculty have dual appointments involving two of the three job responsibility areas (e.g. research, extension or teaching). Nine percent of the FTE is devoted to integrated research and extension activity. However, most of our MAES and COA faculty have extensive extension/outreach initiatives well beyond the Extension financial support in order to meet the needs of Montana stakeholders. 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, manage land and water resources effectively and efficiently for crop, range, conservation, and agency stakeholders.

Since 1994 management of sugarbeet diseases has been a major focus of research and extension education programs. These programs have lead to grower implementation of effective, environmentally friendly, economical controls for 4 chronic diseases and one new disease. Management of the chronic diseases, Fusarium Yellows, Cercospora leaf spot, Rhizoctonia Crown and root rot and Aphanomyces root rot has increased grower profits on more than 88,000 acres in MT. This model is continuously updated.

Fusarium Yellows is common on more than 40,000 acres. In 1994 only one resistant variety was available to growers and this had a yield potential 15-20% less than high yielding varieties in the absence of disease. MAES research developed highly efficient methods to identify resistant germplasm and work with seed and sugar companies has resulted in the identification of many high yielding Fusarium Yellows resistant varieties and the near elimination of susceptible genotypes. Extension education programs have resulted in growers using these varieties on more than 43,000 acres for control of this disease and yields have

increased by approximately 12%. Thus, the impact of this work in the past 2 years has been more than $10.3 million of additional income in Montana. Management of this disease is one of the key factors for record yields in the Billings Factory district (Western Sugar) and has become increasing important in the Sidney Factory district where approximately 4000-5000 acres are affected.

A new fungicide management program developed by MAES research and taught in extension education programs was used on 1500 acres in 1999 and more than 4,500 acres in 2000 for control of this disease and 8,000 acres in 2002. Based on our research plot response this increased profitability by $109 (Based on current Western Sugar Grower Contract price) per acre or $872,000 for MT in 2002. Research used to develop the Quadris fungicide label was started here at MSU and based on our data the full label was granted in 2001. MAES research pioneered the use of azoxystrobin (Quadris) for control of Rhizoctonia black scurf control. Based on our work in MAES research plots and in grower fields yields for the years 1994-2002 are increased an average of 12.8%. Based on the fact that Quadris was used on 3300 acres in 2002 economic returns were increased by more than $300/A (assume 300 cwt/A yield and $8.00/cwt) or more than $990,000. This is a very conservative estimate since yield increases in some years are 15% and many growers have higher base yields. This research has been transferred to other states and the manufacturer of Quadis reports use on more than 150,000 acres nationwide.

Decision-making for cereal leaf beetle management is based on an economic injury level that was developed in Michigan. Research was conducted to evaluate the economic injury level for Cereal Leaf Beetle under Montana conditions and crops. There has been an increasing trend to treat fields with insecticides for this pest. In 1995 about 1,000 acres were treated, 5,000 acres in 1996 and 15,000 acres in 1997. However, a cereal leaf beetle monitoring program and treatment guidelines have resulted in a reduction of sprayed acreage in 1998 to 5,000 acres. With chemical application costs of $12/acre this resulted in a savings to Montana producers of $120,000. Development of an economic injury level that is more appropriate for Montana producers and continued emphasis on monitoring and using decision making guidelines is likely to yield substantial economic benefits each year.

ACTUAL EXPENDITURES OF FEDERAL FUNDING

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: 2005

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)	$1,986,835					
This FY Target Amount	$115,236					
Title of Planned Program Activity						
Epidemiological investigations on arthropod-bourne diseases of domestic livestock and wildlife	13,184					
Integrated pest management of Montana field and forage corps	36,050					
Improve the profitability and competitiveness of the Montana sheep industry	13,760					
Influence of social hierarchy on distribution of rangeland cattle	14,954					
Management practices which influence morbidity, feedlot performance and carcass characteristics of Montana beef calves	18,725					
Ecology of phyllosphere and rhizosphere and their potential role in biological control of disease	38,474					
Total	$135,147					
Carryover	$19,911					

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**