ANNUAL REPORT

MONTANA STATE UNIVERSITY

COLLEGE OF AGRICULTURE
MONTANA AGRICULTURAL EXPERIMENT STATION

FEDERAL FISCAL YEAR 2002

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Introduction

Preface

The College of Agriculture at Montana State University, headquartered in Bozeman, Montana, is comprised of the Montana Agricultural Experiment Station (MAES) and the College's academic programs in undergraduate and graduate studies. The MAES system is a network of eight Agricultural Research Centers, four farms, and two collaborative research programs with two USDA-Agricultural Research Service units at Miles City and Sidney. It does not include the Montana Extension Service though Extension Specialists are housed within departments in the College of Agriculture. The College also does not have programs in Family and Consumer Sciences or Rural Development.

Expanded partnerships include the Montana Extension Service, MSU-Bozeman, 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 are being actively pursued. The location of extension specialists at our seven off-campus Research Centers is being discussed to expand and to improve our outreach capabilities statewide.

The Montana State University Plan of Work consists of 10 programs in research. Research programs have been listed under the one most prevailing goal. Programs are developed on a five-year or greater than five-year timeline although many individual projects have critical short-term goals. Stakeholder input has been solicited in the strategic planning process and will continue to be solicited as programs are developed and dollars are allocated to programs.

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 producer groups, Montana Department of Agriculture, Private Industry, National Institute of Health, National Science Foundation, NASA, and the BLM, funds from regional states and Canadian Providences.

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Vision

The Montana State University College of Agriculture (COA)/Montana Agricultural Experiment Station (MAES) will provide focused and viable science-based education, research, and extension/outreach programs essential for providing knowledge and leadership in agricultural systems and natural resources to preserve the quality of the environment, improve the quality of life, and create added value from our resources for Montana and its people in a global economy.

Mission

As a land-grant institution, Montana State University-Bozeman provides instruction, research, and extension/outreach programs focused to meet the ever-changing needs of Montana and its people. In keeping with this mission, the COA/MAES provides science-based education, new knowledge, and leadership on agricultural and natural resource issues.

Values

- Provide visionary and responsive leadership based on scientific knowledge.
- Develop a community of scholars and learners committed to quality and excellence.
- Create a work environment of open communication, trust, honesty, and acceptance.
- Our conduct embraces the highest standards of ethics and citizenship.

Program Focus and Overarching Goals and Objectives

- COA/MAES program focus and overarching goals and objectives include generating and disseminating knowledge and providing quality educational and outreach activities. Montana agriculture, Montana students, and the people of Montana are a primary focus of COA/MAES programs.

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

  - Provide a scientific basis for developing viable and sustainable plant and animal systems.
  - Enhance the fundamental understanding of plant and animal biology.
  - Enhance the development of value-added agricultural products.
  - Improve plant and animal health through integrated pest management and other sustainable practices.
  - Improve food safety and quality.
  - Contribute to commodity and product marketing and economic development.
  - Create educational programs that address plant and animal systems and biology.

  <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 improve the sustainability of natural resource systems.
  - Create educational programs that address natural resource needs and use patterns.
  - Develop ecosystem improvement programs that promote sustainable management practices and are consistent with enhanced biodiversity.
  - Provide programs to enhance understanding of disturbed, rural, and urban landscapes.

  <u>Strengthen the Quality of Life for Montana and Its People</u>

  - Enhance the development of educational programs and delivery systems, including distance learning, which improve basic learning and life skills among Montana's people.
  - Improve recruitment and retention of students.
  - Partnership with others to improve human nutrition and health, resiliency of families, and the viability of communities.
  - Partnership with others to provide programs to enhance the development of new businesses and community development.
  - Emphasize leadership development programs.

MAES Planned Programs and Key Themes

GOAL 1. AN AGRICULTURAL SYSTEM THAT IS HIGHLY COMPETITIVE IN THE GLOBAL ECONOMY

Executive Summary

Montana producers faced many challenges in 2002. To assist them, we were involved in a wide range of projects. These encompassed such things as experimental cattle feed to improve forage; cattle grazing in Montana climates associated with weight loss; cattle breeding programs for improved lean carcass yield; studies on the effect of mineral supplements influencing ovulation rate in beef heifers; neonatal lamb mortality; various projects on breeding ewes and cows; studies on copper and zinc levels in livers of cattle; feeding behavior and supplement delivery methods for cattle and sheep; contributing factors to the persistence of spotted knapweed.

The Montana Beef Quality Assurance (BQA) program for beef producers focused on best management practices to ensure food safety, feeder calf quality and consistency and source verification. Implementing a feeder calf certification program for beef quality-assurance trained producers based on best management practices for enhancing calf health. Implementing an electronic identification/tracking system to follow calves through various production channels. Conducting education courses focused on food safety, financial, genetic, nutritional, reproductive and marketing management. Providing Montana beef producers with the tools and information necessary to maximize profits from their beef marketing strategies through the integration of workshops, marketing clubs and on-line market information.

The Montana Beef Network (MBN) has three primary objectives; 1) educational programs aimed at meeting beef quality assurance standards, production and marketing goals and providing additional educational programs through interactive-video conferencing, 2) certification of feeder calves that have met defined management protocols and 3) information feedback from the feedlot and packing plant to the cow-calf producer showing if the feeder calves met industry requirements for quality, consistency, safety and red meat yield.

Agricultural systems are continually being attacked by a broad array of arthropod pests. The overall emphasis of research and extension activities is to develop and implement management solutions to economic arthropod pests of small grains, sugarbeets, forages, canola, and potatoes. Pest management techniques using host plant resistance, cultural, biological and chemical controls have been examined for their impact on pest and beneficial insect populations and economics to assure Montana's farm economy remains globally competitive. Dryland crop diversification studies are being conducted in three locations in Montana to determine the influence of cropping sequences, tillage systems and different levels of inputs on crop production, pests, nutrient management, physical and biological properties of soil, economic profitability and environmental benefits.

Numerous field research projects have provided livestock producers and land managers new tools to increase uniformity of livestock grazing and correspondingly improve rangeland health and water quality. Infectious diseases cause millions of dollars in losses to the livestock industry in the context of reduced animal production. Reduced markets for meat products because of infectious disease concerns cause additional financial losses to the livestock industry. Emerging infectious diseases found in wildlife populations, including bison, are becoming increasingly problematic for livestock producers. During the past year, we have made significant strides in investigating a number of livestock- and wildlife-related diseases and in developing vaccine candidates for treating some of these diseases.

Several projects involve the genetic modification of organisms for specific purposes. New strains of pathogenic fungi and bacterial are being developed for specific control of certain weed species. Plant viruses are being designed for the delivery of drugs and other compounds to specific tissues of the body. Invasive species plants that have developed resistance to certain herbicides are being researched. It is possible that this knowledge can be exploited to permit the circumvention of this resistance or to develop new genes for the production of herbicide resistant crops.

Although we have developed an international reputation for our wheat and barley products, our costs of production continue to increase as producers address increasing pressure from pests due to the monoculture nature of our systems. Consequently, diversified systems or crop rotations are being studied to change our cropping systems into more sustainable systems for a semi-arid environment.

Projects were designed in recognition of a changing economic environment. The viability of each production unit depends critically upon those producers' ability to identify and analyze problems that have financial, production, organizational, or risk implications to the firm or to the industry. Our Research results provide management solutions to promote the economic competitiveness and environmental health of Montana agriculture and contribute to the production of high quality agricultural products. County Extension Agents receive the most recent information to pass on to our local population as invited participants in our Research Station advisory meetings.

In Montana and throughout the United States, the environment within which agricultural producers operate is becoming increasingly complex. Sources of this increasing complexity include the financial system, evolving marketing practices and systems, and the myriad government programs that influence producer behavior in agriculture. Agricultural producers, in dealing with financial and management issues, are presented with an increasingly complex set of tools with which to address the problems they face on a regular basis. This added complexity necessitates a continued academic effort that identifies and provides potential solutions for the continuously changing set of problems. With respect to marketing systems, the dynamics of changing foreign and domestic markets produces price volatility and marketing uncertainties to producers and agribusiness firms. These necessitate estimating price/production behavior, margin behavior, and developing appropriate marketing, financial and risk management strategies in an uncertain environment. Such information has the potential to improve the efficiency and competitiveness of the U.S. agricultural sector. Government policies affect every aspect of agricultural and natural resource economic activity through their impacts on consumer and producer welfare, the welfare of farm input suppliers and food processors, and on rural communities and taxpayers. Economic analysis of selected policies under this plan of work will enhance the competitiveness and efficiency of U.S. agriculture.

PROGRAM 1. PLANT AND ANIMAL IMPROVEMENT

Key Themes - Plant Improvement

Plant Genomics

Activity:
Studies of Plants Living in Extreme Environments
Genetically Engineering Plant Light Responses to Improve Crop Quality
Genetics of Self-Regulation

Genetic Studies of Legumes and Grasses

Impact/accomplishments:
An interaction between a soil fungus and a native grass has been shown to be one of the factors that permit the grass to grow in hot soils found in Yellowstone National Park and other such thermal regions. The virtue of the interaction is being explored at the molecular level. Similarly the process of nitrogen metabolism and plant senescence is being investigated in wheat, using genetic tools. Comparative genomics is proving to be an extremely efficient way to locate important genes in legume crops such as pea, lentil and chickpea. Similar work in wheat is being used to locate the genes controlling qualitatively inherited trains of particular interest for breeders. Genetic information developed for one crop often can be applied to a closely related crop through comparative genomics. Such applications are being performed in wheat (using various grass models), in pea (using Medicago truncatula as a model) and in lentil (using pea as a model). The location of numerous important genes has been identified using this approach.

Source of Funding: Hatch, State

Scope of Impact: State Specific

Biotechnology

Activity:
Genetic Manipulation of Small Grains to Improve Quality Characteristics
Genetic Improvement of Biological Control Agents for Weed Control
Bacterial and Fungal Endophytes
Mechanisms of Plant Virus Transmission and Assembly

Impact/accomplishments:
Several projects involve the genetic modification of organism for specific purposes. Fungal and bacterial plant pathogens specific to certain weeds have been developed as biocontrol agents. These organisms have been genetically modified to increase virulence and also reduce their visibility when the host plant is not available. Such biocontrol organisms are proving very useful in locations where chemical herbicides are not appropriate such as riparian habitats and high use areas. Grain quality in wheat and other small grains is being improved by modifying hardness genes and genes controlling specific steps in starch biosynthesis. Transformed wheat with modified hardness; increased disease resistance and Roundup™ resistance have been developed. New strains of bacteria and fungi with biocontrol properties have been developed or identified.

Source of Funding: Hatch, State

Scope of impact: Multistate

Plant Health

Activity:
Plant Diseases
Control of Fungal Disease by Mating Inhibition
Identification of Defense Related Genes in Plant Defense Systems
Biocontrol Agents for Diseases in Potato and Sugar Beet

Impact/accomplishments:
Development of plants resistant to common diseases and the understanding of the pathogens are two important goals. *Cercospora* leaf spot in sugarbeet has been effectively controlled by a combination of partially tolerant germplam and use of biocontrol agent Bac-J that is now under commercial production. An understanding of the genetics of mating types in *Ustilago hordei* is being explored to identify methods for controlling this fungus in barley. Compounds isolated from endophylic fungi have been shown to have antibiotic properties. These compounds are volatile and have tremendous potential for reducing populations of specific plan pathogens in the soil.

Source of Funding: Hatch, Smith-Lever, and State

Scope of impact: Integrated Research and Extension

Key Themes - Animal Improvement

Animal Genomics

Activity:
Functional analysis of bovine γδ T cells - Evidence suggests that γδ T cells are important in host responses against viral, bacterial, and protozoan infections. These T cells are selectively recruited and proliferate in response to a number of infectious agents; however, their role in clearing these pathogens from the host is not understood. In the context of the recruitment of γδ T cells into different tissues, we have made progress in our characterization of tissue-specific adhesion molecules and chemokines that direct the migration of specific γδ T cell subsets into the gut versus peripheral tissues. In the past year, we further defined the control of the selective migration of CD8+ γδ T cells into the gut mucosal and identified unexpected pathogen recognition receptors on γδ T cells whose signaling leads to selective expression of specific T cell chemokines. As stated last year, these studies have implications in the design of new adjuvants for the stimulation of the bovine immune system. Another area of progress has been in establishing the nation's first functional genomics research program on bovine γδ T cells. New insights have been gained for the function of these cells, which have led to the identification of new ways to control their activity. Specifically, we found that γδ T cells express toll-like receptors (TLRs), which serve as pathogen recognition receptors on cells. TLR agonists induce unique gene expression profiles in γδ T cells.

Impact/accomplishment:
The direct implications of this research relates to the development of new ways to stimulate the activity of bovine γδ T cells. It is thought that γδ T cells are an important natural defense mechanism against a variety of pathogens. Enhancing their activity may increase the innate resistance of cattle to mucosal and respiratory pathogens, particularly under conditions of stress associated with shipping. A goal of this work is to identify a low cost feed supplement that could be used to enhance γδ T cells.

Source of Federal Funds: Hatch, State

Scope of Impact: Multistate: Montana, Washington, Minnesota

Animal Health

Activity:
Temporal and spatial distribution of Culicoides vectors of bluetongue
Impact/Accomplishments:
Light trapping of adult midges indicated that the primary vector of bluetongue is present in parts of eastern and southwest Montana. A more comprehensive study will be initiated in 2002 to establish the vectorial capacity of the Culicoides complex.

Source of Funding: USDA

Scope of Impact: State, Regional, International

Activity:
Immunity and Inflammation of Trichomoniasis - *Tritrichomonas foetus* is an important cause of reproductive failure in U.S. cattle. The main losses are aborted calves and disrupted breeding management. No effective vaccination or approved drug therapy is available and protective immunity is poorly understood. Our research focuses on the host responses that destroy *T. foetus* as well as those that may contribute to disease (eg. inflammation) for the long-term purpose of vaccine development. Previously we have shown that macrophages can destroy this parasite and recent results show that infection in a mouse model results in macrophage infiltration of the reproductive tract tissues. We have also shown that direct macrophage exposure to trichomonads leads to increased production of NO and COX-2, markers of macrophage activation. These results are consistent with the hypothesis that innate immune responses and inflammatory responses are directly triggered by trichomonads. The results also suggest innate immunity is likely to be important in destruction of *T. foetus* during infection.

Impact/Accomplishments:
The results of these studies address a fundamental lack of understanding of protective immunity to *T. foetus*. Knowledge of which immune responses can destroy *T. foetus* is required for an effective vaccine development strategy.

Source of Funding: Hatch, State, USDA

Scope of Impact: Multistate (Montana, Washington, Minnesota), State, USDA

Activity:
The role of the innate cellular antiviral response in rotavirus infections - Rotavirus is the major viral cause of neonatal calf scours. Currently available vaccines are sub-optimal and fail to effectively control infections that can be initiated by multiple circulating viral serotypes. In addition, adult animals are resistant to disease, but not to infection, and consequently serve as a reservoir for persistence of rotavirus in the environment. Toward a long-term goal of developing new methods to inhibit rotavirus replication in bovine of all ages, we seek to define the molecular interactions between the viral nonstructural proteins and host cell proteins that regulate viral and cellular gene expression. Current research efforts have focused on the functions of nonstructural protein NSP1. The function of NSP1 in the replication cycle is not known, but some data have suggested this protein plays a role in virulence, in host range restriction, and in regulation of rotavirus replication efficiency. We recently discovered that NSP1 binds the cellular transcription factor interferon regulatory factor 3 (IRF-3), a major player in induction and regulation of the innate immune response to viral infection in the form of induction of the antiviral interferon (IFN) response. IFNs and IFN-stimulated genes regulate multiple cellular functions including antiviral responses, growth and differentiation, and molecular modulation of the adaptive immune response. Evidence that there is a link between innate and adaptive immune responses to pathogens continues to accumulate, providing

impetus to understand the triggering mechanisms that induce IFN synthesis, and the virus-encoded functions that down-regulate antiviral gene expression.

Impact/Accomplishments:
The IFN response is a ubiquitous antiviral defense mechanism. Therefore, the impact of discovering deliverable methods to inhibit rotavirus interference with a cell's ability to defend against infection extends beyond rotavirus disease, and will likely be applicable to a range of enteric viral infections. Discovery and development of new, targeted antivirals that are cost effective and amenable to large-scale use in susceptible populations is a long-term goal of this basic research program.

Source of Funding: Hatch, USDA

Scope of Impact: National

Activity:
Development of bovine vaccine delivery systems - we investigated the feasibility of an attenuated *Salmonella* vector to immunize heifers against bovine enterotoxigenic *Escherichia coli* (ETEC). Studies focused on the hypothesis that protective immunity to ETEC is antibody-dependent. In an effort to develop a safe and effective vaccine for the prevention of F5+ ETEC infections, a balanced-lethal *asd+* plasmid carrying the complete K99-operon was constructed and designated, pMAK99-*asd+.* Introduction of this plasmid into attenuated *S. typhimurium* strain H683 resulted in the strain, AP112, which stably expresses the *E. coli* K99 fimbriae. Furthermore, *Salmonella* strains were developed where the K99 fimbrial antigen was either limited to the periplasmic compartment (AP114) or to the cytoplasmic compartment (AP116). To assess the effectiveness of each *Salmonella* construct in delivering the fimbrial subunit to mucosal inductive tissues, outbred CD-1 mice were orally immunized and showed elevated mucosal and serum antibody titers to K99. Peyer's patches and splenic lymphocytes from BALB/c and CD-1 mice were harvested one week after oral immunization with each construct and assayed using a cytokine-specific ELISPOT. Our results confirmed that variation in the expression of K99 fimbrial subunit within different compartments of *Salmonella* vaccine vectors alters the type of responses elicited. This further demonstrated that cell surface or excreted passenger antigens might favor the stimulation of predominantly Th2-type cells. This vaccine is currently being evaluated in heifers to test its efficacy in challenged, newborn calves.

Impact/Accomplishment:
We have developed a vaccine prototype for scours that is currently being evaluated for its efficacy in protecting newborn calves.

Source of Funding: Hatch, USDA, State

Scope of Impact: National

Activity:
Vaccine Development for Brucellosis in Bison - Brucellosis is a communicable disease, and poses a major threat to the Montana livestock industry. Montana must retain its *Brucella*-free status to sustain this industry. Thus, efforts spearheaded by VMB have focused on developing a better understanding of the bison immune system and the development of novel vaccine delivery systems and vaccines for bison. We have recently tested a prototype vaccine for bovine scours in bison, and learned that the *Salmonella*-based vaccine is well tolerated. After two oral vaccinations, elevated mucosal and systemic antibodies were found to the vaccine. In addition, immunized female bison calves produced and maintained elevated vaccine-specific antibody titers in their vaginal secretions. Thus, oral immunization does represent a route of

delivery whereby appropriate mucosal immunity can be obtained in bison. To develop the next generation brucellosis vaccines, we have cloned nearly 70 *Brucella abortus* genes and have placed them into DNA eukaryotic expression vectors as a method to enable bison vaccination. Four bison were vaccinated with these DNA vaccines and then shipped to collaborators at Texas A&M University where the animals were then challenged. Three of the four vaccinated bison showed protection against *B. abortus* challenge whereas two of two vector –immunized bison showed no protection. Thus, these studies suggest that our DNA vaccine is protective for bison. On-going studies are optimizing the delivery of this vaccine for improved efficacy.

Impact/Accomplishment:
These studies show that we have developed a vaccine prototype for brucellosis in bison that warrants further study.

Source of Funding: Hatch, USDA, State

Scope of Impact: State, Regional

Activity:
Innate defense mechanisms in cattle - studies were performed to investigate the composition and regulation of the bovine leukocyte NADPH oxidase.

Impact/Accomplishment:
A better understanding of the bovine leukocyte NADPH oxidase at the molecular level could eventually lead to the development of therapies or strategies for enhancing leukocyte host defense processes and possibly influencing or preventing the inflammatory aspects of bovine mastitis and other inflammatory diseases in livestock. Two of the essential cytosolic components of the NADPH oxidase are $p47^{phox}$ and $p67^{phox}$. Previously, only the human and murine homologues of these proteins have been sequenced. Thus, we carried out studies to clone, sequence, and express bovine $p47^{phox}$ and $p67^{phox}$. Using PCR cloning techniques and a bovine bone marrow cDNA library, we have cloned both of these bovine NADPH oxidase cytosolic components. Comparison of the bovine sequences with those of the human and murine homologues showed that they were highly conserved, but also revealed important information regarding key structural features of $p47^{phox}$ and $p67^{phox}$, including location of putative phosphorylation sites. Functional expression of bovine $p47^{phox}$ and $p67^{phox}$ showed that these proteins could substitute for the human proteins in reconstituting NADPH oxidase activity in a cell-free assay system, again demonstrating the high degree of conservation between human and bovine homologues. This study greatly contributes to our understanding of the potential structural/functional regions of $p47^{phox}$ and $p67^{phox}$ as well as gives us information that can be used to study the role of neutrophils in bovine inflammatory diseases. Differential release of neutrophil intracellular granules is a widely accepted model of how neutrophil function can be modulated. We found that bovine neutrophils contain secretory granules and that these granules were readily mobilized by a number of inflammatory agents. We also found that these granules are distinctly mobilized and may represent evidence of priming in bovine cells.

Source of Funding: Hatch, USDA, State

Scope of Impact: National

Activity:
Innate defense mechanisms in bison - studies were performed to investigate antimicrobial proteins used by bison leukocytes for host defense against bacteria.

Impact/Accomplishment:
This project studies the types of antimicrobial proteins present in bison neutrophils and how active they are against several relevant pathogens. A better understanding of these proteins could potentially lead to practical applications to controlling infectious disease in bison and other wildlife. Since intracellular granules are believed to contain the majority of neutrophil anti-microbial peptides, we isolated the granules from disrupted bison neutrophils using differential centrifugation. The crude granule preparations were then disrupted using several cycles of freeze-thawing, and the protein concentration of the extracts was determined. Cultures of both gram-negative (*E. coli*) and gram-positive bacteria *(S. aureus*) were treated with various concentrations of granule proteins for 30 minutes, and the effect on bacterial survival determined. Bison neutrophil granule extracts showed potent killing activity against *E. coli* at concentrations $\geq$ 100 μg/ml. Conversely, the neutrophil extracts did not kill *S. aureus* and, in fact, had a permissive effect at a dose of 100 μg/ml. Extracts that were prepared in an identical fashion from bovine neutrophils had similar effects as the bison granule extracts. These results show that bison neutrophil granules possess potent anti-microbial activity, at least for *E. coli*. To identify genes coding for putative antimicrobial peptides, we screened bison bone marrow total RNA using RT-PCR primers to nucleotide sequences that were conserved between bovine Bac5 and Bac7 cDNAs. The amplified RT-PCR products were cloned and sequenced. Sequence analysis showed that our products were partial cDNA clones corresponding to bison Bac7. The bison nucleotide sequence determined from the partial cDNA clone was then used to design primers to perform 5' and 3' RACE of bison Bac7. Amplified products from the 5' and 3' RACE reactions have been cloned and correspond to the 5' and 3' ends of bison Bac7. Further studies will focus on characterizing this peptide as well as screening for other novel bison microbicidal peptides.

Source of Funding: Hatch, USDA, State

Scope of Impact: National

Activity:
Drug Discovery for the Treatment and Prevention of Coccidiosis H - Infectious diseases caused by coccidian parasites are some of the most important health problems of food animals and humans. Compared to the cells of their mammalian hosts, coccidian parasite development is highly unusual, and therefore, represents a major area for drug discovery.

Impact/Accomplishments:
We have developed novel experimental models for the study of *Eimeria bovis* (causative agent of coccidiosis in cattle) and *Toxoplasma gondii* in order to characterize biochemical mechanisms responsible for successful parasitism by these microorganisms. One of the goals is to apply a modern functional genomic approach to these parasitic diseases. We have successfully established the technique for serial-analysis-of-gene-expression (SAGE) in the model coccidian *T. gondii*. With this technique, all ~7,000 parasite genes can be sorted from the nearly 15,000 host genes in a single genetic library prepared from infected animal cells. Over the next year with funding from NIH (R21-AI53815) we will produce ~500,000 tags from *T. gondii* sporozoites, early-fast growing tachyzoites, growth-shifted tachyzoites and bradyzoites (tissue cyst stage). This data set will represent the most comprehensive study of gene expression across the intermediate life cycle of a coccidian parasites. Currently, sporozoite and early-fast growing libraries have been constructed and are undergoing sequencing. Our plan is to integrate the SAGE data into the NIH-sponsored *Toxoplasma* DB (http://ToxoDB.org/) such that tags are displayed on an assembled 12X genomic coverage of this protozoan pathogen. The target date for completing these activities is early 2004.

Source of Funding: Hatch, State

Scope of Impact: Multistate (MT, WY, ID, CO, CA, etc) State

Activity:
Parameters affecting the efficiency of targeted mutagenesis in bovine cells **-** targeted mutagenesis can be used to create genetically modified animals; however, to date, other than one reported success in sheep (which was published almost 3 years ago), there are only published reports of success in mice.

Impact/Accomplishment:
Our project is aimed at increasing the efficiency of targeted mutagenesis in bovine cells, which could, in the future, be used to initiate modified breeds of animals. We have produced pure lines of bovine embryonic fibroblast cells (BEFs) from a purebred breed of dairy cattle (American Holstein) and from a genetically distant breed (Montana beef cattle, out-bred, with a high contribution of Angus). We also produced a genomic DNA library in lambda-phage from the American Holstein BEFs. Using a DNA clone from this library, we are constructing model vectors for targeted mutagenesis. Differences in targeting efficiency between the two cell lines will be correlated to the number of DNA sequence differences between the cell lines at the targeting locus. We will then introduce specific mutations into the targeting vector and measure the effects of these on targeting efficiency in the two cell lines. Our goal is to measure how critical it is to use isogenic vectors for targeting mutations into bovine cells. Were targeted mutagenesis to become tractable in cattle, it could both increase the value of existing cattle-based commodities and allow creation of countless more valuable cattle-based products. Thus, it could allow production of particularly disease resistant herds, or production of herds exhibiting increased milk or beef production. As an example of its potential value, one might look at recent events overseas. Bovine spongiform encephalopathy (BSE) in the UK devastated most of the European cattle and sheep industry. The technology that we are trying to optimize could potentially be used to produce a breed of cattle that entirely lacked the PrP gene. Such a breed of cattle could neither acquire nor transmit BSE, even if housed with animals that were affected, or on grounds that had harbored affected animals in the past. Studies in mice suggest that this modification would not compromise the health or vitality of the modified breed. Thus, such cattle might provide a valuable barrier to BSE outbreaks and might increase consumer confidence in products coming from areas that have endemic reservoirs of endemic PrP-based diseases, including bovine BSE, ovine scrapie, and (of increasing concern in the US), cervid chronic wasting (CW) disease.
This project is expected to be of great potential future benefit for Montana. Much of Montana's economic base relies on the cattle market, and is very sensitive to cattle-related animal health and production issues. Thus, advances that either increase cattle-based production or increase cattle disease resistance are critical to maintaining these state interests. Moreover, Montana is one of the states that are known to be a reservoir of CW. Were this disease found to cross species barriers into livestock, Montana's beef industry would likely fare no better than did the European beef industry during the BSE outbreak. The technology that we are striving to develop might provide a mechanism for insulating the state from the impact of such an event.
Although the potential benefits of this research are expected to be national or international in scope, our research project, at the current time, has no out-of-state components.

Source of Funding: Hatch, USDA**,** State

Scope of Impact: National

Activity:
Pathogenesis of and immunity to bovine shipping fever - bovine respiratory disease complex (shipping fever) is a group of economically important diseases of cattle. The National Animal

Health Monitory System (NAHMS) has estimated the annual loss of cattle associated with respiratory disease to be higher than any other cause of animal death; the estimated annual loss is in the billions of dollars. In addition, over $3 billion are spent annually for prevention and treatments of the disease complex. The overall objective of our research program is to understand the pathogenesis of and immunity to bovine shipping fever and to develop novel strategies for prevention and control of this economically important bovine disease complex. To accomplish this objective, we will characterize the primary and memory T cell responses to respiratory virus infection in the mucosa of the nasal passages and compare these to the responses in the lower respiratory tract. We will then determine whether the local lymphoid tissues associated with the upper respiratory tract play a role in the immune responses to virus infection in the upper and lower respiratory tract mucosa. Finally we will determine how the initial deposition of virus at different levels of the respiratory tract affects primary and memory responses to influenza.

Impact/Accomplishment:
Results obtained will provide information that increases the understanding of the pathogenesis of and immunity to bovine respiratory diseases such as shipping fever. Such information is essential for future development of effective measures for prevention and treatment of this economically important disease to cattle industry.

Source of Funding: State

Scope of Impact: National

Emerging Infectious Diseases

Activity:
Develop research program focused on emerging infectious diseases.
Continue Development of the Center for Bison and Wildlife Health.

Impact/Accomplishments:
Emerging infectious diseases represent a growing threat to public and animal health. A potential major source of new and spreading infections is the interaction livestock and wildlife, which are in close association in Montana. Many infectious organisms, which have reservoirs in wildlife and livestock, are also considered potent biowarfare agents. Therefore, it is essential that we begin to develop an understanding of these diseases and identify mechanisms to prevent their spread. The goal of this plan is to increase our research effort (facilities and personnel) directed toward understanding the pathogenesis of emerging infectious diseases and what mechanisms the host brings to bear against these diseases.

Impact/Accomplishments: Veterinary Molecular Biology has developed a center focused on wildlife health. One of the goals of this Center is to carry out investigation of infectious disease affecting wildlife. Further participation of researchers in this Center and acquisition of funding will be a goal during the 5 year Plan of Work.

Source of Funding:
State, Hatch, USDA-NRICGP, USDA-Institutional

Scope of Impact:
National

PROGRAM 2. CROP AND ANIMAL PRODUCTION AND MANAGEMENT SYSTEMS

Key Themes - Crop Production and Management Systems

Invasive Species

Activity:
Integrated weed management practices

Impact/Accomplishments:
A one-pass system to apply a herbicide and seed more desirable species have been implemented in a cost-effective manner. Build support for the importance of competitive desirable species in preventing weed invasion which result in programs that are affordable and result in plant communities that meet landowner and land manager land use objectives, increased productivity, and ecosystem health.

Source of Funding: Hatch, Smith Lever, USDA, State

Scope of Impact: Integrated Research and Extension

Activity:
Knapweed Control.

Impact/Accomplishments:
Spotted knapweed's success cannot be attributed to an overwhelming greater competitive ability or efficiency than native grasses. Spotted knapweed does not significantly alter soil physical or biological properties, but it uses soil water later into the summer than native grasses. Other than such strong differences in soil water use patterns, no single plant or soil characteristic explains why spotted knapweed is so successful in western North America.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension.

Activity.
Monitoring of injurious insect pests

Impact/Accomplishments:
Monitoring systems are in place for the following: pale western and army cutworms, cereal leaf beetle, cabbage seedpod weevil, green peach aphid, potato aphid, clover root curculio and sugar beet root aphid. Results of monitoring systems are used to alert producers for these insect pests via the internet and Extension programs.

Source of Funding: Hatch, Smith Lever, State

Scope of Impact: Multistate Extension (WY, NE, CO, ND), Multistate research (WY, NE, CO)

Activity:
Biological control of invasive hawkweeds

Impact/Accomplishments: Five potential biocontrol agents for use against invasive hawkweed species in North America are currently being considered. CABI Bioscience, Switzerland, originally tested these for use in New Zealand. At MSU we are conducting additional host specificity tests for the gall wasp, *Aulacidea subterminalis* to determine its potential utilization of native hawkweeds. L. Wilson (Co-PI) U. of Idaho has collected or provided invasive or native hawkweed species for testing, and galls were obtained from G. Grosskopf, CABI Bioscience. Adult wasps were reared from the galls in place on 23 plant species (134 different replications) in no-choice development tests. Galls were only formed in the control plants and *Hieracium floribundum*. No native species were infested. A biological control work plan has been drafted by Wilson, Grosskopf, and Littlefield, MSU, and will be incorporated into the Montana Hawkweed Management Plan.

Source of Funding: Hatch, State

Scope of Impact: This project impacts state, tribal, federal, provincial, and private lands, and is of regional and international importance.

Activity:
Biological Control of Whitetop

Impact/Accomplishments:
Host specificity testing has been initiated for the eriophyid mite, *Aceria drabae*. The mite causes leafy galls which stunts the plant or prevents flowering. Three mite shipments from Greece and Turkey were received for testing in 2002, but mites in all shipments were dead (of unknown reasons) on arrival. A host test plant list is still being developed in cooperation with L. Wilson, U. of Idaho. A number of plants species from the list were collected for use at MSU, CABI Bioscience, and the USDA-ARS-EBCL.

Source of Funding: Hatch, State

Scope of Impact: This project impacts state, federal, and private lands, and is of regional and international importance.

Activity:
Biological Control of Field Bindweed

Impact/Accomplishments:
Plots were established at a site near Roy, MT to monitor the phenology and population development of the leaf mite, *Aceria malherbae*. Plots were periodically visited between May and September for the past three years. Infested and non-infested plants were counted and measured. Plants were also collected to determine mite numbers. Five releases of the bindweed mites were also made during the summer of 2002. Releases were made at sites located in McCone, Gallatin, Phillips, Park and Yellowstone counties. Monitoring of 2001 releases indicated that the mite successfully over wintered at one site near Lambert, MT, although this establishment is being hindered by drought conditions and an outbreak of tortoise beetles.

Source of Funding: Hatch, State

Scope of Impact: This project impacts primarily privately held lands, and is of regional importance.

Activity:
Biological Control of Russian Knapweed

Impact/Accomplishments:
Host testing has been completed for: *Urophora kasachstanica*, *Urophora xanthippe* (flower gall flies), and *Aceria sobhiani* (stem mite). Open field tests using the gall flies were repeated at a site located in Uzbekistan in 2001, and the flowerheads processed in 2002. Nine plant species were tested. Both flies appear to be host specific, therefore a biological assessment for the release of the two *Urophora* species is currently being finalized. *Aceria sobhiani* was not tested in 2002 due to genetic bottle necks within the lab population of the mite. *Aceria acroptiloni* (flower mite) was collected from Uzbekistan and limited rearing and host specificity tests were conducted. In 2002 a population of a chrysomelid (prob. *Galeruca* sp) was located by U. Schaffner in Uzbekistan. A shipment of 98 larval leaf beetles was received at the MSU quarantine. For the younger or smaller larvae a choice-feeding test was conducted using Russian knapweed and six test species consisting of closely related plants. Russian knapweed was generally fed upon first, although larvae occasionally fed upon small portions of yellow starthistle and *Centaurea rothrockii* leaves but usually only after the Russian knapweed leaves were consumed. In addition, twenty Russian knapweed clones (point infestations) of various sizes were selected in Phillips County, Montana. These were monitored throughout the summer and fall for rate of spread, plant density, plant height, number of flowers and associated insect feeding. In the fall quadrates were clipped for biomass and flower heads were collected to determine seed production. A sister study was also conducted in Turkey by Schaffner (CABI). The two studies will be used to compare weed ecology in native verses introduced habitats of the plant.

Source of Funding: Hatch, State, USDA

Scope of Impact: This project impacts state, federal, tribal, and private lands, and is of regional importance.

Activity:
Biological Control of Tansy Ragwort

Impact/Accomplishments:
The objectives of this project are to determine biotypic differences in the phenology and host specificity of several populations of the tansy ragwort flea beetle for use in Montana. Study sites were selected in Switzerland at various elevations to follow the phenology of tansy ragwort and the beetle. In addition, DNA analysis was conducted to determine the extent of genetic differences among the populations of the beetle. Host specificity tests were conducted in the field in Switzerland and in the quarantine lab at MSU to determine possible utilization of native *Senecio* plants by the beetle. The data suggest that the Swiss population of the beetle will be more phenologically adapted to environmental conditions in Montana, and that the beetle is reasonably host specific, thus would be safe for release. A release permit was granted by APHIS and several releases of Longitarsus eggs were made in 2002 in the Flathead National Forest.

Source of Funding: Hatch, State

Scope of Impact: This project impacts state, tribal, federal, provincial, and private lands, and is of regional and international importance.

Activity:
Biological Control of Rush Skeletonweed

Impact/Accomplishments:
An environmental assessment for the field release of the root moth, *Bradyrrhoa gilveolella*, was submitted to APHIS and received concurrence from the Fish & Wildlife Service. Permission to release the moth was granted in late August 2002, and a small release consisting of infested plants was made near Garden Valley, Idaho. In addition two collections of infested roots were made in Greece and processed at the MSU quarantine to establish a laboratory colony. Habitat matching of skeletonweed sites with and without the moth in Europe will be conducted to determine optimal site conditions for the release of the moth in North America.

Source of Funding: Hatch, State

Scope of Impact: This project impacts state, federal, provincial, and private lands, and is of regional and international importance.

Activity:
Biological control of leafy spurge

Impact/Accomplishments:
Research has shown that certain flea beetle species are associated with particular chemical and physical properties of the soil, chemical properties of the spurge roots and foliage, and levels of plant productivity. Habitat association models developed from soil, plant and flea beetle data from Europe were validated with similar information collected from 48 research sites in Montana, North Dakota, and Wyoming. The habitat association information will be helpful in guiding the release of flea beetles in the appropriate spurge habitats in the future, thus improving their chances for establishing and having an impact on leafy spurge in North America.

Source of Funding: Hatch, State

Scope of Impact: Multi state regional research

Activity:
Investigation of the mechanism of herbicide resistance in *Kochia* and development of new biocontrol agents

Impact/accomplishments:
The change in protein sequence leading to herbicide resistance in *Kochia* has been identified, providing information on how to design new herbicides to circumvent this resistance. Microbial biocontrol agents for several weeds are at various stages of development. The bacterial control agent for Hound's Tongue is being commercialized.

Source of Funding: Hatch, State, USDA

Scope of Impact: Regional

Plant Production Efficiency

Activity:
Improving monitoring techniques and cultural controls for the management of insect pests of small grains, forages and oilseeds.

Impact/Accomplishments:
Activities focused on the impact of early cutting and raking of forages as alternatives to pesticide control of the alfalfa weevil. This research demonstrated that early cutting, an important cultural control, can be improved by addition of a raking step to the harvest process. As a result, a savings up to $15 per acre was calculated for alfalfa hay production due to decreased pesticide need for alfalfa weevil control. With 1.7 million acres of harvestable alfalfa hay in the state, if this technique saves an insecticide application on 10% of the total acres, a savings of $2 million can be realized each year.

Source of Funding: Hatch funds, Smith Lever, State

Scope of Impact: Multistate integrated research and extension with WY, ND, CO, NE

Activity:
Elucidating mortality factors of alfalfa leafcutter bees

Impact/Accomplishments:
In western North America, managed populations of the leafcutting bee *Megachile rotundata* are used to maximize seed yield in alfalfa seed production. Producers also attempt to maximize bee production in order to sustain pollinator populations and market bees to other growers. Bee production is often constrained by mortality due to parasitoids and diseases, and by a condition called “pollen ball” (a cell containing pollen, but no developing bee). Research at MSU is aimed at identifying the biotic and abiotic causes of mortality and designing potential low-cost remedies.

Sources of Funding: Smith Lever, State

Scope of Impact: Regional (NW U.S. and western Canada)

Activity:
Research to support the development of the canola industry in Montana.

Impact/Accomplishment:
This project initiated canola and rapeseed variety evaluations in 1986, three years prior to private industry initiating contract production in the state and providing support for research. Canola acreage has stabilized around 30,000-50,000 acres in Montana.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Activity:
Research to control kochia infestations in small grain production.

Impact/Accomplishment:
Kochia is a severe weed problem in all of Montana’s dryland cropping systems. Recent research conducted at SARC and in other parts of Montana resulted in new, effective methods to control kochia by using post harvest management strategies. Recommendations based on this research are presented in a new MontGuide (#200213 “Post harvest kochia management in small grains” by James A. Mickelson, A.J. Bussan, and Ed S. Davis). All 500 copies of the first

printing sold out within 2 months of release. Furthermore, the MontGuide is available on the web and has been downloaded an unknown number of times.

Source of Funding: Hatch**,** State,

Scope of Impact: Integrated research and extension

Activity:
Developing wheat cultivars with increased kernel size to increase crop competitiveness with weeds.

Impact/Accomplishment:
Wheat derived from larger wheat tends to reduce the fecundity and viability of wild oats. Preliminary data also indicate increasing wheat kernel size increases milling and baking quality. This project is expected to impact both production costs and marketability of Montana wheat.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Activity:
Introduction of Haybet awnless hay barley

Impact/Accomplishment:
The popularity of Haybet has grown to the point that it is now seeded on more acres than any other feed grain barley variety. More barley is now grown for hay in Montana than is grown for feed grain.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Activity:
Evaluation of air drill openers to assist growers in the selection of openers appropriate to specific production needs.

Impact/Accomplishment:
Selection and purchase of an inadequate opener type not only results in average direct cash loss of $5,000 per mistake, but wheat yield differences associated with openers can amount to as much as 25 percent. Economic impact potential is very significant. If only a 10 percent yield advantage was gained by equipping air drills with more appropriate openers, and such improvement was made on air drills involved with only 10 percent of Montana's air-drill-sown wheat (approximately 3.7 million acres total) which at 30 bushel per acre and $3.50 per bushel average yield and price respectively, would result in an average gross return increase of $3.9 million.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Activity:
Cooperated on the selection, evaluation and release sawfly resistant winter wheat cultivars.

Impact/Accomplishment:
The sawfly resistant winter wheat cultivars 'Vanguard' and 'Rampart' were released. Wheat stem sawfly causes up to $30 million in crop losses annually. The demand for Vanguard and Rampart seed is exceptionally high. These two varieties will have a major impact on reducing losses due to sawfly.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Precision Agriculture/GIS/GPS

Activity:
Implementing mapping strategies with GPS and GIS for wild oats and wheat stem sawfly in farmer fields. In addition, we have superimposed nitrogen fertilizer over the weed treatments.

Impact/Accomplishments:
Fields with wild oats may be ecological sinks for sawfly larvae because larvae do not survive in the wild oat stems. Residue management practices will be critical for the over wintering of the wild oat seedbank and the wheat stem sawfly. Cutting heights may need to be higher in sawfly-infested areas to allow for natural predators to work on the pest. Spot treatments of wild oat herbicides reduce input costs and decrease the likelihood of resistance development.

Source of Funding: Hatch, State, Smith Lever, USDA

Scope of Impact: Integrated Research and Extension

Activity:
Research on applications of geographic information systems (GIS), global positioning systems (GPS), sensors and remote sensing technologies such as yield monitors, satellite imagery, variable rate application equipment, tracking technologies, and field navigation devices.

Impact/Accomplishments:
Farmers and ranchers have new opportunities to incorporate precise, site-specific information into their decision making process.

Source of Funding: State, UDSA

Scope of Impact: State and Regional

Diversified/Alternative Agriculture

Activity:
Dryland diversified cropping systems.

Impact/Accomplishments:
Demonstrated adaptability of alternative crops such as peas, chickpeas and lentils into wheat and barley systems no-till systems. In addition, organic approaches have been included. Over

the long-term, this will disrupt pest cycles and decrease input costs, and thereby, increase net stakeholder returns.

Source of Funding: Hatch, State, Smith Lever, USDA

Scope of Impact: Integrated Research and Extension.

Activity:
Dryland crop diversification studies

Impact/Accomplishments:
Crop rotations decreased spring wheat production costs by decreasing fertilizer inputs without compromising spring wheat yield or quality. It was documented that diverse crop rotations can positively influence spring wheat yield and quality. Diverse crop rotations and no-till planting can be used to effectively manage disease and weed problems in spring wheat production in Montana. Legume and oilseed crops left sufficient post-harvest residues for protection of soils from wind and water erosion. Differences in insect numbers were recorded among the various crops. Legumes for the most part had the fewest pest problems while wheat following fallow had the highest number of potential pests. Plant diseases were less in no-till than conventionally tilled plots. Fusarium crown rot was found in higher levels in wheat produced with conventional tillage than wheat in zero tillage systems.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Activity:
Field crop production for south central Montana

Impact/Accomplishments:
Field experiments to examine the feasibility of growing soybean as a new annual legume crop for south central Montana in irrigated rotations as a feed protein and high-energy source. Initial studies indicate yield potential and crop quality are superior to levels experienced in traditional mid-western soybean production areas. Added benefits would include rotation-related pest suppression in rotation crops as well as reduced nitrogen fertilizer use. A projected 25,000 acres of soybean would have a minimum economic impact of $ 7 million to the local economy. Computer-based information technology has been implemented to assist in dissemination of SARC research results and recommendations to the public. The center currently possesses full time internet connectivity and is equipped with an on-site server system. Web access at http://www.sarc.montana.edu currently provides current and historical weather information assisting crop management decisions.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Adding Value to Agricultural Products

Activity:
Development of value-added safflower products (high oleic / low saturate and high linoleic / low saturate oils) at the MSU Eastern Agricultural Research Center.

Impact/Accomplishments:
The value-added high oleic safflower oil is higher in monounsaturates than olive oil and lower in saturates than olive oil. The product is grown on 50,000 acres, processed and marketed locally by the safflower oil processing plant, Montola Growers, Inc., in Culbertson, Montana. The safflower meal is utilized by the area livestock industry. The high quality Montola safflower oil has market potential in birdseed, cosmetics, infant foods, lubricants, in dietary food preparation, and as a feed additive for livestock.

Source of Funding: Hatch, State

Scope of Impact: Multistate integrated research and extension with North Dakota.

Agriculture Competitiveness

Activity:
Breeding of field crops including winter and spring wheat, barley, alfalfa, oats, peas, and development of new crops (Indian ricegrass).

Impact/accomplishments:
New Varieties of spring wheat (Explorer), winter wheat (Paul), alfalfa (Cooper) and barley (unnamed) have been released. A new crop (Indian ricegrass) is being commercialized with demand currently outstripping supply.

Source of Funding: Hatch, State, USDA

Scope of impact: Multistate (MT, OR, ID, ND, SD)

Activity:
Measure the effects on meat packer and cattle feeder prices of declining retail beef demand.

Impact/Accomplishments:
Research was conducted measuring the effects of declining retail beef demand (65 percent) on slaughter and feeder cattle prices from 1976 to 1999. The subsequent declines in meat packer and cattle feeder demand reduced producer revenues by $13.3 billion. Programs to increase beef demand would return 58 percent to the marketing system and 42 percent to ranchers and cattle feeders. Real wholesale-retail beef and pork margins increased substantially from 1970 to 1998 due to declining retail grocery labor productivity, increased cost of new services, and increased retail grocery concentration. These factors accounted for a $21/cwt average real price decline in cattle and hogs; thus, policies increasing labor productivity and retail competition would benefit livestock producers.

Funding source: Hatch, State

Scope of impacts: State, Regional and National

Activity:
Estimate impacts on Montana irrigated farmlands, of a change in U.S. sugar import policies.

Impact/Accomplishment:
The effect of sugarbeet prices and changes in U.S. sugar import policies on Montana land prices were investigated. Results indicate quality-adjusted expected prices of sugarbeets

positively influenced land price. Significant reductions in Montana county irrigated farmland prices of 19 percent to 35 percent can be expected if sugarbeet production is closed off due to significant liberalization of U.S. sugar import policies.

Funding source: Hatch, State

Scope of impacts: State and regional

Activity:
Assess impacts of voluntary GMO labels on the demand for retail food products, and thus GMO-wheat varieties.

Impact/Accomplishment:
Research has assessed the impact of voluntary GMO labels on the demand for retail food products. The results are essential for Montana producer decisions regarding adoption of biotech food crops and livestock products. The project addresses a multi-million dollar decision regarding GMO-wheat varieties.

Funding source: Hatch, State

Scope of impacts: Montana and national

Activity:
Investigate impacts of crop pesticide applications

Impact/Accomplishments:
Crop pesticide applications have been investigated. Given the costs of application for some herbicides, an adherence to these recommendations has the potential to reduce herbicide costs on some acres by 50 percent.

Funding source: Hatch, State

Scope of impacts: Montana and national

Key Theme – Animal Production Management Systems

Animal Production Efficiency

Activity:
Sheep Nutrition

Impact/Accomplishment:
Range ewes fed supplement in block form had 30% non-consumers and 37% of animals met target intakes; while ewes fed supplement in pellet form had 2% non-consumers and 83% met target intakes. Lambs subjected to cold stress at birth show an immediate and positive response to safflower supplementation of the ewe during late gestation and colostrum intake. Positive response to late gestation supplemental vitamin E on lamb survival does not enhance immune function. Additionally, although Zn supplementation increases serum vitamin E levels, high levels of dietary zinc may have a negative impact on immune function.

Source of Funding: Hatch, State, Smith-Lever

Scope of Impact: Integrated research and extension.

Activity:
Sheep Reproduction

Impact/Accomplishment:
Selection for reproductive rate in ewes does not alter the mating behavior of male offspring. Testing conditions such as restrained and unrestrained ewes and number of libido tests can affect the evaluation of ram libido. Progestin synchronization of mature ewes does not affect gross oviductal characteristics or protein secretion. Although oviducts of ewe lambs are shorter and weigh less than mature ewes, they contain equivalent quantities of proteins.

Source of Funding: Hatch, State.

Scope of Impact: Integrated research and extension.

Activity:
Wool Quality

Impact/Accomplishment:
Automated, more accurate evaluation of fleece characteristics of purebred ram producers allows more accurate selection of replacement rams by commercial producers.

Source of Funding: Hatch, State, and Smith-Lever

Scope of Impact: Integrated research and extension

Activity:
Crop Pest Management Using Sheep

Impact/Accomplishment:
Preliminary results suggest that grazing of wheat stubble fields by sheep reduces crop residue, and reduces habitat for disease and insect pests such as wheat stem sawfly. Application of this technology will help maintain or improve environmental quality and convert wheat stubble from a liability into a useful feedstuff.

Source of Funding: Hatch, State, Smith-Lever, USDA

Scope of Impact: Integrated research and extension.

Activity:
Beef Cattle Nutrition

Impact/Accomplishment:
Form of trace mineral supplement may alter the effects of antagonistic minerals on animal performance. Cows fed moderate quality forage do not increase forage intake when supplemented with increasing levels of CP. Valier was recently released by the Montana State University Experiment Station, and is the first barley variety to have documented feeding quality prior to its release. Valier and LB13 were selected for their improved agronomic performance. Although feeding value was equal, these lines showed improved agronomic characteristics when compared to the parent lines.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension

Activity:
Beef Cattle Reproduction
Impact/Accomplishment:
Bull exposure increased ovulation rate; however neither bull exposure nor restricted suckling of first-calf suckled beef cows enhanced pregnancy rates in cows synchronized with the OV-Synch protocol. Presence of bulls increases the proportion of beef cows that resume cycling activity after calving. Exposing cows to excretory products of bulls also hastens the resumption of postpartum cycling activity; therefore, the biostimulatory effect of bulls appears to be mediated by pheromones in their excretory products.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension

Activity:
Meat Quality

Impact/Accomplishment:
Finishing beef cattle on specific varieties of feed barley could result in increased color shelf-stability and thus increase the uses of barley for finishing rations. Sire selection based on carcass EPD is effective in altering progeny carcass quality. Selection based on marbling EPD changes USDA quality grade; however selection based on percent retail product EPD may be only marginally effective in changing USDA yield grades.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension

Activity:
Beef Production Efficiency

Impact/Accomplsihment:
Techniques developed at MSU permit animal morbidity to be predicted four days before conventional methods. The ratio of calf weight at weaning to cow weight at weaning appears to be a good predictor of cow/calf biological efficiency under range conditions. For beef enterprises managing forage resources similar to those in the Northern Great Plains, optimal marketing strategies for calves are not constant throughout the cattle cycle and different for different calving seasons. Morbidity of beef calves can be significantly improved by implementing a weaning protocol that includes viral vaccinations, supplemental crude protein, vitamins and trace minerals. A feeder-calf certification program has been implemented for beef quality-assurance trained producers based on best management practices for enhancing calf health. Central to this networking approach is the exchange of information from the producer to the end user (feedlot, packing plant).

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension.

Activity:
Since 1996 'Efficiency and Sustainability of Beef Cattle Production' has provided livestock producers and land managers have been provided new tools to increase uniformity of livestock grazing and correspondingly improve rangeland health and water quality.

Impact/Accomplishment:
On rugged and extensive rangelands, uneven livestock distribution limits the amount of forage available for grazing and may result in natural resource degradation. Cattle can be lured to previously under grazed rangeland on rugged terrain and at long distances from water by strategically placing dehydrated molasses supplements. Grazing use was enhanced by 10 to 20 percent within 600 yards of supplement placement. In addition, producers may be able to improve livestock grazing patterns by selecting breeds that were developed in mountainous terrain. Research conducted at NARC demonstrated that cattle developed in the French Alps (Tarentaise) used higher terrain and steeper slopes than cattle developed in more gentle terrain in England (Hereford). Ongoing research is also investigating the potential of selecting individual animals within a breed to improve uniformity of grazing.

Source of Funding: State

Scope of Impact: State

Activity:
Beef Cattle Improvement

Impact/Accomplishment:
Research shows that selected crossbred cows for Montana environment can wean heavier calves and return $70.00 per cow per year more when compared to straightbred cows.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

PROGRAM 3. AGRICULTURAL FINANCE, MARKETING, AND POLICY

Risk Management

Activity:
Examine the efficiency of a number of crop insurance products, provisions, and incentives and develop provisional changes to reduce adverse selection, moral hazard, and fraud incentives.

Impacts/Accomplishments:
The research found strong evidence of informational asymmetries between producers, insurance companies and governmental agencies. Evidence of adverse selection, moral hazard, and potential fraud was found in most areas and crops examined. Changes were to reduce adverse selection, moral hazard, and fraud incentives were developed, several of which have been implemented via congressional legislation or agency action. These include provisions to enable more accurate tracking of a producer's loss history over time and a statistical screening system designed to identify potentially aberrant conduct or loss patterns. The statistical screening process directly estimates the prevalence and associated costs of a given type of crop insurance misconduct. One version of the statistical screening system is currently being used by the risk Management Agency to screen a majority of insurees in the federal crop

insurance program. Evidence indicated that the premiums charged low risk producers are currently overpriced relative to their inherent risk. Statistical risk indicators were identified that may potentially enable lower risk producers to effectively signal their lower risk status to insurers, resulting in lower premiums and more effective insurance coverage. The results of this project are likely to reduce insurance premium costs to the majority of producers who do not participate in crop insurance abuses. Since a majority of Montana, regional, and national major crop producers purchase crop insurance, the research has the potential to lower insurance premiums for a large number of Montana, regional, and US producers.

Funding source: State, USDA

Scope of impacts: National

TOTAL GOAL 1 Funding- $10,195,694 FTE- 224.7

GOAL 2. A SAFE AND SECURE FOOD AND FIBER SYSTEM

Executive Summary

MAES is involved in two programs that meet the goal, A SAFE AND SECURE FOOD AND FIBER SYSTEM: Production and sale of certified seed is a major program at MAES. Certified seed assures a form of quality food handling. The Food Resource Management program provides one of the most basic needs of a plant breeding program, the maintenance and supply of germ plasm that may contain useful genes not currently present in the breeding lines. The science of plant breeding is responsible for approximately one-half of the dramatic yield gains experienced for most of our major crops over the past few decades. Additionally, genes for resistance to major insects and diseases have been incorporated into successful crop cultivars. The basis for plant improvement through breeding is the exploitation of genetic variability. In order for this variability to be accessible to plant breeders, plant collections must be developed, catalogued, and characterized. Finally, once superior varieties have been developed, it is vital that pure and healthy seed stocks be maintained throughout the seed production and commercialization process. Another source of important genes is the endophytes that live in association with plant species. Characterization of these species has led to the identification of medically and agriculturally important compounds.

The U.S. food and fiber system is responsible for providing consumers with adequate quantities, high quality, and safe food products at reasonable cost. Securing such a system requires responsibilities and efficiencies of relevant market players including producers of raw agricultural commodities, manufacturers/processors, and distributors and retailers. Factors such as flexible markets, price incentive structures, business organization structure and behavior, and public regulation and monitoring are essential to maintaining a progressive food and fiber system into the future. Many of the market and non-market parameters essential to a healthy and secure food system are in a dynamic state such as market concentration, price discovery, value-added opportunities, food-born illnesses, and regulation activities. Research in these areas is vital to examine economic effects on consumers and market participants from current and likely changes in the future.

PROGRAM 4. PLANT GENETIC RESOURCE CONSERVATION AND UTILIZATION

Food Resource Management

Activity:
Plant Genetic Resource Conservation and Utilization

Impacts/Accomplishments:
Most economically important plants are not native to the US. It is important to maintain, characterize, and preserve plants that have been collected throughout the world. These collections serve as a source of diversity that can be incorporated into economically important plant species.

Source of Funding: State, Hatch

Scope of Impact: Multistate, National

PROGRAM 5. FOOD PERFORMANCE SYSTEM

Food Handling

Activity:
State Seed Testing Laboratory

Impacts/Accomplishments:
The service ensures high quality seed free of weed seeds, disease, and other contaminants.
The need for expedient, accurate results is extremely important for everyone involved, whether a small farmer testing their own seed to replant or a large company involved in international shipments.

Source of Funding: State

Scope of Impact: State, Regional

TOTAL GOAL 2 Funding- $51,071 FTE- 3.1

GOAL 3. A HEALTHY, WELL NOURISHED POPULATION

Executive Summary
Projects related to Human Nutrition and Medicinal Plants help MAES meet this goal., a HEALTHY, WELL NOURISHED POPULATION. The effects of improved food product content labeling on consumer purchases of dairy products are being investigated. Initial results indicate that credible and accurate labeling about bST content and organic and non-organic milk products leads to important changes in consumer purchases and, by implication, improved consumer choices. The FDA has set requirements for labeling of the products.

The end use of a cereal defines what quality attributes are desirable in the grain. The milling and baking attributes of cereal such as wheat and barley are unique. Several factors underlie quality parameters of wheat and barley. These include environmental, variation, interaction of genotypes with the environment, and varieties adapted to the climatic conditions of the environment. It is important to understand and improve the quality of all wheat and barley market classes. Sources of new pharmaceutical chemicals have become limited. There is need to tap into the diverse array of microbes associated with plants that may prove to be a source of useful pharmaceutical compounds.

PROGRAM 6. IMPROVING HUMAN FOODS AND HEALTH

Human Nutrition

Activity:
End-use properties of wheat and barley.

Impacts/Accomplishments:
Complementing the traditional domestic bread market an emerging market for wheat in the Pacific Northwest is for noodle production. Examination of the genetics and management practices for noodle and bread production from wheat in the Pacific Northwest aids in identification of wheat varieties with superior quality to enhance marketing opportunities for farmers in Montana and other states.

Source of Funding: State

Scope of Impact: National

Medicinal Plants

Activity:
Endophytes of plants: their biology, economic value and potential use.

Impacts/Accomplishments:
Unique chemicals are produced through the interaction of plants with their endophytes which have multiple impacts on our society by virtue of the development of new knowledge, national and international patents that have and will be licensed to pharmaceutical, agricultural and industrial based companies.

Source of Funding: Hatch, State

Scope of Impact: National

TOTAL GOAL 3 $214,538 FTE- 5.4

GOAL 4. AN AGRICULTURAL SYSTEM WHICH PROTECTS NATURAL RESOURCES AND THE ENVIRONMENT

Executive Summary

MAES Research Centers are focused on Biological Control of Weeds, and Soil Quality. We are involved in two multi-institutional and multi-state projects. One is “An Evaluation of the Effectiveness of Livestock Distribution Practices of Grazed Watersheds,” and the other is “High-Value and Alternative Crop Production for Eastern Montana.” Also, successful patterns of sagebrush communities are being researched and considered in relation to fire recovery under a wide variety of conditions.

A survey of hunter management strategies used by ranchers in Montana has been completed. Findings led to the development of landowner/hunter education programs aimed at landowner concerns. A project currently underway includes a study attempting to identify prescriptions to use livestock grazing to improve habitat for elk. Elk and cattle habitat use patterns are being monitored.

IPM seeks to optimize grower profitability and natural resource sustainability through development, selection and implementation of appropriate pest management tactics that are economically sound and environmentally acceptable.

Cropland weeds are the major pest impacting Montana cropland agriculture. Developing integrated weed management systems requires the study of weed biology, herbicide efficacy, and crop performance. Field and greenhouse studies were utilized to quantify these relationships and develop management strategies for the numerous weeds impacting small grain production.

Relationships among streamside and wetland vegetation, hydrology, water quality, and ag land management were emphasized in greenhouse and field studies. In cold winters, low-cost artificial wetlands potentially can treat wastewater from agricultural facilities and small towns in Montana. Correct selection of plant species greatly impacted nutrient removal and sediment retention. Results imply that species should be matched to site conditions to improve odds of successful ecological restoration.

The movement of chemicals through soils under different water conditions can negatively impact water quality. Water shortages, increased multiple use pressure for water resources, and surface water runoff all speak to efficient uses of irrigation water. Field and laboratory experiments were conducted to evaluate the calibration of approaches with TDR to provide real-time estimates of solute (i.e. fertilizer salts) distributions in soils. This increases our ability to more intensively manage agricultural inputs in fields, increase resource utilization efficiency, and improve environmental quality.

Montana producers are continually challenged by myriad pests to produce crops and livestock in an efficient and economical way. Many of these competitive pests require pesticides to significantly reduce their direct impact on food and fiber production. Increasing public concern related to food quality, natural resource biodiversity, and sustaining the quality of soil, air, and water are mandating less reliance on pesticides and more on non-chemical pest control options. IPM seeks to optimize grower profitability and natural resource sustainability through development, selection and implementation of appropriate pest management tactics that are economically sound and environmentally acceptable. IPM systems are dynamic and the application of IPM is site-specific in nature; selection of individual tactics is determined by the particular crop-pest-environment scenario. IPM research and education programs need to integrate new technologies that are rapidly advancing agriculture production (e.g., remote sensing, molecular biology, chemical ecology) into improving existing pest management systems and developing new ones.

Landscapes are diverse mixtures of biological, chemical and physical processes in soil, plant communities, and surface and groundwater systems. Land management

practices impact these components and potentially change the quality and quantity of soil, plant, and water resources. As a headwater's state with multiple land uses, Montana is in a unique position to understand how land management practices, e.g. grazing of riparian areas, fate and transport of applied pesticides and natural constituents, impact ecosystems. From pristine to highly managed land uses, the multitude of practices that occur on the Montana land surface influence environmental quality, economic vitality, and, ultimately, quality of life. For example, rangelands comprise 70% of the land area in Montana. The greatest environmental challenge is better management of cattle grazing in concert with riparian habitats, wildlife, and clean water. Characterization and understanding of the complex interactive components will lead to improved soil, plant, and water resources in ecosystems.

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. The sustainability of alternative land uses is equally critical for public and private lands. Because private and public lands comprise common ecological resources (e.g., river systems, wildlife) it is also important to study these lands together. Current and future changes in economic conditions, agricultural policy, and environmental policy raise serious questions about agriculture. Understanding how the various land uses (e.g., farming, ranching, timber, recreation, mining, development and subdivision) are determined is crucial in determining the sustainability of these lands. In order for farmers, ranchers, forestland companies, and public land mangers to adapt to changing conditions it is essential that they be provided with information in the link between economic decisions, government programs, land use, and sustainability. Economic analysis of these issues can provide this information.

PROGRAM 7. INTEGRATED PEST MANAGEMENT

Integrated Pest Management

Activity:
Cropland weed control practices

Impact/Accomplishments:
Applications of herbicides at the 1-2 leaf stage reduced yield loss compared to applications at later growth stages. Bioeconomic models are being developed which include the emergence of the crop relative to weed seedlings. Ultimately, weed population thresholds and crop density will help to determine the most economical herbicide to use over multiple years.

Source of Funding: Hatch, Smith Lever, State.

Scope of Impact: Multistate Integrated Research and Extension (CO, ID, KS, MT, NE, UT, WA, WY)

Activity:
Wheat Stem Sawfly Management

Impact/Accomplishment:
The wheat stem sawfly, a perennial small grain pest in Montana, cannot be managed by conventional agricultural practices (e.g., burning, tillage, swathing, insecticides). Thus, there is

an urgent need to develop new tools for its management. Recent advances in the understanding of sawfly ecology are providing tools for development of innovative management strategies for this pest. These include the investigation of two sources of compounds discovered in wheat fields in Montana that are toxic to this insect. One source is microbial and the other is from commonly occurring grass species. The compounds responsible for the plant toxicity are being characterized using analytical equipment and biological assays. Research efforts have also identified chemical odors that are used for sawfly mating and for location of host plants. Behavior-modifying chemicals, pathogens, and plant-derived toxins are highly desirable management tools because minute amounts are needed to be effective and they pose limited environmental challenge. New analytical equipment designs and recent chemical techniques have simplified ongoing research, and will lead to an integrated biorational sawfly management program. Overlapping research approaches are being used for these novel naturally occurring chemicals. The first focuses on pheromones which are produced by sawflies when they are searching for suitable mates. Second, plant odors from cereal crops and feral grasses that act to attract or repel sawflies and aphids are being identified. Third, we are investigating methods for enhancement of parasitoid efficacy. These natural enemies of the sawfly and cereal aphids are endemic to Montana. The parasitoids are attracted to odors produced by infested plants. Plants vary in the amount of odors that are produced, therefore this is a new tool that can be used by wheat breeders to promote biological control.

Source of Funding: Hatch, State, USDA

Scope of Impact: State and Regional

Activity:
Cereal Leaf Beetle Management

Impact/Accomplishment:
Cereal aphids can cause up to $5 million in losses during outbreak years in Montana. Cereal aphid control relies primarily on insecticides, which are very costly to use in wheat production, because of the low profit margin for production. Cereal aphids can cause up to $5 million in losses during outbreak years in Montana. Cereal aphid control relies primarily on insecticides, which are very costly to use in wheat production, because of the low profit margin for production. This is a potential source of resistance that can be incorporated into new wheat breeding lines. Economic thresholds for cereal leaf beetle in barley and spring wheat were examined and based on research conducted in irrigated barley, an economic threshold of two to five cereal leaf beetle larvae per tiller was determined to cause a significant reduction in grain yield and can be adjusted for the cost of insecticide application and crop value. As this pest continues to spread into the Pacific Northwest, this research has the potential application to a much larger region. This research was conducted in collaboration with University of Wyoming. Cereal leaf beetle monitoring studies indicate that populations were not economical and therefore insecticide applications were not needed. This saved at least 10,000 acres of malting barley from being treated with insecticide ($12 per acre) at a total savings of $120,000. At the current distribution of cereal leaf beetle in Montana, the potential acreage affected by this pest is 950,000 acres of spring wheat and barley. Improved economic thresholds and monitoring guidelines have the potential of saving Montana producers hundreds of thousands of dollars.

Source of Funding: Hatch, State

Scope of Impact: State and Regional

Activity:
Regional cutworm-monitoring Program

Impact/Accomplishment:
A regional cutworm-monitoring program has been in place for more than 10 years. Activity of adult pale western and army cutworms are monitored using pheromone traps to indicate relative activity of each species in an area and provide a prediction of cutworm larvae and damage the following spring. Correlations between trap catches and larval densities and critical weather data are being developed for a regional forecasting model. Because extensive larval cutworm damage can occur rapidly in the spring, cutworm moth catches reaching or exceeding economic thresholds in the fall can be used to alert producers in those areas about potential cutworm problems the following spring.

Source of funding: Hatch, State

Source of Impact: State and Regional

Activity:
Integrated Pest Management in Canola

Impact/Accomplishment:
One of the most damaging insect pests in canola production is the crucifer flea beetle. A two-year study found that flea beetle damage to emerging canola plants was reduced when grown under a no-till system compared to conventional tillage. These findings suggest that an insecticide seed treatment can be eliminated when planting canola into no-till grain stubble. This would have a stakeholder savings of $8 - 10 per acre and reduce seed treatment applications and foliar insecticide treatments. The cabbage seed pod weevil was found in economically damaging levels in canola throughout a large part of the canola production region in Montana. Economic infestations of 35% were recorded in canola fields in northern Montana. This necessitates the need for development and implementation of a pest management program for this pest of canola.

Source of Funding: Hatch, State, Hatch, USDA

Scope of Impact: National

Biological Control

Activity:
Insect Quarantine Laboratory

Impact/Accomplishment:
In Montana noxious weeds are of major economic importance. To control these pest species, a variety of control techniques must be utilized, including biological control utilizing exotic arthropods and plant pathogens. The primary objective of the MSU Biological Control Containment Facility is to facilitate the importation, augmentation, study, and release of potential agents for the biological control of noxious weeds of regional importance. Twenty shipments representing 13 arthropod species and several pathogen strains were received in 2002. These included: *Tyta luctuosa* for the control of field bindweed, *Aulacidea subterminalis* (hawkweeds), *Spurgia capitigena* (leafy spurge), *Bradyrrhoa gilveolella* (rush skeletonweed), *Urophora kasachstanica*, *U. xanthippe*, a chrysomelid beetle, *Aceria sobhiani*, and *Aceria acroptiloni* (Russian knapweed), *Aceria thessalonicae* (diffuse knapweed), *Longitarsus jacobaeae* (tansy ragwort), and *Cephus fumipennis* & *Collyria* sp. (a parasitoid for wheat stem sawfly). Various strains of pathogens have been brought into the containment lab for the control of leafy spurge and Canada thistle.

Source of Funding: State

Scope of Impact: State
Activity:
Biological Control of Leafy Spurge, Spotted Knapweed and Dalmation Toadflax

Impact/Accomplishment:
Infestations of rangeland weeds, leafy spurge, spotted knapweed and Dalmatian toadflax continues to rank among the most serious pests affecting rangeland and agricultural production. The occurrence of these weeds on rangeland limits the amount of money which can be justified for conventional weed management. Many of these infestations occur in areas in which it is impossible or undesirable to apply herbicides. Thus, effective and environmentally safe methods of weed management, such as biological control, are being developed for long term management of weeds on lands of low economic return. Habitat association models were developed for five flea beetle species that are established on leafy spurge. These models relate flea beetle abundance with particular chemical and/or physical properties of the soil, chemical properties of the spurge roots/foliage, and levels of plant productivity. A dynamic state variable model was developed for two seed head flies that attack spotted knapweed. Starch-gel electrophoresis results suggest that weevils found on Dalmatian toadflax are genetically distinct from those found on yellow toadflax, indicating the possibility of host races in the weevil species.

Source of Funding: Hatch, State

Scope of Impact: State and Regional

Activity:
Introduction of 12 biological control agents against spotted knapweed in Montana.

Impact/Accomplishment:
Two seed head flies (*Urophora* spp.), introduced in the 1970's, are widespread throughout Montana and are reducing knapweed seed production by a minimum of 50 percent. This program has reared and redistributed an estimated 313,000 *Agapeta zoegana* (root moth) and 93,000 *Cyphocleonus achates* (root weevil) during the past 9 years. Interaction with more than 120 cooperators has resulted in the release of these two insects at over 3100 sites in the state. These efforts are beginning to have measurable negative impacts on knapweed growth and survival. Knapweed infestation is conservatively estimated to cause $14 million in direct negative impacts and $28 million in indirect effects to the state of Montana.

Source of Funding: Hatch, State

Scope of Impact: State, Regional and International

PROGRAM 8. IMPROVING SOIL, PLANT, AND WATER RESOURCES IN ECOSYSTEM

Biodiversity

Activity:
Montana Entomology Collection

Impact/Accomplishments:
Biodiversity documentation in Montana provides knowledge of the existence and distribution of species for management of public lands and the ability to use them without legal challenge. The Montana Entomology Collection is the largest repository for information on the existence and distribution of species in Montana. It continues to grow apace, and it is used by public land managers to achieve and document compliance with appropriate laws.

Source of Funding: State

Scope of Impact: State

Activity:
Grazing to Manage Insect Pests

Impact/Accomplishment:
Grazing research has focused on quantifying the abundance and community composition of grasshoppers and how they are affected by differential cattle grazing. Intensive grazing was shown to influence the species of grasshoppers that occupied rangeland. Important rangeland pest species were less abundant in heavily grazed plots than ungrazed plots.

Source of Funding: Hatch, State

Scope of Impact: Regional

Natural Resource Management

Activity:
Artificial wetlands were created and monitored under controlled growing conditions in the greenhouse and the effluent was monitored for multiple climatic cycles.

Impact/Accomplishments:
Identified key plant species for optimum performance of nutrient uptake and sediment retention. These artificial wetlands could be used in the tertiary water treatment processes. Although traditional approaches were not compared, the biological nature of the system would most likely make this an economically feasible approach. The system should, however, be tested in northern climates to fully determine adaptability.

Source of Funding: Hatch, Smith Lever, State

Scope of Impact: Integrated Research and Extension.

Activity:
Rangeland Ecology

Impact/Accomplishment:
Successional patterns of sagebrush communities are being researched in relation to fire recovery under a wide variety of conditions. Investigations continue on the effects of herbivory on several shrub types, and the nutritional relationships of different sagebrush taxa with a variety of foraging histories. Natural resource agencies are adapting policies based on this research.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension.

Activity:
Riparian Ecology
Impact/Accomplishment:
Information developed via on-going research efforts will provide cost estimates for the preservation and enhancement of threatened trout populations in conjunction with irrigation and fertilization strategies that have the potential to maintain farm and ranch economic viability.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated research and extension.

Activity:
Grazing Behavior

Impact/Accomplishment:
Identifiable and stable social dominance hierarchies appear to exist in rangeland cattle. Habitat use patterns of the cows are influenced by their social rank. Therefore, if herd size remains unchanged, culling of individual cows based on their habitat use patterns is unlikely to reduce cattle use of any sites in a pasture. Windbreaks are of minimal benefit to cattle grazing foothill rangelands during winter. Cattle activity patterns and orientation are highly responsive to weather, which may explain minimal changes in backfat, body weight, immune response, and reproductive efficiency. Cattle may benefit considerably from the winter sun, which lowers their need to increase intake, or use endogenous reserves. Increased winter grazing could help lower winter feed costs.

Source of Funding: Hatch, State, Smith-Lever, USDA

Scope of Impact: Integrated research and extension

Activity:
Wildlife-Livestock Interactions

Impact/Accomplishment:
Approximately 12% of ranchland in Montana is closed to hunting. Most ranches have their land open or require only permission and the size of the ranch influences strategies. Landowner/hunter educational programs targeting landowner concerns have been developed. Studies of spatial, temporal, and dietary overlap between beef cattle and elk suggest that mid-elevation sage-grasslands used by elk in the spring may be potential areas for competition. In fall and winter elk exhibit preference to foraging sites that have been moderately grazed by cattle the previous spring or summer.

Source of Funds: Hatch, State, Smith-Lever, USDA

Scope of Impact: Integrated research and extension.

<u>Soil Quality</u>

Activity:
Researching stubble management to conserve moisture and protect crops and soils with the goal of increasing and stabilizing crop production.

Impact/Accomplishment:
No-till research at Western Triangle Ag Research Center showed increased moisture conservation; improved stand establishment in dry years; increased winter survival; decreased air and water pollution; decreased soil erosion; decreased production costs; and increased crop yield. Grower adoption of no-till chem-fallow continues to be enhanced by this research activity. Stand establishment for canola has been far more successful with no-till than tillage systems because no-till maintains moisture closer to the soil surface.

Source of Funding: Hatch, State

Scope of Impact: Integrated research and extension

Water Quality

Activity:
Soil Water Measurements and discharge waters from coal bed methane development

Impact/Accomplishments:
New methodology has been developed to measure *in situ* water contents across the entire soil wetness range, ability to maintain hydraulic continuity across a wide range of porous media, and efficiency based on using the same instrumentation for all measurements. In addition, the capability to measure chemical transport has been improved. This will lead to superior water and chemical use efficiency and improved environmental quality. Initiating research on the impacts of coal bed methane extracted water on soil productivity, plant adaptation and growth, and water quality.

Source of Funding: Hatch, State, USDA

Scope of Impact: Integrated Research and Extension.

PROGRAM 9. ECONOMICS AND SUSTAINABILITY OF PUBLIC AND PRIVATE LANDS

Land Use

Activity:
Investigate crop fallow techniques to sequester carbon dioxide in soil and raise income while contributing to environmental goals.

Impact/Accomplishments:
Montana farmers who reduce the use of fallow and who adopt reduce tillage practices may be able to sequester atmospheric carbon dioxide in soils and increase the long-term sustainability of the dryland grain production systems. MSU research shows that Montana farmers could successfully compete in a national carbon emissions trading system, thereby raising agricultural income while contributing to environmental quality.

Source of Funding: Hatch, State, USDA

Scope of Impact: State

Activity:

Assess effects of higher carbon dioxide levels on yields and farm incomes in possible warmer and drier climate.

Impact/Accomplishment:
Montana's dryland grain production system is vulnerable to the changes in climate (drier, warmer) that have been observed during the past several decades. Without the offsetting yield enhancements of higher CO_2 levels, 50% or more could reduce yields and incomes. The lower-productivity areas of Eastern Montana are more vulnerable to these changes than the more productive north-central region, although the degree of vulnerability depends critically on the prices of grains and livestock.

Source of Funding: State, USDA

Scope of Impact: State

TOTAL GOAL 4 Funding- $1,548,122 FTE- 37.1

GOAL 5. ENHANCED ECONOMIC OPPORTUNITY AND QUALITY OF LIFE FOR AMERICANS

PROGRAM 10. BIOBASED PRODUCTS AND FOOD SCIENCE

The future of Montana's agricultural economy depends on maximizing net returns per acre or per animal unit with the most efficient use of our resources. The development of value-added end-use products in particular, biofuels, plastics, pharmaceuticals, etc. could potentially further improve our agricultural base. Montana exports approximately 85% of its raw commodity products. Improved quality of existing commodity products will increase demand in the world marketplace. Currently, Montana's wheat is marketed predominately in the Pacific Rim and is recognized in this market for its high quality. In the future, it will be increasingly important to add value to raw agricultural commodities and processed food products before they leave the state. The revitalization of agriculture and rural communities in Montana is essential for the state's economic sustainability and competitiveness in the global marketplace. Advances in biotechnology and information technology are and will continue to have an increasing impact on agriculture, the properties of food, and the ability to manage the environment. Montana producers must address production from a precise systems perspective that reduces input costs and minimizes environmental impacts while optimizing yield. A biobased economy will provide in-state manufacturing, product development, rural development, and jobs. Additionally, food and national security issues will be addressed. Food systems will be safer and more sustainable, the environment cleaner, and producers will have expanded opportunities for success.

Biobased Products and Food Science

Activity:
Institute for Biobased Products and Food Science

Impacts/Accomplishments:
The Institute for Biobased Products has been established and, in addition to the state funding, federal funding is complete. A biobased food science and technology program will facilitate in

Montana and the region product development, value-added commodity products, food safety, marketing, and science-based risk assessments of agricultural and environmental technologies (e.g., biotechnology, pesticides).

Source of Funding: State, USDA

Scope of Impact*:* Regional

TOTAL GOAL 5 Funding- $411,979 FTE- 5.8

Stakeholder Input

The Montana Agricultural Experiment Station (MAES) and College of Agriculture (COA) uses multiple approaches to obtain stakeholder input on programs conducted and actively solicits input on changes in program direction by the methods shown below.

MAES Advisory Committees: Each of the seven MAES research centers has an advisory committee consisting of at least one member from each of the counties in the represented districts. These individuals are nominated by the local county agent and are active in the their local commodity groups. These committees meet at least once annually to review research projects and provide input on new research directions. Each center also conducts field days for the presentation of research to clientele and the public in general. Scientists from the department also present research results at growers meetings throughout the state. These formal activities, along with informal visits with clientele, provide hundreds, perhaps thousands, of opportunities annually for clientele to gain knowledge**.** The State advisory committee includes one elected member from each individual research advisory committee and representatives of the major Montana commodity groups, i.e. Montana Stockgrowers Association, Montana Grain Growers, Montana Farm Bureau, Montana Wheat and Barley Committee. Term limits of two to three years are applicable to all advisory committee members. The local and state advisory groups provide a direct line to all stakeholders in the state of Montana. Special topics or program needs of Montana producers (stakeholders) are addressed internally at annual planning conference.

Extension: The Cooperative Extension Service manages the budgets for extension programs; however, colleges are responsible for extension programs outlined by their faculty. The Dean of Extension now meets on a regular basis with department heads and the Dean and Director of MAES to discuss programs and future joint priorities.

Commodity Groups: Several major commodity groups provide funding for various areas of research. These include, but are not limited to, the Montana Wheat and Barley Committee, the Montana Sugarbeet Growers, the Montana Mint Growers and the Montana Fertilizer Advisory Board. Research is funded on a competitive basis from proposals submitted by MAES faculty. These groups not only have direct input in the research they fund but also make recommendations for other areas of research where they feel there is a need.

USDA – ARS: Joint research programs are conducted with USDA - ARS in Miles City (Fort Keogh Livestock and Range Research Laboratory) and Sidney (Northern Plains Agricultural Research Laboratory).

Council for Agricultural Research, Extension, Teaching (CARET): CARET members in Montana provide an avenue for MAES dialogue on a county and state level where program

issues and needs are discussed. THE MAES State Advisory committee includes the Agricultural Experiment Station CARET representative.

Under Served: Native Americans constitute the majority of those considered under served in Montana. The Native American population in Montana is more than 50,000. There are 11 tribal groups and 7 reservations (5.5 million acres). Initiated programs such as "Agriculture in a Global Context" with Dull Knife Memorial and Fort Peck Community Tribal Colleges are continuing. MAES and the COA are in the process of increasing partnerships and programming efforts with the Tribal Colleges in Montana. Native Americans are directly involved in the integrated weed management practices, while preserving native and culturally unique plant species.

Informal: Stakeholder input also occurs informally by one to one contacts with producers at research center field days, telephone calls, and written correspondence. Several Departments rely heavily on field studies conducted on stakeholder lands that lead to management decisions, by the landowner or land management agency. They directly participate in the development of research questions, design layout, monitoring, and practical interpretation of results, when available. Also, in most situations they provide partial funding for the research.

Listening Sessions: Although it is the intent of the Director to annually hold one or more open-to-the public, out-in-the-state listening sessions this was not accomplished this year. Due to budget constraints MAES does not have an Associate Director and the Director is performing the duties of both positions and time availability is a major factor. However, in view of the above the Director does attend the annual meetings of the major Montana Commodity groups and makes presentations, allowing time for a question and answer period. Topics, both positive and negative, addressed at commodity group meetings are immediately addressed internally with department heads. Due to the expected state budget reduction for the next biennium the ability to travel to commodity group meetings will be curtailed. MAES values the input of all stakeholders and strive to meet their needs by the methods summarized above.

Program Review

Hatch Projects are subject to a very strenuous review beginning at the department level, followed by a peer review with final approval at the Director's level. The MAES Director's Office is responsible for oversight of the 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. Seminar schedules are also made available to all faculty and their attendance and input is encouraged. Reviewers written recommendations are on the following items: relevance and importance; relation to previous research; objectives; approach and methods; scientific and technical quality; resources; and environmental, economic, and/or social impacts are complied and provided to the PI during a meeting with the MAES administrator and department head. The PI is required to revise the project as recommended by the reviewers'. The project is then resubmitted to the MAES administrator and department head for additional review and approval. After the project has been approved by the MAES administrator and department head it is submitted to the director for final approval. Any projects that do not meet the expectations will not be approved and deferred until all of the key elements listed above are 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 and affiliated areas. 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 component 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, that incorporate both target and nontarget organisms.

In conjunction with the states of Alaska, CA-Berkley, CA-Davis, CA-Riverside, New Mexico, and Oregon, MAES faculty participated in W-147, 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 can result in severe losses for growers. Economic losses to soilborne pathogens are estimated at 50-75% of the attainable yield for many crops. 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 agriculture industries. About 90% of the major diseases of the principle crops in the US are caused by soilborne plant pathogens. It has been estimated that the monetary losses to soilborne diseases is in excess of $4 billion /year. While a number of biocontrol agents are now available commercially, problems with production, storage, delivery, reliability, efficacy, establishment and understanding mechanisms of action have prevented most biocontrol products for plant disease control from becoming established in mainstream agriculture. We believe that tremendous progress has been made in the field of biological control of plant disease and this project has been a major contributor to this progress. Members of this research group seek to find environmentally friendly solutions for management of plant pests. Towards this goal, we are examining both basic and applied research areas.

Biological diversity in plants benefits human welfare both directly and indirectly. Plant species are used directly to satisfy basic human needs for food, fiber, domestic animal feed, and indirectly to support many biological processes essential to human survival and progress such as pharmaceutical applications or as sources for chemicals used in industrial processes. Cultivated plants are part of our human heritage. W-006 Plant Genetic Resource Conservation and Utilization, assures a food source without which we would not be free to engage in or to afford activities associated with the quality of life considered normal in the United States. The value of U.S. farm products was $43 billion in 1994 and crop exports make up 9% of the total U.S. export revenue (1995 U.S. Agricultural Statistics). 972 million acres of the U.S. are farmland. A key to the current and continued productivity of the U.S. agricultural sector has been the development of the scientific disciplines associated with the conservation and utilization of plant genetic resources.

New approaches for maintaining quality of cereals and oilseeds from harvest to delivery, while preserving environmental quality and consumer safety, must be developed and implemented if the U.S. is to remain at the forefront of the world's major producers. NC-213, Marketing and Delivery of Quality Cereals and Oilseeds, research activities will continue to advance scientific

knowledge and generate new technologies and methodologies. Outcomes will be published in scientific journals and extension delivery of information will be achieved using multiple media approaches. Some technology advances will be transferred to the industry through patents to enhance commercialization opportunities. New varieties to expand market opportunities and add value to cereals and oilseeds will be developed and released.

Despite recent advances in reproductive technology, cattle and sheep producers are still faced with the persistent problem of low fertility. Indeed, recent work indicates that the fertility of domestic ruminants, even under optimal conditions, is about 50%. That is, at best, 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 also 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. Additionally, we expect that our efforts will result in the development of effective and efficient methods of immunocastration for use in male and female calves and lambs.

Montana is part of a three-state project, An Evaluation of the Effectiveness of Livestock Distribution Practices on Grazed Watersheds, which includes the University of California, Davis, Oregon State University and USDA-ARS, Burns, OR. Ongoing research from this project has shown the potential to manipulate cattle grazing to improve uniformity of grazing. The proposed research will continue the development and evaluation of novel management tools designed to prevent heavy grazing in sensitive rangeland areas and increase use of areas that typically are under grazed. Improving the uniformity of grazing increases the sustainability of rangeland livestock operations, prevents degradation of fisheries and wildlife habitat and helps ensure the water quality is maintained and improved.

High-Value and Alternative Crop Production for Eastern Montana was involved in 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. An MSU faculty member serves as the superintendent/director of both of these research centers. Approximately 42,500 acres of sugarbeets were grown in the MonDak region. A conservative value of $900 per acre generated more than $38 million in sugarbeet payments to this region's economy. Investments in sugarbeet research has supported the expansion of the Holly Sugar Corporation and the expansion of the sugarbeet acreage from 35,000 to 48,000 acres with a phase II expansion to 80,000 acres scheduled over the next five years. 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 grown in eastern Montana at this time and the sugarbeet industry provides many jobs both in beet production and the processing, refinement, and marketing of the sugar. The Lower Yellowstone River Valley consistently produces the highest quality sugarbeets in the United States.

A number of MAES researchers collaborated together 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 (*Aegilops cylindrica*) 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 *A. cylindrica* 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, and Wyoming. This NASA sponsored effort builds upon the leadership in this department and collaboration of scientists in MT, WY, ID, ND, and SD.

Through cooperation with the Wapiti Ridge Coordinated Resource Management Program (WP-CRMP) in Cody, WY and two ranches near White Sulphur Springs, MT research is being conducted on elk and cattle habitat use patterns. These are being monitored twice monthly via systematic aerial surveys from fixed-wing aircraft. At each ranch, enclosures have been erected at sites representative of the following vegetation types: sagebrush steppe, riparian areas adjoining sagebrush steppe, coniferous forests, montane parklands, and 2 types of seeded tame pastures. Fecal samples from both cattle and elk are being collected each month.

A companion project also is being conducted in cooperation with the Wapiti Ridge Coordinated Resource Management Group (WR-CRM). All data collection occurs on these four ranches. Land managed by each ranch represents a combination of private, state, and federal (Bureau of Land Management and U.S. Forest Service) ownership.

Integrated Research and Extension Activities

Most Montana State University College of Agriculture faculty have dual appointments involving two of the three functional areas (i.e., extension, research, 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, but are not credited for these activities. MAES and the Montana Cooperative Extension Service are assessing future joint appointment needs. 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 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 different 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.

Fusarium Yellows. This disease is common on more than 40,000 acres and in 1994 only one resistant variety was available to growers and this variety had 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 income in MT. 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.

Cercospora Leaf Spot. This disease would reduce growers profits by $70-165.00 per acre on more than 60,000 acres in MT if no fungicides were applied for control. MAES research at the Eastern Agricultural Experiment Station demonstrated to both growers and the sugar companies that control of this disease was required to maximize economic return and that a weather-based disease prediction program could potentially reduce fungicide use as compared to calendar spray programs. In 1994, less than 20% of the acres were sprayed for control and by 1997 this increased to over 99% in the Sidney factory district (Holly Sugar) and to 20-25% in the Billings Factory district (Western Sugar). In 1997 the weather-based Minnesota Prediction model for Cercospora Leaf spot infection and loss was implemented in 4 sites and validated for MT conditions. In 1998, through the use of extension education programs the weather-based prediction model was used on 17% of acres and in 1999 67% of acres were using this model to predict the need to spray. By 2000, extension education programs resulted in scouting for Cercospora and weather based forecasting being used on 100% of the acres in MT. Extension pathologists trained growers and both Coop and sugar company personnel on scouting and weather-based disease prediction and they implemented the scouting and weather monitoring program. This resulted in saving an average of 1 spray on 50,000 acres and 2 sprays on 30,000 acres with no loss in disease control in 1999 and 2 sprays on 77,000 acres in 2000. This resulted in saving more than $1.8 million in 1999 and $2.3 million in 2000, 2001 and 2002 as compared to a calendar based spray program. In Cercospora research, we demonstrated that use of a moderate level of resistance would allow growers to save 1-2 sprays compared to that needed on susceptible varieties without reducing yields. This data has been used by the Holly Sugar-Sidney factory district to require new approved varieties have a moderate level of Cercospora resistance (KWS score less than 5.0). The impact of this work is that approximately 50,000 acres would receive one less spray @$15.00 per acre = $750,000. In 2002 all susceptible varieties (KWS scores > 5.5) have been eliminated form the approved list since the more resistant varieties have given equal yields with 1-2 fewer applications of fungicide. This should save growers in the Sidney factory district $940,000-$1.8 million in fungicide and application costs in 2003.

Rhizoctonia Crown and Root Rot. The new fungicide management program developed by MAES research and taught in extension education programs was used on 1500 acres in 1999 and more than 4500 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.

Aphanomyces Black root rot. This disease is both difficult to identify and to control. MAES research identified this as a significant problem for MT growers in 1994 and this project began a research effort to develop control strategies. Control is difficult because resistance is incomplete and there are no varieties adapted to MT. The fungicide seed treatment Tachigaren is moderately effective in reducing seedling losses but must be used with pelleted seed due phytotoxicity. In 1995 several promising rhizosphere inhabiting Bacilli were identified that provided control equal to Tachigaren. These were tested in production fields in 1996-2002 the result of this research is the identification of MSU 341-16-5 a Bacillus pumilis strain that provides better control of Aphanomyces than Tachigaren, better control of Pythium and Rhizoctonia than the standard seed treatment Apron-Thiram and does not have to be used with pelleted seed. In 28 location years of data using commercially treated seed, this isolate provided higher final stands and an average of 670 lbs/A more extractable sugar per acre than the standard seed treatment Apron-Thiram or Apron-Thiram -Tachigaren. This isolate will be developed commercially.

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 $300.00/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.

Pale western and army cutworm**.** Sporadic pests of Montana's 5 million acre wheat crop, cutworms are difficult to control because intensive monitoring for this pest is time consuming and costly. Typical spray applications for this pest are estimated to cost $12/acre. Significant damage can be sustained before management practices can be implemented. A monitoring program was initiated in 1992 for adult moths to forecast potential larval populations in the subsequent spring. However, its usefulness was limited by the inability to incorporate influential environmental effects into the forecast. Recently, competitive grant funds have been obtained through the Western Regional Integrated Pest Management Program to improve our ability to predict occurrence of damaging numbers of these pests and expanded the program into Wyoming, Nebraska and South Dakota. Both temperature and moisture have been incorporated into the forecast and have improved the ability to interpret monitoring program results. Results of this program have been delivered through numerous Extension programs in Montana and are available on the web at http://cutworm.org.

Cereal Leaf Beetle. 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 $12.00/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.

Alfalfa Weevil. An improvement in early cutting as a management strategy for alfalfa weevil has been developed at MSU and is responsible for reducing pesticide applications and improving the economics of alfalfa weevil control. Early cutting is a cultural control method for alfalfa weevil that is very effective in Montana because of the synchrony of the insect population and

alfalfa growth and development. However, early cutting does not necessarily eliminate the need for a pesticide application following harvest to control the alfalfa weevil. By raking hay during harvest, alfalfa weevil populations can be reduced an additional 50% over early harvest alone. This reduction can make a post-harvest pesticide unnecessary resulting in a savings of $12 to $15 /acre. With 1.7 million acres of harvestable alfalfa hay in the state, if this technique saves a pesticide application on 10% of the total acres, a savings of $2 million can be realized.

Non-irrigated alfalfa production represents 54% of the 1.7 million acres of alfalfa harvested in Montana. Research conducted at MSU found that insecticide treatment of dryland alfalfa resulted in a 35% yield increase due to pressure by spotted alfalfa aphid and the alfalfa weevil larvae. These results have been presented through Extension programs throughout Montana. Timing of insecticide treatments is also being investigated.

Lamb Survivability. To date, ten studies have been conducted. The field data analysis and draft manuscript of one of these studies will be completed in the Fall of 2002. Completed research has addressed serum vitamin E, immune function and reproductive performance as influenced by dietary supplementation; effects of supplement form on ewe response; effects of feeding management strategy and dietary supplementation with high linoleic safflower on growth and carcass performance; and the effects of selection line and estrus induction on reproductive performance. Neonatal lamb losses are a major drain on profitability to U.S. lamb producers. Typically, starvation and hypothermia are the major causes of mortality. In our studies, lambs subject to a controlled cold stress at birth show an immediate and positive response to safflower supplementation of the ewe during late gestation and colostrum intake. Positive response to late gestation supplemental vitamin E on lamb survival, however did not indicate enhanced immune function. Additionally, although supplemental Zn increased serum vitamin E levels, high levels of dietary zinc may have a negative impact on indices of immune function.

Influence of Social Hierarchy on Distribution of Rangeland Cattle. In spring 1998, 1999, 2000, and 2001, social dominance hierarchy was identified each year in a rangeland herd of 155 cows, and the herd's social dominance hierarchy was found to be very stable from year to year. In Summer 1998, 1999, 2000, and 2001, the habitat use and calf performance of these cows was monitored. Forage and environmental variables were also measured. In hot, dry years, high-ranked cows competitively excluded low-ranked cows from riparian areas and forced low-ranked cows to occupy lower quality habitat. These differences depressed calf weight gains from low-ranked cows. Cow habitat use and calf performance were less affected by social dominance in a cool, wet year when habitat conditions were less limiting. Based upon observations in Summer 1999, 2000, and 2001, about 15 cows were culled each year and replaced with young cows. The 15 culled cows were those that spent the most time grazing in riparian habitat the previous summer. Cow habitat use and calf performance were monitored in Summer 2000 and 2001, and this activity will continue in Summer 2002 and 2003. An identifiable social dominance hierarchy existed within a rangeland cattle herd. This hierarchy was very stable from year to year, and habitat use patterns of the cows were influenced by their social rank. Therefore, if total herd size remains unchanged, selective culling of individual cows based on their habitat use patterns is unlikely to reduce cattle use of any sites in a pasture.

Integrated Total Quality Management for Beef Production. A system to provide information feedback between various segments of the beef industry was implemented. This program is a cooperative effort between the Montana Stockgrowers Association and Montana State University. A systems approach was implemented which allows for source and process verification of calves from the ranch in Montana to the feedlots in other states and provinces and eventually to the packing plant. Information collected throughout the production chain is shared among all the owners of the cattle. The first group of calves (23,000 calves) were eartagged in the fall on 1999, approximately 24,000 calves was eartagged in the fall of 2000 and 8,000

calves were tagged during the fall of 2001. Results of feedlot performance and information feedback to the cow-calf producer are being continually provided to the rancher as soon as animals are harvested. Central to this networking approach is the exchange of information from the producer to the end user (feedlot, packing plant). This systems approach for information transfer is the foundation of the Montana Beef Network. Funding was used to develop and publish training manuals and present over 80 Beef Quality Assurance educational programs in MT so 600 producers could certify that calves were vaccinated using a standard health management protocol.

In addition to the effective integration of extension with the research component productivity as measured by extension publications/presentations and referred publications has been significant. The Montana Beef Network, the Montana Sheep Institute, and the Undaunted Stewardship Program are excellent models of integrated, collaborative USDA-CSREES federally funded partnerships.

Integrated Management of Annual Grass Weeds in Small Grain. Field experiments were initiated to compare competitiveness of sunflower, canola, wheat, and fallow with Persian darnel. A large-scale rotation study was initiated near Moore, MT. The focus of this study was to quantify spatial and temporal dynamics of weeds in response to cropping systems. More importantly, this research will attempt to quantify the positive aspects of cultural weed management (i.e., crop rotation, increased seeding rates, altered crop seeding dates) relative to reliance on selective in crop herbicides.

Integrated Management for Spotted Knapweed Infested Rangeland. An integrated weed management program includes prevention, early detection and eradication, containment of existing infestations, and management to reduce large-scale infestations. Our research objective was to develop management strategies that address each area of integrated weed management using the causes of succession as the ecological basis. The underlying hypothesis was that as weed management strategies increasingly address the three general causes of succession in a complimentary manner, successional trajectory will be accelerated toward a desired plant community. The general causes of succession are site availability, species availability, and species performance. To this end, we have initiated a number of field studies. Restoration of weed infested river bottoms and riparian areas using desirable species from diverse functional groups addresses using the three causes of succession to restore weedy areas and prevention of weed spread along river corridors. Two studies have been initiated to determine our ability to use the R star theory in managing knapweed infested rangeland and the impact of biological control on spotted knapweed. Two restoration studies have also been initiated one determining site variability on establishment of desirable plants and their competitiveness, and one developing augmentative restoration. In addition we continue to monitor long-term studies on herbicide management, combining herbicides with grazing or biological control, revegetation, and the importance of forbs and diversity in preventing weed invasion. The results of our studies continue to build support for the importance of competitive desirable plant species and a diversity of species, or functional groups of species, in preventing weed invasion and sustainable weed control. This information is important in developing integrated weed management programs that are affordable and result in plant communities that meet land owner and managers land-use objectives, increased productivity, and ecosystem health.

U.S. Department of Agriculture
Cooperative State Research, Education, and Extension Service
Supplement to the Annual Report of Accomplishments and Results
Multistate Extension Activities and Integrated Activities

Institution__MONTANA AGRICULTURAL EXPERIMENT STATION
State_____ MONTANA
Check one: ____ Multistate Extension Activities
__X Integrated Activities (Hatch Act Funds)
____ Integrated Activities (Smith-Lever Act Funds)

	Actual Expenditures				
Title of Planned Program/Activity	**FY 2000**	**FY 2001**	**FY 2002**	**FY 2003**	**FY 2004**
Ecology of Phyllosphere & Rizosphere Mico-Organisms & their Role in Biological Control of Plant Diseases	37,889	40,795	38,138		
Lamb Survivability	2,529	13,523	13,207		
Influence of Social Hierarchy on Distribution of Rangeland Cattle	2,382	12,387	13,128		
Management Practices which influence Feedlot Performance & Carcass Characteristics of Montana Beef Calves	2,918	16,716	17,920		
IPM of Montana Field and Forage Crops	16,796	3,084	3,883		
Integrated Management of Annual Grass Weeds in Small Grain	10,876	37,686	24,107		
Integrated Management for Spotted Knapweed infested Rangeland			9,233		
Biocontrol of Pest Management Systems of Plants	55,991	41,951			
Biological Control of the Wheat Stem Sawfly		12,641			
Total	**129,381**	**178,783**	**119,616**		

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Sharron Quisenberry, Director Date