

ANNUAL REPORT OF ACCOMPLISHMENTS
AND RESULTS

MONTANA STATE UNIVERSITY

COLLEGE OF AGRICULTURE
MONTANA AGRICULTURAL EXPERIMENT STATION



FEDERAL FISCAL YEAR 2004

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TABLE OF CONTENTS

INTRODUCTION.....	3
Vision	4
Mission.....	4
Values.....	4
Program Focus and Overarching Goals and Objectives.....	4
MAES PLANNED PROGRAMS AND KEY THEMES	5
Goal 1. An Agricultural System that is Highly Competitive in the Global Economy	5
Executive Summary	5
Program 1. Plant and Animal Improvement.....	7
Program 2. Crop and Animal Production and Management Systems.....	10
Program 3. Agricultural Finance, Marketing, and Policy.....	29
Goal 2. A Safe and Secure Food and Fiber System.....	32
Executive Summary	32
Program 4. Plant Genetic Resource Conservation and Utilization.....	32
Program 5. Food System Performance.....	33
Goal 3. A Healthy, Well Nourished Population.....	33
Executive Summary	33
Program 6. Improving Human Foods and Health.....	34
Goal 4. An Agricultural System which Protects Natural Resources and Environment	34
Executive Summary	34
Program 7. Integrated Pest Management.....	36
Program 8. Improving Soil, Plant, and Water Resources in Ecosystems.....	37
Program 9. Economics and Sustainability of Public and Private Lands	43
Goal 5. Enhanced Economic Opportunity and Quality of Life for Americans.....	43
Executive Summary	43
STAKEHOLDER INPUT	44
PROGRAM REVIEW	46
MULTISTATE RESEARCH	47
INTEGRATED RESEARCH AND EXTENSION ACTIVITIES	49
FORM CSREES-REPT (2/00)	51

Introduction

Preface

The College of Agriculture (7 departments) at Montana State University, headquartered in Bozeman, Montana, is comprised of the Montana Agricultural Experiment Station (MAES) and the College's academic programs (6 departments) 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 5 departments in the College of Agriculture. The College also does not have programs in Family and Consumer Sciences, Food Science, Sociology, or Rural Development.

Expanded partnerships include the Montana Extension Service, MSU-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, e.g., NDSU, SDSU, and WY.

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 longer timeline although many individual projects have critical short- and medium-term goals. Stakeholder input has been solicited in the strategic planning process and will continue to be solicited as programs are developed, implemented, and changed 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 crop and animal agricultural groups, conservation and wildlife groups, Montana Department of Agriculture, Montana Research and Commercialization Board, Montana Wheat and Barley Committee, Montana Fertilizer Advisory Committee, Montana Noxious Weed Trust Fund, Private Industry, National Institute of Health, National Science Foundation, NRCS, NASA, BIA, USFS, and the BLM, funds from regional states and Canadian Provinces.

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Vision

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

Mission

As a land-grant institution, Montana State University provides instruction, research, and extension/outreach programs focused to meet the ever-changing needs of Montana and its people. In keeping with this mission, the COA/MAES provides science-based education, discovers new knowledge, and exercises 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
- Embrace 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 Montana citizens are the primary focus of COA/MAES programs, although impacts are also regional, national, and international in scope.

Enhance Economically Viable and Sustainable Agricultural Systems

- Provide a scientific basis for developing viable and sustainable plant and animal systems.
- Improve our fundamental understanding of plant and animal biology.
- Foster the development of value-added biobased agricultural products.
- Improve plant and animal health through integrated pest management 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/ecology.

Improve Natural Resource Management and Enhance Environmental Quality

- Provide a scientific basis for developing land and water use policies and practices.
- Enhance environmental quality and improve the sustainability of natural resource systems.
- Create educational programs that address natural resource needs and patterns of use.

- Develop ecosystem improvement programs that promote sustainable management practices consistent with enhanced biodiversity.
- Devise programs to enhance understanding of rural, urban and disturbed landscapes.

Strengthen the Quality of Life for Montana and Its People

- Facilitate the development of educational programs and delivery systems, including distance learning, which improve basic learning and life skills.
- Improve recruitment and retention of students.
- Partner with others to improve human nutrition and health, resiliency of families, and the viability of communities.
- Develop partnerships to provide programs that 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

In Montana and throughout the United States, agricultural producers operate in an environment made increasingly complex due to the financial system, evolving marketing practices and systems, and the myriad of government programs that influence 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 the welfare of our rural communities and taxpayers. Economic analysis of selected policies under this plan of work will enhance the competitiveness and efficiency of U.S. agriculture. The dynamics of changing foreign and domestic markets produces price volatility and marketing uncertainties, necessitating an estimate of price/production behavior and margin behavior, and the development of appropriate marketing, financial and risk management strategies. Therefore, projects were designed in recognition of a changing economic and risk 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 provides 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, industry and other state, federal, and non-profit groups receive the most recent information in our Research Center advisory meetings, State Advisory Council meetings, conferences, workshops, tours, and in-depth training programs. This information potentially can improve the efficiency and competitiveness of U.S. agriculture.

Montana producers were challenged strongly by markets, drought, animal health and international trade issues in 2004 and we became involved in a range of projects to assist them. Said projects studied experimental cattle feed to improve forage, cattle grazing in Montana climates, cattle breeding programs for improved lean carcass yield, mineral supplements and ovulation rate in beef heifers, neonatal lamb mortality, ewe and cow breeding, hepatic copper and zinc levels in cattle, feeding behavior and supplement

delivery methods for cattle and sheep, and factors contributing to spotted knapweed persistence.

The Montana Beef Quality Assurance (BQA) program for producers focused on best management practices to ensure food safety, feeder calf quality and consistency and source verification. Our feeder calf certification program for beef quality-assurance trained producers in best management practices for improving calf health, and developed an electronic identification/tracking system to follow calves through production channels. We offered educational courses that focused on food safety and financial, genetic, nutritional, reproductive, and marketing management. Our faculty provided Montana beef producers with information 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 to meet beef quality assurance standards, production and marketing goals and provide 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 verify that feeder calves met industry requirements for quality, consistency, safety, and red meat yield.

Arthropod pests continually attack our agricultural systems. Our research and integrated extension/outreach activities help producers develop and implement management strategies to economically control arthropod pests of small grains, sugarbeets, forages, canola, and potatoes. Pest management strategies using host plant resistance and cultural, biological and chemical controls have been examined for their impact on pest and beneficial insect populations and economics to insure that 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 with new tools to increase uniformity of livestock grazing and correspondingly to 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. Smaller markets for meat products because of concerns over infectious disease cause additional financial losses. Emerging infectious diseases found in wildlife populations, including bison, have become increasingly problematic for livestock producers. 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.

A number of projects involve analysis and elucidation of the nature of innate disease resistance in cattle and new ways to stimulate the activity of bovine $\gamma\delta$ T cells, an important natural defense mechanism against a variety of pathogens. This research may increase cattle resistance to mucosal and respiratory pathogens. Vectors that carry pathogens that attack humans, such as West Nile, are being studied and their presence in Montana quantified.

Several projects involve finding new applications for canola, safflower, sunflower and other oilseed crops as well as for non-glutinous cereals and hull-less oats. These will stimulate industrial growth in the state through the development of biobased products. A farmer-owned cooperative has been established to develop new oil products and we now design lubricants for the U.S. Navy, U.S. Army, and the National Park system. Hull-less oats and non-glutinous products are marketed through organic food sales and the internet.

Several projects involve the genetic modification of organisms for specific purposes. New strains of pathogenic fungi and bacteria are being developed for control of specific weed species. Plant viruses are being designed for the delivery of drugs and other compounds to specific tissues of the body. Invasive plant species that have developed resistance to certain herbicides are being researched. New knowledge may permit us to circumvent this resistance and to integrate new genes for herbicide resistance into crops.

We have developed an international reputation for our wheat and barley products, but production costs continue to rise as producers address increasing pressure from pests due to the monoculture nature of our mapping systems. Consequently, the value of crop rotations and diversified cropping systems is being studied to improve the sustainability of such systems in our semi-arid environment. This includes new crops and cropping systems such as organic, natural, and pesticide free.

Total Goal 1

Funding – \$10,342,528

FTE – 228.9

PROGRAM 1. PLANT AND ANIMAL IMPROVEMENT

Key Theme - Animal Genomics

Activity: Functional Analysis of Bovine $\gamma\delta$ T Cells

Evidence suggests that $\gamma\delta$ 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 $\gamma\delta$ 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 $\gamma\delta$ T cell subsets into the gut versus peripheral tissues. In the past year, we identified unexpected pathogen recognition receptors on $\gamma\delta$ T cells whose signaling leads to selective expression of specific T cell chemokines. These studies have implications in the design of new adjuvants for the stimulation of the bovine immune system. We have initiated a drug discovery program focused on identifying $\gamma\delta$ T cell agonists that enhance innate host defense of the gut mucosa. New high throughput screening assays are being used in drug discovery efforts. Another area of progress has been in our functional genomics research program on bovine $\gamma\delta$ 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.

Impact/Accomplishments: The direct implications of this research relates to the development of new ways to stimulate the activity of bovine $\gamma\delta$ T cells. It is thought that $\gamma\delta$ 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 $\gamma\delta$ T cells.

Source of Federal Funds: Hatch, State, USDA NRI, and NIH

Scope of Impact: Multistate: Montana, Washington, Minnesota

Key Theme – Animal Production Efficiency

Activity: Efficiency and Sustainability of Beef Cattle Production

Impact/Accomplishments: Uneven livestock distribution limits the amount of forage and may degrade natural resources. Strategic placement of low-moisture supplements can lure cattle into grazing previously underutilized rangeland. The value of additional grazing use often exceeds the cost of the supplement, irrespective of the nutritional benefits of the product. Our research demonstrated that cattle developed in the French and Italian Alps (Tarentaise and Piedmontese) used higher terrain than cattle developed in more gentle terrain in Great Britain (Hereford and Angus). Selection of individual animals within the herd that use higher terrain and travel further from water can increase the time that cattle graze a pasture without damaging riparian areas and sensitive rangeland.

Source of Funding: State, Hatch, and Private Industry

Scope of Impact: Integrated Research and Extension

Activity: Breed Selection to Develop Crossbred Cows for the Montana Environment

Impact/Accomplishment: Selected cows crossbred for the Montana environment can wean heavier calves and return \$70 per cow per year more than straightbred cows.

Source of Funding: State, Hatch, and Private Industry

Scope of Impact: Integrated Research and Extension

Key Theme - Biotechnology

Activity: Genetic Manipulation of Small Grains to Improve Quality
 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 organisms. 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 to reduce their visibility when the host plant is not available. Such biocontrol organisms are useful in locations where 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 (patented technology) and genes controlling specific steps in starch biosynthesis. Genes involved in grain texture also have anti-fungal activity. Transformed wheat with modified hardness, increased disease resistance, and Clearfield™ resistance technologies have been developed. We have developed the use of empty viral protein cages devoid of their nucleic acid for constrained reaction vessels for nano materials synthesis and/or entrapment (patented technology). This work has significant implications for both biomedical and material sciences.

Source of Funding: Hatch, State, USDA, and NIH

Scope of Impact: Multistate and National

Key Theme - 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: Interaction between a soil fungus and a native grass is one factor that permits the grass to grow in hot soils of Yellowstone National Park and other thermal regions. The nature of the interaction is being explored at the molecular level. The genetic/molecular basis of light sensing via multiple phytochrome genes is being analyzed in a model system. The elucidation of functional domains of the phytochrome photoreceptors and the demonstration of a role for calcium signaling in determination of inflorescence architecture will accelerate the development of novel crop varieties and new applications in agriculture. Similarly the process of nitrogen metabolism and plant senescence is being investigated in wheat, using genetic tools. Comparative genomics is proving to be an 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 traits 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, USDA, and NSF

Scope of Impact: State, Regional, and National

Activity: Plant Genetic Resource Conservation and Utilization

Impact/Accomplishments: Conserving and evaluating new plant germplasm is an important step in the cultivar development process. Nine individuals recently received 243 germplasm accessions in Montana. Seven of the nine were associated with Montana State University. The agricultural community and allied industries depend on new cultivars of important crops to remain competitive in the world market place. New cultivars depend on a diverse source of genetic variability.

Source of Funding: Hatch, State

Scope of Impact: Multistate regional research

PROGRAM 2. CROP AND ANIMAL PRODUCTION AND MANAGEMENT SYSTEMS

Key Theme - Adding Value to New and Old Agricultural Products

Activity: New Applications for Oilseed Crops such as Canola, Safflower and Sunflower

Impact/Accomplishments: Commercialization will help stabilize production and develop new industries in Montana. Using 50,000 acres of land for production, the value at the farmgate will be \$7 million. Value-added products derived from production and byproduct sales will add an estimated \$15 million for a value of \$22 million per annum to the state economy. Market growth is expected to remain steady at 7.2% per year barring large increases in competitive petroleum costs. A farmer-owned cooperative has been established to develop these products. Market contacts are through US Federal agencies. Currently, we are designing lubricants for the U.S. Navy, U.S. Army and the National Park system.

Source of Funds: State, Hatch, and Federal

Scope of Impact: Integrated Research, Extension and Private

Activity: New Applications for Non-glutinous Cereals
New Applications for Hull-less Oats and Legumes

Impact/Accomplishments: Commercialization will help stabilize production and develop new industries in Montana. Farmgate value on 10,000 acres in non-glutinous cereals will be \$8 million and value-added products derived from production and by-product sales will add an estimated \$19 million per annum. Farmgate value on 40,000 acres in hull-less oats and legumes will be \$10 million, with value-added products derived from production and byproduct sales bringing in an estimated \$21 million per annum. A farmer-owned cooperative has been established to develop these products. Market contacts are through organic and natural food sales and internet sales.

Source of Funds: State, Private, Hatch and Federal

Scope of Impact: Integrated Research, Extension and Private Collaboration

Activity: Development of Products for the Equine Industry

Impact/Accomplishment: Development of feeds specific for horse classes (athletic, geriatric, and brood mare) presents a new market for Montana producers. A new hay developed has a relative feed value of 150 (alfalfa has an RFV of 100). New products include an identity-preserved hay blend specific for horses and a supplement compatible with this hay. Other products include a hoof moisturizer and protector, and a dust control system for enclosed arenas.

Source of Funds: Hatch and Federal

Scope of Impact: Integrated Research and Private Collaboration

Activity: Development of New Products and New Uses for Crops

Impact/Accomplishments: Practices for producing dill for essential oil have been developed, including recommendations for plant density, row spacing, harvest timing, and nitrogen fertility. Dill oil, with a gross return of over \$500/acre, has the potential to provide crop diversity to current peppermint growers.

Source of Funding: State and Private Industry

Scope of Impact: Integrated Research and Extension

Activity: Development of Value-added Safflower Products

Impact/Accomplishments: Value-added high oleic safflower oil is higher in monounsaturates and lower in saturates than olive oil. Safflower is grown on 50,000 acres, processed and marketed locally. The meal is used 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: State, Hatch, Private Industry

Scope of Impact: Multistate Integrated Research and Extension (ND)

Key Theme – Agricultural Competitiveness

Activity: Economic and Environmental Sustainability of Agricultural Production Systems

Impact/Accomplishments: This research aims to develop methods to better assess the short-term and long-term economic returns to agricultural production systems, and their environmental consequences. It integrates information and models from bio-physical sciences (crop science, soil science, ecology) with economic data and models. The research tests the hypothesis that through this integration, our ability to predict the long-term properties and behavior of these systems will be improved. Applications include assessing impacts of climate change on agriculture in the U.S. and assessing the causes and policy remedies for agricultural land degradation in the U.S. and developing countries. It has also developed weed management strategies for the more diversified cropping systems in the northern Great Plains.

Source of Funding: USDA, NASA, MWBC, Industry, and NWTF

Scope of Impact: Multistate Research (MT, SD, MN, IA, WI, NB, IL, OH, and MI)

Activity: Fertilizer Use Efficiency

Impact/Accomplishments: Research is conducted in farm fields and at research centers to determine the response of new varieties and new crops to fertilizers and manures. This research will optimize fertilizer use, minimize negative impacts on the environment, and improve net returns. Fertilizer guidelines are based on this research and disseminated throughout Montana.

Source of Funding: Montana Fertilizer Committee

Scope of Impact: State Specific

Activity: Breeding Field Crops including Winter and Spring Wheat, Barley, Alfalfa, Oats, and Peas, and Development of New Crops (Indian Ricegrass)

Impact/Accomplishments: New varieties of durum wheat (Ben, Mountrail, Maier and Avomlea), a solid-stemmed winter wheat (Genou), and feed barley (Eslick) have been released. A new crop (Indian ricegrass) is being commercialized with demand currently outstripping supply.

Source of Funding: Hatch, State, and USDA

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

Key Theme – Animal Health

Activity: Innate Defense Mechanisms in Cattle

Impact/Accomplishments: White blood cells play an essential role in protecting cattle against infection by producing microbicidal agents. However, unregulated activation of these cells may be involved in the frequency and severity of mastitis. The purpose of this activity is to examine how the bovine leukocyte microbicidal system is regulated and the role of external inflammatory factors in this process, as modulation of NADPH oxidase activity may be involved in the frequency and severity of mastitis and possibly other bovine infections. We are analyzing regulation of the neutrophil NADPH oxidase in bovine blood and in milk and the effect of milk proteins on oxidase assembly and activity. We have identified and cloned all bovine leukocyte NADPH oxidase components and have developed systems for studying regulatory events. These studies provide a basis for further understanding of bovine host defense mechanisms and could lead to the development of novel therapies for controlling inflammation in cattle.

Impact/Accomplishments: Despite increased educational efforts and improved dairy herd management, mastitis still represents one of the most costly diseases of the dairy industry. Thus, it is extremely important that we develop a better understanding of mammary defense mechanisms in order to establish effective therapeutic approaches. One of the most practical means for treatment of dairy with mastitis is to enhance the natural host defense mechanisms of the animal and prevent establishment of chronic infection. However, before effective strategies can be developed, a better understanding of the initial inflammatory response and the effectors involved is essential. Toward this end, we have established a program of investigation focused on understanding the role of innate immune parameters in bovine host defense. In recent studies on the role of chemotactic factors in phagocyte recruitment during mastitis, we cloned and sequenced

the bovine anaphylatoxin C5a receptor. We are now in the process of characterizing this receptor and developing specific analytical reagents for this bovine system. Ongoing studies include analysis of the expression of C5a receptor in bovine immune cells and mammary epithelial cells and analysis of the effects of milk components on C5a receptor binding and activation. It is expected that these studies will provide the basic foundation for more extensive studies on the structure and function of the bovine C5a receptor and its role in bovine host defense processes during mastitis or other inflammatory diseases.

Source of Funding: Hatch, USDA, and State

Scope of Impact: National

Activity: Defense Mechanisms in Animals

Impact/Accomplishments: During the host defense process, neutrophils migrate into infected tissues where they become activated, resulting in the assembly of membrane and cytosolic proteins to form a superoxide anion-generating complex known as the NADPH oxidase. The NADPH oxidase plays an important role in both immune and non-immune cell functions. In nonimmune cells, novel NADPH oxidases have been identified and shown to play roles in epithelial surface defense. We are in the process of cloning the Nox1/NoxO1/NoxA1 system in bovine cells and have found evidence it may be functional in bovine colon (as expected from comparative studies in human cells), but also in bovine mammary epithelial cells. This may represent a completely novel location for an NADPH oxidase and could contribute to mammary epithelial cell defenses. Further work is in progress to determine the functional relevance of these studies and complete the cloning of all components.

Source of Funding: Hatch, USDA, State

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 to establish the vectorial capacity of the Culicoides complex.

Source of Funding: USDA

Scope of Impact: State, Regional, and International

Activity: Routes of Prion Neuroinvasion

Impact/Accomplishments: Recent findings in experimental models indicate that prions can rapidly spread to the brain following exposure of the tongue to the prion agent. Neuroinvasion was via cranial nerves and was not dependent on agent replication in lymphoreticular tissues. Prion agent was also found in both nerve fibers and skeletal muscles of the tongue. These findings suggest that prion agent entry via lesions on the tongue can result in agent replication in muscle and neuroinvasion via motor fibers. Our latest studies in scrapie-infected sheep indicate that the scrapie agent can replicate in the tongue. These findings have implications for human food safety.

Source of Funding: USDA

Scope of Impact: National and International

Activity: The Protective Antigens of *Streptococcus equi*

Impact/Accomplishments: To identify vaccine candidates among *S. equi* CWPs (cell wall-linked proteins), putative CWPs were identified by bioinformatic analysis of a *S. equi* genome sequence, eleven of twenty-one CWP genes identified were selectively cloned, the recombinant proteins were overexpressed in *Escherichia coli*, and seven antigenic CWPs were identified. Further testing of these CWP antigens may identify new target(s) for the development of a safe and effective protein-based *S. equi* vaccine.

Source of Funding: State

Scope of Impact: National

Activity: Immunity and Inflammation of Trichomoniasis

Impact/Accomplishments: 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. 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, and USDA

Scope of Impact: Multistate (MT, WA, and MN)

Activity: Role of the Innate Cellular Antiviral Response in Rotavirus Infections

Impact/Accomplishments: 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. 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.

Source of Funding: Hatch and USDA

Scope of Impact: National

Activity: Development of Bovine Vaccine Delivery Systems

Impact/Accomplishments: 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 demonstrates 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. 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, and State

Scope of Impact: National

Activity: Vaccine Development for Brucellosis in Bison

Impact/Accomplishments: To develop the next generation of 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. These studies show that we have developed a vaccine prototype for brucellosis in bison that warrants further study.

Source of Funding: Hatch, USDA, and State (MT and TX)

Scope of Impact: State and Regional

Activity: Drug Discovery for the Treatment and Prevention of Coccidiosis H

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 of the approximately 7,000 parasite genes can be sorted from the nearly 15,000 host genes in a single genetic library prepared from infected animal cells. 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 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.

Source of Funding: Hatch, State, and NIH

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

Activity: Parameters Affecting the Efficiency of Targeted Mutagenesis in Bovine Cells

Impact/Accomplishments: Increasing the efficiency of targeted mutagenesis in bovine cells could 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.

Source of Funding: Hatch, USDA, and State

Scope of Impact: National

Activity: Epidemiological Investigations of *Culicoides sonorensis* and Bluetongue Virus

Impact/Accomplishments: Three generations of *C. sonorensis* occur in summer. To determine vector competency to bluetongue virus, wild caught flies were fed a blood virus suspension and incubated for 12 days. Appropriate controls were used in the experimental design. Virus assays indicated flies were refractory to virus development. Age grading of wild caught females indicated that a small percentage of flies (<1%) take 3 blood meals and complete two gonotrophic cycles. These data suggest that Montana *C. sonorensis* have a low vector competency rating and may explain why there appears to be limited transmission of bluetongue virus in domestic livestock. These data will be provided to the Canadian Food and Inspection Agency for reassessment of the export restrictions placed on Montana ranchers.

Source of Funding: USDA

Scope of Impact: State, Regional, and International

Key Theme – Animal Production Efficiency

Activity: Sheep Nutrition

Impact/Accomplishments: A major factor reducing profitability in sheep operations is lamb mortality. Hypothermia/starvation, stillbirth/dystocia, and pneumonia are the three leading causes of death. Even a marginal increase in cold tolerance of lambs will have a substantial impact on lamb survivability and producer profits. Several nutritional strategies are being evaluated for their effects on lamb mortality and the physiological parameters thought to mediate thermogenesis and immune response. Safflower supplementation of the ewe during late gestation and colostrum intake by lambs subjected to cold stress at birth provide an immediate and positive response in survivability. 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 and Smith-Lever

Scope of Impact: Integrated Research and Extension

Activity: Wool Quality

Impact/Accomplishments: Objective measurements of whole wool clips are the standard for selling. Practical and efficient individual measurements would facilitate more accurate genetic selection for wool characteristics. Initial research efforts were to evaluate the effectiveness of the OFDA2000 portable field machine compared to the OFDA100 (laboratory standard) for fiber diameter. Fiber diameters as measured by the OFDA2000 were highly correlated (.97) with, but 0.66 microns coarser than, diameters measured by the OFDA100.

Source of Funding: Hatch, State and Smith-Lever

Scope of Impact: Integrated Research and Extension

Activity: Crop Pest Management Using Sheep

Impact/Accomplishments: Sheep grazing alfalfa from mid-fall to mid-spring dramatically reduced weevil numbers compared to non-grazed controls. Grazed alfalfa resulted in significantly less biomass at the end of the grazing period in mid-spring; however, in early summer these differences were not apparent. Hay yields were not different between grazed and non-grazed plots. Grazing sheep may be a viable means of controlling alfalfa pests without having negative effects on hay yields. Grazing sheep on wheat stubble results in higher wheat stem sawfly mortality than tillage or burning. In addition, weed populations in the spring were either lower or not different from traditional management methods. Sheep grazing did not negatively affect soil compaction. Application of this technology will help maintain or improve environmental quality and convert wheat stubble from a liability into a useful feedstuff, minimizing numerous pest problems.

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

Scope of Impact: Integrated Research and Extension

Activity: Beef Cattle Nutrition – Concentrates

Impact/Accomplishments: Barley is an important feed grain in Canada and the Pacific Northwest, while corn is the predominant grain source in finishing diets throughout the United States. Limited comparisons are available evaluating differences between the feed value of corn and barley. Three barley varieties (H3, Harrington, Valier) were compared to corn. There were no differences among diets for growth rate, feed intake, feed efficiency, and starch digestibility. Steers fed corn had greater fat thickness and higher yield grades at harvest, but other carcass characteristics were similar. While there are inherent differences between corn and barley in nutrient composition and digestibility, lack of differences in animal performance indicates that barley and corn have similar feeding values in high concentrate diets. National Research Council feed standards for barley appear to be underestimated.

Source of Funding: Hatch, State and USDA

Scope of Impact: Integrated Research and Extension

Activity: Beef Cattle Nutrition – Forages

Impact/Accomplishments: Barley hay is a significant source of winter forage for livestock in Montana. Limited data is available using hay barley as a roughage source for backgrounding steers. Three hooded barley varieties (MT981060, Westford, Haybet) and one awned variety (Valier) were evaluated as a source of hay. Steer fed MT981060 and Valier had 55% greater ADG than steers fed Haybet and Westford, and 14% better feed efficiency than steers fed Haybet. Feeding an awned variety did not negatively impact DMI, ADG, or feed efficiency. MT981060 has superior feeding value for backgrounding steers and is scheduled for release by the Montana Agricultural Experiment Station. These new locally-grown barleys increase livestock producers' bottom line profits by decreasing imported corn purchases. Crop barley producers will have an expanded market for their barley.

Source of Funding: Hatch, State, USDA and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Beef Cattle Nutrition - Minerals

Impact/Accomplishments: Adequate dietary trace minerals are an essential component to growth and sexual development in males. The form of trace mineral supplement may alter the effects of antagonistic minerals on animal performance. Peripubertal bulls fed mineral supplements of different combinations of sulfate versus complex forms did not differ in scrotal size or semen characteristics. However, bulls fed complexes of minerals reached puberty earlier than bulls fed only sulfate trace minerals. Liver biopsies suggested that NRC recommendations for Zn might be inadequate for peripubertal bulls. The economic advantage of utilizing yearling bulls compared to two-year-old bulls is applicable if yearling bulls have reached puberty by breeding time. Feeding bulls at least some complexed trace mineral will decrease the number of days to puberty. Trace mineral supplementation has been incorporated into nearly all preconditioning recommendations and production cattle rations in Montana.

Source of Funding: Hatch, State, and Industry

Scope of Impact: Integrated Research and Extension**Activity:** Beef Cattle Reproduction

Impact/Accomplishments: Pregnancy rates after an estrus synchronization and mass AI breeding protocol using CIDR's are generally low if first-calf suckled cows have not resumed ovarian cycling activity. Exposing first-calf suckled beef cows to bulls for one month before an estrus synchronization protocol involving the use of a CIDR can increase mass AI breeding performance, but exposing cows to bulls during or after mass AI does not have a positive effect on AI breeding performance. Bull exposure appears to increase pregnancy rates of first-calf suckled beef cows bred by AI using a modified CO-Synch protocol for 35 d after calving. Using the same bull continuously or switching bulls had similar effects.

Source of Funding: Hatch, State, and USDA**Scope of Impact:** Integrated Research and Extension**Activity:** Beef Production Systems

Impact/Accomplishments: This research evaluated the impact of season of calving (SOC), weaning strategy (W), post-weaning management of replacement heifers (PWM), and retained ownership (RO) on enterprise profitability. SOC evaluated were late winter (Feb), early spring (Apr), and late spring (Jun). Feb and Apr calves were weaned at 6- and 8-mo of age; Jun calves were weaned at 4- and 6-mo of age. PWM strategies included one treatment intended to allow heifers to grow at a constant rate from weaning to breeding and the second intended to minimize harvested feed inputs. RO options included backgrounding and finishing in El Reno, OK (1), backgrounding in Miles City, MT, and finishing in El Reno, OK (2), and backgrounding and finishing in Miles City, MT (3). The data utilized were collected during a 3-yr study conducted at the Fort Keogh Livestock and Range Research Laboratory near Miles City, MT. Production systems were modeled to characterize each possible combination of factors (n=60). Economic performance of each system was based on animal performance and variable cost inputs. Systems were analyzed at each level of production (cow-calf, backgrounding, and finishing). There were no differences between systems utilizing the different PWM. For cow-calf enterprises selling calves at weaning, the Jun late-weaned system yielded higher ranch gross margin (RGM = gross revenue minus variable costs) than all other systems (n=6), and the Apr early-weaned system was lowest. All other systems were not statistically different. When steer calves were backgrounded after weaning, few differences were found among possible backgrounding scenarios (n=18), and Jun calving remained superior to other seasons. When steer calves were retained to slaughter, finish option 1 had higher cumulative gross margin than options 2 or 3 in all SOC. Many cow-calf producers consider changes in calving season either to increase fall calf weights or to more closely match nutrient requirements to the available forage quality. Retained ownership options may also be considered as options to increase profitability. For producers in the Northern Great Plains, managing ranches similarly to these systems, June calving offers promise as a means to increase profit.

Source of Funding: Hatch, State, and USDA

Scope of Impact: Multistate Integrated Research and Extension

Activity: Beef Production Efficiency

Impact/Accomplishment: 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 are different for different calving seasons. Morbidity of beef calves can be significantly decreased 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, and USDA

Scope of Impact: Integrated Research and Extension

Key Theme – Diversified/Alternative Agriculture

Activity: Soybean as a New Annual Legume Crop

Impact/Accomplishments: Initial studies indicate Montana yield potential and crop quality are superior to those in traditional mid-western soybean production areas. Added benefits include pest suppression in rotation crops as well as reduced nitrogen fertilizer use. A projected 25,000 acres of soybeans 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 research center results and recommendations to the public. Web access at <http://www.sarc.montana.edu> currently also provides current and historical weather information assisting crop management decisions.

Source of Funding: State and Hatch

Scope of Impact: Integrated Research and Extension

Activity: Develop Winter Triticale Varieties (Grain and Forage Types) for Montana

Impact/Accomplishments: Winter triticale has resistance and/or tolerance to some diseases that infect early-seeded winter wheat and thus provides a wider period of forage utilization. Forage varieties can provide fall grazing, mid-spring grazing, and/or hay. Triticale grain has an array of flavors and mixing qualities that provide the opportunity to develop uniquely flavored food and snack products to target markets niches.

Source of Funding: State and Hatch

Scope of Impact: Integrated Research and Extension

Activity: Selecting Winter Pulse, Pea and Lentil Lines for Improved Winter Hardiness

Impact/Accomplishments: Winter pulses can provide mid-spring livestock grazing and/or green manure nitrogen for cereal grain production. Fall seeded winter pulse crops mature earlier than spring seeded pulse and cease water use sooner. This facilitates increased soil water accumulation for fall seeded winter wheat. Additional spring grazing on seeded crops can postpone moving on to native pastures and improve species composition and yield of the native pastures.

Source of Funding: State and Hatch

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. Diverse crop rotations can even positively impact 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 soil from wind and water erosion. Differences in insect numbers were recorded among the various crops. Legumes had the fewest pest problems while wheat following fallow had the most. 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 and State

Scope of Impact: Integrated Research and Extension

Activity: Adoption of Specialty Crops

Impact/Accomplishments: MSU is collaborating with USDA to expand producer's crop insurance alternatives. Furthermore, in concert with the Montana Grain Grower's Association, Montana Department of Agriculture, and Fort Peck Community College, producers' knowledge of specialty crop markets, contractual arrangements, and delivery mechanisms is being expanded. Agronomic constraints for chickpea, winter lentil and winter pea production are being evaluated. As a result of specialty crops research, constraints to chickpea production in the U.S. Northern Plains region have been well-communicated to farmers resulting in shifting acreage from chickpea to pea and lentil. Pea and lentil production in Montana was predicted to increase by at least 50% in 2004 due to favorable Farm Program loan rates and increased confidence in best management practices due to timely research with these crops.

Source of Funding: USDA, MWBC, and Montana Fertilizer Committee

Scope of Impact: Multistate Research (MT, ND, and SD)

Key Theme – Emerging Infectious Diseases

Activity: West Nile Virus and Mosquito Surveillance

Impact/Accomplishments: A statewide mosquito surveillance program was initiated in the spring of 2003 following the arrival of West Nile virus (WNV) in 2002. Adult mosquito populations were monitored in 2003 and 2004 using CDC light traps baited with dry ice. In 2003 mosquitoes were monitored in 22 counties and 35 counties plus 14 State Parks in 2004. Captured mosquitoes were pooled by species and submitted for virus testing. In 2003 a total of 657 mosquito pools were tested for virus. Twenty-one percent (138/657) of these pools were positive for WNV; 134 or 97% of the positive pools were *Culex tarsalis*. In 2004, 364 pools were submitted WNV testing. This total included 323 *Cx. tarsalis* pools of which 6 were positive. WNV was not detected in mosquitoes pools submitted from collections west of the Continental Divide in 2003 or 2004. Mosquito infection rates were calculated for 2003 and approached or exceeded 20 / 1,000 mosquitoes for Miles City, Malta, Glasgow, and Great Falls. Values over 4.0 are considered to constitute a potential human health threat. Mosquito infection rates were lower and in fewer localities in 2004 compared to 2003. The highest infection rate was 7.1/1,000 mosquitoes recorded at Miles City in July. Most of these positive pools for both years came from sites located along the Milk, Yellowstone and Missouri rivers and are likely focal zones or 'hot spots' of WNV transmission. This work has resulted in identifying spatial and temporal distributions of putative WNV vectors along with establishing baseline population densities and vector infection rates. Focal zones of virus transmission located along riparian corridors in the state have been identified. These surveillance efforts and subsequent outreach programs have played a key role in minimizing the impact of WNV on urban and rural populations in the state.

Source of Funding: Hatch, State, and Centers for Disease Control

Scope of Impact: Multi-state Regional Research

Key Theme – Invasive Species

Activity: Montana Noxious Weed Mapping System

Impact/Accomplishments: Spatial information about the distribution of invasive plant species and associated environmental characteristics is critical to effective weed management strategies. Standardized methods to survey and map weed infestations facilitate management objectives. MSU, in conjunction with county, state, federal, and private landowners, developed the Montana Noxious Weed Surveying and Mapping System (MNWSMS) as a methodology for surveying and mapping weed infestations and for housing statewide weed data. Statewide maps were created for 5 invasive species. BLM is using MNWSMS as a prototype to develop similar databases throughout the nation. MSU is cooperating with the National Park Service to map 14,197 acres to assist with weed management. Improved mapping will lead to better and more economical control measures in the short term and improved plant biodiversity in the long term.

Source of Funding: BLM, NWTF, and NPS

Scope of Impact: Multistate Research and Extension (MT and WY)

Activity: Monitoring of Injurious Insect Pests

Impact/Accomplishments: Monitoring systems are in place for the following: pale western and army cutworms, cereal leaf beetle, clover root curculio, alfalfa weevil, and lygus bug. Findings of monitoring systems are used to alert producers via the internet and in Extension programs. Monitoring of army and pale western cutworm has been expanded to eight states and one province and a risk model has been developed that improves our ability to weight factors that influence expected risk of cutworm infestations.

Source of Funding: Hatch, Smith Lever, and State

Scope of Impact: Multistate Extension and Multistate Research (WY, CO, ID, ND, SD, NV, NE, and UT)

Activity: Biological Control of Leafy Spurge

Impact/Accomplishments: Establishment of certain flea beetle species is associated with particular chemical and physical properties of the soil, chemical properties of the spurge roots and foliage, and levels of plant productivity. We have recently completed an extensive spatial analysis of post-establishment changes in the plant community as the leafy spurge is gradually suppressed. We rigorously explored the methods used to discriminate change and found that geostatistical approaches are much more powerful than classical transects. An important finding is that post-biocontrol plant communities are often composed of a significant proportion of other undesirable species.

Source of Funding: Hatch and State

Scope of Impact: Multistate Regional Research

Activity: Dalmatian Toadflax Biological Control

Impact/Accomplishments: The first collection for redistribution of the stem-mining weevil, *Mecinus janthinus*, occurred at an established insectary site in eastern Montana in the summer of 2004. This agent is very effective on Dalmation toadflax. We anticipate that several more sites will be collectable in 2005. The development of collectable insectaries is a critical early step in the suppression of target weeds over broad areas. Basic field and laboratory research, using *Mecinus janthinus* on Dalmation toadflax, has shown that measurement of plant primary physiology and plant secondary metabolite production in response to herbivory may serve as important indicators of potential impacts on weed fitness. Collection of this type of data could be valuable in initial overseas screening of candidate biological control organisms.

Source of Funding: Hatch and State

Scope of Impact: Multi-state Regional Research

Activity: Biological Control of Invasive Hawkweeds

Impact/Accomplishments: Screening tests of potential biocontrol agents for use against invasive hawkweed species in North America are currently being conducted at CABI Bioscience, Switzerland, and at the insect quarantine facility. Host specificity tests for a stolon-galling wasp, *Aulacidea subterminalis* (Hymenoptera: Cynipidae), were conducted at MSU to determine its potential utilization of native hawkweeds. Thirty-two plant species (255 different replications) were used in no-choice development tests. Plants consisted of 7 invasive species, 17 North American hawkweeds and 8 plants of closely related genera. Galls were only formed on the invasive species orange hawkweed (*H. aurantiacum*), mouse-ears hawkweed (*H. pilosella*), *H. flagellare*, and *H. floribundum*. No native species were infested.

Source of Funding: Hatch and State

Scope of Impact: State, Regional and International

Activity: Biological Control of Tansy Ragwort

Impact/Accomplishments: Tansy ragwort is a recent invader in the northwestern portion of Montana. Significant progress has been made over the past several years with the use of biological control for the management of this weed. This progress represents collaborative efforts among personnel from MSU and various federal, state, and international agencies or organizations. Comparisons of the biological, phenological, and genetic attributes of two populations (from Switzerland and Italy via Oregon) of the tansy ragwort flea beetle have made to select a population that may be more compatible with colder conditions found within the state. Recent studies have suggested that the Oregon population has modified its phenology making it more likely to interbreed with Swiss flea beetles. This possible interbreeding may result in populations that are more superior to either parent population. Further studies will be conducted to determine which population may actually be superior in limiting the spread and density of this weed; and if interbreeding does occur, what are the consequences.

Source of Funding: Hatch and State

Scope of Impact: Multi-state Regional Research

Key Theme - 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 Sugarbeet

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 germplasm and use of the 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 and other fungal pathogens in cereals. Transgenic plants expressing the anti-fungal wheat puroindoline genes show promise in controlling a number of fungal diseases (patented technology) including wheat head blight caused by *Fusarium graminearum*. Compounds isolated from endophytic fungi

have been shown to have antibiotic properties (patented technology). These compounds are volatile and have tremendous potential for reducing populations of specific plant pathogens in the soil as an alternative to methyl bromide.

Source of Funding: Hatch, Smith-Lever, State, and Federal (USDA)

Scope of impact: Integrated Research and Extension

Activity: Selection, Evaluation and Release Sawfly Resistant Winter Wheat Cultivars

Impact/Accomplishments: The sawfly resistant winter wheat cultivar Genou was released. Wheat stem sawfly causes up to \$30 million in crop losses annually. The demand for seeds of the previously released solid-stemmed winter wheat varieties Vanguard and Rampart has been exceptionally high. These three varieties will have a major impact on reducing losses due to sawfly.

Source of Funding: Hatch, MWBC, and State

Scope of Impact: Integrated Research and Extension

Key Theme – Plant Production Efficiency

Activity: Managing Plant Microbe Interactions in Soil to Promote Sustainable Agriculture

Impact/Accomplishments: This project is to identify and develop microbial-based biological control products for use in sustainable potato and sugarbeet production. *Bacillus* isolate MSU 341-16-7 provided sugarbeet yield increases equal to seed treatments with Apron-Thiram and Apron. Thiram provided greater yield increases than Apron-Thiram-Tachigaren where only *Pythium* and *Rhizoctonia* damping-off were present. In the presence of *Aphanomyces* damping-off, seed treatment with this *Bacillus* and a 20 g/kg seed treatment of Apron-Thiram-Tachigaren resulted in higher yield than untreated seed or seed treated with Apron-Thiram-Tachigaen at 45 g/kg seed. MSU 341-16-7 sugarbeet seed treatment applied with 20 g/kg Tachigaren provided better control of *Aphanomyces* damping-off than seed treatment with either 20 or 45 g/kg Tachigaren alone. *Musocder albus* mycofumigation provides control of potato scab and *Rhizoctonia* equal to the best available fungicide treatments.

Source of Funding: Hatch and State

Scope of Impact: Multistate Regional Research

Activity: Nutrient Management and Agronomic Practices for Dryland Malting Barley

Impact/Accomplishments: Montana dryland grain producers are being asked to increase malting quality barley production for the new International Malting Corporation plant. Recent research indicates that production techniques need to focus on quality rather than yield potential and that nitrogen fertilization has marked effect on the quality attributes of grain protein content and kernel plumpness. Dryland producers should focus nitrogen fertilizer recommendations on a plump kernel percentage goal of 70 to

80%, and corresponding yield goals of 35 to 70 bushels per acre depending on expected precipitation. Current research indicates barley needs about 1.2 lbs of nitrogen per bushel for acceptable malting quality.

Source of Funding: State, Hatch and Private Industry

Scope of Impact: Integrated Research and Extension

Activity: Developing Wheat Cultivars with Increased Kernel Size

Impact/Accomplishments: Wheat derived from larger wheat seeds tend 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: State, Hatch and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Development of a Montana Canola Industry

Impact/Accomplishments: 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. Montana canola acreage has grown to 30,000-50,000 acres.

Source of Funding: State, Hatch and Private Industry

Scope of Impact: Integrated Research and Extension

Activity: Research to Control Kochia Infestations in Small Grain Production

Impact/Accomplishments: Kochia presents a severe weed problem in all of Montana's dryland cropping systems. New post-harvest management strategies have effectively controlled kochia.

Source of Funding: State, Hatch and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Introduction of Haybet Awnless Hay Barley

Impact/Accomplishments: Haybet is 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. These are a direct result of MSU research.

Source of Funding: State, Hatch and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Air Drill Evaluation

Impact/Accomplishments: 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. 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 \$4 million.

Source of Funding: State, Hatch and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Small Grain Production and Research for the MonDak Region

Impact/Accomplishments: Busch Agricultural Resources, Inc., (BARI), Cargill, Inc., and Coors, Inc. increased malt barley production from 0 bushels in 1998 to 18 million bushels in 2003, to enable MonDak producers to become preferred suppliers of malt barley and to increase economic returns. A new 1.5 million bushel malt barley handling and storage facility was built by BARI and put into operation in 2003. Companion businesses expanding in the area include seed cleaning and storage, transportation, and certified seed production. Objectives of this project include the development of new and better adapted 2-row and 6-row malt barley varieties to assure consistent, high quality malt barley production under both irrigated and dryland growing conditions in the MonDak region and the refinement of barley management practices for malt barley production under irrigation and dryland production.

Durum varieties adapted to Montana will improve yield and quality. Pasta production and durum mills in North Dakota and Montana are successful and provide a ready market for high quality Montana durum. New pasta plants in Montana may be an alternative for Montana producers with new and improved higher yielding and higher quality durum varieties.

Source of Funding: State, Hatch and Private Industry

Scope of Impact: Multi-state Integrated Research and Extension (MT and ND)

Activity: Forage Production and Research for the MonDak Region

Impact/Accomplishment: The ability to produce and identify high quality alfalfa has promoted increased production and marketing of value-added alfalfa hay. An increase in value of \$25/T on 2,000 acres yielding 6 T/acre of alfalfa has added \$300,000 in value for eastern Montana producers. Production of value-added forage has stimulated the start-up of 2 dairies, Bostana Dairy at Crane, MT and Northwest Dairy at Parshall, ND and a new alfalfa cubing and pelleting processing plant at Tioga, ND.

Source of Funding: State, Hatch and Private Industry

Scope of Impact: Multi-state Integrated Research and Extension (MT and ND)

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. The important cultural control of early cutting can be enhanced by the addition of a raking step to the harvest process. As a result, a savings of up to \$15/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 over \$2.5 million can be realized each year.

Post-cutting distribution of alfalfa weevil larvae has identified weevil locations as dry matter increases during the forage curing process. Alfalfa weevil larvae were found to remain in windrows of cut forage until dry matter accumulation reached 60% when larvae increased in beneath and between windrow locations. This information provides the basis to further improve cultural controls for alfalfa weevils.

Source of Funding: Hatch, Smith-Lever and State

Scope of Impact: Multistate Integrated Research and Extension (WY, CO and 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. Bee production is often constrained by mortality due to parasitoids and diseases, and by a condition called “pollen ball”. Research at MSU has shown that the occurrence of these mortality factors is dependent both on the date that a nest cell was provisioned and the position of the cell in the nest. Work in progress is aimed at determining the pollen preferences of *M. rotundata* and variation in protein content of pollen masses as a potential correlate of mortality.

Sources of Funding: State

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

Activity: Wheat stem sawfly management

Impact/Accomplishments: Loss in wheat head weight due to wheat stem sawfly feeding is primarily caused by premature senescence during late grain fill. This information can be used by our laboratory and by breeders to develop varieties that can more effectively subvert losses due to sawfly. Production of volatile attractants for adult wheat stem sawflies has been evaluated in a number of wheat varieties. In field and laboratory experiments, female sawflies choose to lay most of their eggs in varieties that produce more attractants. This is being further pursued in the development of trap crop approaches for sawfly management. In new research wheat breeders will investigate the heritability of volatile attractant production in spring wheat, with the end goal of better varieties for wheat stem sawfly management. Naturally occurring parasitic wasps play a major role in sawfly population regulation. These beneficial insects are impacted negatively at harvest. The natural enemies can be conserved in no-till production using

higher cutting heights for solid-stem wheat varieties. Tillage and ground-level cutting adversely impact overwintering parasitoids, with little measurable impact on sawfly populations. Hollow stem wheat varieties may have a lower capacity to support a large natural enemy population. These cultural practices are very important as long-term approaches for sawfly-impacted areas to prevent the resurgence of large, damaging populations. Field research has also shown that several factors may contribute to the collapse of large, damaging sawfly populations. Large numbers of natural enemies play a critical role, including both insect natural enemies and several disease organisms. This endemic suppression can be enhanced by cultivation of solid-stem wheat varieties, which typically cause moderate levels of mortality in the immature stages of the wheat stem sawfly. Oats and wild oats both show complete resistance to wheat stem sawfly. In infested stems, all individuals die as larvae. Extractable fractions cause this mortality and we are currently evaluating the activity of specific fraction components. The goal is to determine the metabolic pathway for the production of these mortality factors, to facilitate adequate expression in wheat.

Source of Funding: Hatch, State and USDA

Scope of Impact: Multi-state Regional Research

Key Theme – Precision Agriculture

Activity: Precision Agriculture

Impact/Accomplishments: Conventional, uniform management practices in crop and livestock systems ignore temporal and spatial variability in physical, chemical and biological processes that occur in fields or rangelands. This natural variability affects crop and livestock system performance and, consequently, whole farm and ranch productivity and profitability. Through on-going educational workshops involving, among other things, GIS and GPS applications, remote sensing technologies, satellite imagery, and 3D visualization models of field landscapes, farmer/rancher learning groups are discovering new opportunities to incorporate precise, site-specific information into their decision-making process.

Source of Funding: USDA, State and Industry

Scope of Impact: Multistate Research and Extension (MT, ND, SD, ID, and WY)

Program 3. Agricultural Finance, Marketing, and Policy

Key Theme - Adding Value to New and Old Agricultural Products

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

Impact/Accomplishments: The beef industry is becoming more consumer-focused and specific quality and consistency targets are being established in all segments of the industry. To meet customer needs and return additional revenue to cattle producers, a systems network must be in place to ensure that a quality and consistent product is

being produced. In this project we are attempting to determine if an experimental E. coli 0157:H7 vaccine would reduce fecal shedding in freshly weaned calves – calves destined for finishing in Midwestern feedlots.

Source of Funding: Hatch, State, and USDA

Scope of Impact: Multistate Regional Research

Activity: Agricultural Marketing, Price Analysis, and Trade Problems in Dynamic Markets

Impact/Accomplishments: Wholesale-retail margins for beef, pork, and other livestock prices were affected more by the retail grocery sector than by the meat processing sector. NAFTA resulted in a net gain to beef producers because of the expanding Mexican market. Country-Of-Origin Labeling (COOL) will require a 3% increase in demand to cover its costs, and revenue risk from fed cattle grid pricing depends upon carcass traits and base price. The pre-outbreak program of vaccinating all cattle herds for brucellosis with tests of 25% random selection dominated other vaccinations/testing programs. Impacts included the following: (1) Increased retail grocery concentration and decreased retail grocery productivity decreased cattle and hog prices by an average of \$3.02/cwt and \$2.28/cwt, respectively; (2) Improved U.S. net beef trade from pre-NAFTA to post-NAFTA increased revenues in the fed and feeder cattle sections by \$0.57 billion and; (3) Loss of sugarbeet production in Montana would reduce irrigated land values by an average of \$272/acre.

Source of Funding: Hatch and State

Scope of Impact: Regional and International Markets

Activity: Climate Change and Greenhouse Gas Mitigation

Impact/Accomplishments: We developed a new method to simulate carbon supply curves for the adoption of reduced fallow and conservation tillage practices and compared this new method to results from farm-scale analysis conducted for Montana. We estimated field-scale carbon rates using the Century ecosystem model and used these data to derive carbon supply curves at the sub-MLRA level. These results will enable government and private entities to assess the economic feasibility of agricultural emissions reductions for greenhouse gases.

Source of Funding: Hatch and State

Scope of Impact: State, National and International

Activity: Agricultural Policy

Impact/Accomplishments: Research addressed risk management and crop insurance policy, the honey program, grain markets, segregation programs, and the importance of biotech labeling policies. Research output from this project has been widely disseminated to researchers, policy makers, and farmers and ranchers both in Montana and throughout the United States. Impacts were experienced by over 1,200 farmers,

agribusiness leaders, and policy makers in the four state region of Montana, North Dakota, South Dakota and Wyoming.

Source of Funding: Hatch and State

Scope of Impact: Multistate (MT, ND, SD, and WY)

Activity: Agricultural Finance and Farm and Ranch Management

Impact/Accomplishments: Researchers examined the incentives, efficiency, and firm level effects of crop insurance provisions, insurance moral hazard-fraud incentives, natural resource policy, contractual arrangements, and environmental/disease event policies. They developed new statistical procedures for identifying some types of fraudulent conduct. Studies examined the costs and implications of fraud, moral hazard, and other implications of information asymmetries. Impacts were felt by a widely dispersed audience ranging from policy makers and readers of professional journals to the general public and agricultural producers who were able to make more timely, informed, efficient, and rational choices with respect to their physical, economic, and financial environment. As an example, their research results with respect to fraudulent conduct provide policy makers with evidence of needed reforms in crop insurance provisions. If adopted, such reforms should lead to lower costs to both honest producers and the taxpayer.

Source of Funding: Hatch and State

Scope of Impact: State, Regional, and National

Activity: Impact Analysis and Decision Strategies for Agricultural Research

Impact/Accomplishments: The benefits of agricultural economics research were estimated and a major 450 page volume on the value of economics and agricultural economics research is scheduled to be published through John Hopkins University Press. The impact of this project has been substantial in documenting the impact of U.S. agricultural research programs.

Source of Funding: Hatch and State

Scope of Impact: Regional and National

Activity: Four-State Ruminant Consortium

Impact/Accomplishments: Scientists from North Dakota, South Dakota, Wyoming and Montana are working collaboratively on several new projects as part of the Four-State Ruminant Consortium. Topics include production and marketing strategies for both beef cattle and sheep and the integration of annual forages into beef production systems.

Source of Funding: Hatch, State and USDA

Scope of Impact: Multistate Regional Research

GOAL 2. A SAFE AND SECURE FOOD AND FIBER SYSTEM

Executive Summary

The U.S. food and fiber system provides consumers with adequate quantities of high quality and safe food products at a reasonable cost. Securing such a system requires responsibilities and efficiencies of relevant market players including producers of raw agricultural commodities, manufacturers/processors, 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. These include market concentration, price discovery, value-added opportunities, food-borne illnesses, and regulation activities. Research in these areas is vital to an examination of economic effects on consumers and market participants with current systems and will help to develop new safe and secure systems.

Development of new varieties and distribution of certified seed are essential components of current and future food and fiber systems. Variable genetics provides one of the most useful needs of a plant breeding program, the maintenance and supply of germplasm that may contain useful genes not currently present in the breeding lines. Plant breeding accounts for approximately one-half of the dramatic yield gains in most of our major crops over the past few decades in part through the expression of genes for insect and pathogen resistance. The basis for plant improvement through breeding is the exploitation of genetic variability made accessible to plant breeders in plant collections that have been catalogued and characterized. When superior varieties have been developed, it is vital that pure and healthy seedstocks be maintained throughout the seed production and commercialization process. Another source of important genes is the endophytes that associate with plant species. Characterization of these species has led to the identification of medically and agriculturally important compounds.

Total Goal 2

Funding- \$885,490

FTE – 14.6

PROGRAM 4. PLANT GENETIC RESOURCE CONSERVATION AND UTILIZATION

Key Theme - Food Resource Management

Activity: Plant Genetic Resource Conservation and Utilization

Impacts/Accomplishments: Most economically important plants are not native to the United States. 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 and Hatch

Scope of Impact: Multistate and National

PROGRAM 5. FOOD SYSTEM PERFORMANCE

Key Theme - 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 his own seed in a replant situation or a large seed company involved in state, regional, and international shipments.

Source of Funding: State and Program Fees

Scope of Impact: State and Regional

Key Theme – Food Safety

Activity: Environmental Risk Assessments for Genetically Engineered Crops

Impact/Accomplishments: Human health and ecological risk assessment research is being conducted within two major biotechnology crop areas: Roundup Ready® spring wheat and plant-based biopharmaceuticals. Roundup Ready® spring wheat is not grown commercially in Montana but considerable public discussion already has occurred about its environmental and economic impact. Therefore, comprehensive risk assessments are being conducted for Roundup Ready® wheat. In 2003, a comparative risk assessment was completed between Roundup herbicide and herbicides commonly used on spring wheat in Montana. This information will be used by stakeholders to improve decisions regarding this new biotechnology. In 2003, efforts were made to outline approaches for conducting risk assessments for plants genetically engineered to produce pharmaceuticals. These approaches are currently being used to conduct environmental risk assessments for pharmaceutical proteins currently being grown in crops.

Source of Funding: State, USDA and Industry

Scope of Impact: State and Regional

GOAL 3. A HEALTHY, WELL NOURISHED POPULATION

Executive Summary

Human nutrition studies and the use of medicinal plants can improve our health and nourishment. 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 products.

The end use of a cereal defines what grain quality attributes are desirable. The milling and baking attributes of cereals such as wheat and barley are unique and several factors underlie their quality parameters. These include environmental variation, genotype/environment interactions, and the adaptability of varieties to the climatic. It is important to improve the quality of Montana wheat and barley market classes for the domestic and international market places.

Traditional sources of new pharmaceutical chemicals are limited, but there is an opportunity to study the diverse array of endophytes associated with plants that may prove useful as non-traditional sources of pharmaceutical compounds.

Total Goal 3

Funding - \$373,156

FTE – 6.5

PROGRAM 6. IMPROVING HUMAN FOODS AND HEALTH

Key Theme - Human Nutrition

Activity: End-use Properties of Wheat and Barley

Impacts/Accomplishments: Complementing the traditional domestic bread market is an emerging noodle market for wheat in the Pacific Northwest. 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 qualities to enhance marketing opportunities for farmers in Montana and other states.

Source of Funding: State

Scope of Impact: National

Key Theme - Medicinal Plants

Activity: Endophytes of Plants: Their Biology, Economic Value and Potential Use

Impacts/Accomplishments: Unique chemicals are produced through the interaction of plants and their endophytes. These impact our society by the development of new knowledge and the issuance of national and international patents licensed to pharmaceutical, agricultural and industrial companies.

Source of Funding: Hatch and State

Scope of Impact: National

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

Executive Summary

Even in a semi-arid environment with its associated limitations on plant and animal growth, pests, the soil-plant-water-air continuum, wildlife, livestock and other agricultural

enterprises and natural systems interact in complex ways. Introduction of humans into the interactions makes a study of this complex even more intriguing.

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 since they comprise common ecological resources (e.g., river systems, wildlife). Understanding how the various land uses (e.g., farming, ranching, timber, recreation, mining, development, subdivision) are determined is crucial in determining the sustainability of these lands. In order for farmers, ranchers, forestland companies, and public land managers 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 be an essential component in this discussion and analysis.

A completed survey of hunter management strategies used by ranchers in Montana has led to the development of landowner/hunter research and education programs to address landowner concerns. A project currently underway includes a study attempting to identify prescriptions for the use of livestock grazing to improve elk habitat.

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 systems.

Montana producers are continually challenged by multiple 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 that are economically sound and environmentally acceptable. IPM systems are dynamic and the application nature of IPM is site-specific; selection of individual tactics is determined by the particular crop-pest-environment complex. IPM research and education programs continue to integrate new technologies that are rapidly advancing agricultural 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 Montana land 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 grazing management in

concert with preservation of riparian habitats, wildlife, and clean water. Characterization and understanding of the complex interactive components will lead to improved soil, plant, and water resources in those ecosystems.

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 necessitate efficient use for irrigation. Field and laboratory experiments were conducted to evaluate the calibration of approaches with TDR to provide real-time estimates of solute (e.g., 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.

Relationships among streamside and wetland vegetation, hydrology, water quality, and agricultural 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 ecological restoration.

Total Goal 4

Funding - \$4,140,145

FTE – 120.1

PROGRAM 7. INTEGRATED PEST MANAGEMENT

Key Theme – Biological Control

Activity: Introduction of Biological Control Agents against Spotted Knapweed

Impact/Accomplishments: Spotted knapweed is conservatively estimated to cause \$42 million in direct and secondary impacts to the state of Montana. Research indicates that biological control agents are having measurable impacts on spotted knapweed in Montana; five insect species are reducing seed production by 75-90%, while two other species are significantly reducing knapweed density and biomass.

Source of Funding: State, Hatch, County, State, and Federal Resource Managers

Scope of Impact: Multistate and International (MT, ID, WY, and Canada)

Key Theme - Integrated Pest Management

Activity: Integrated Pest Management of Montana Field and Forage Crops

Impact/Accomplishments: Sites have been identified for investigating factors affecting alfalfa stand longevity. Research has shown that timing of fall harvest has a significant impact on yield. We are also investigating the impact of biopesticides on wireworm populations in small grains. We have identified a production area in southwestern Montana with recurring wireworm populations that offer a field site with consistent populations. Other research has identified an insect growth regulator with potential for controlling lygus bug the key damaging insect of alfalfa seed in Montana. Developing reduced risk pesticide alternatives to traditional synthetic chemistries reduce human and

environmental health risks and negative impacts on natural enemy and pollinator populations.

Source of Funding: Hatch, State and USDA

Scope of Impact: Multi-state Regional Research

Activity: Regional Cutworm-Monitoring Program

Impact/Accomplishments: 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, 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. Targeted monitoring, possibly spot or field pesticide applications can be made, and ultimately dollars can be saved and resources are routinely protected.

Source of funding: Hatch and State

Source of Impact: State and Regional

Key Theme – Soil Quality

Activity: Stubble Management to Conserve Moisture and Protect Crops and Soils

Impact/Accomplishments: No-till research 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. 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: State, Hatch and MWBC

Scope of Impact: Integrated Research and Extension

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

Key Theme – 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, Regional, and International

Key Theme – Natural Resources Management

Activity: Greenhouse Gas Mitigation

Impact/Accomplishments: This research assesses the economic feasibility of sequestering carbon in agricultural soils to decrease greenhouse gas emissions. Two components of the research are: quantifying the on-farm costs associated with changing production practices to increase soil carbon (e.g., reductions in use of fallow, changes in tillage practices) and assessing the costs of implementing contracts for soil carbon sequestration, including the transaction costs and costs of measuring and monitoring the quantity of carbon sequestered in soils. The impact of cropping intensity, crop diversity, and fertilizer practice is being investigated for nitrous oxide emissions. Carbon credit markets will create uncertainty for Northern Plains producers, and this research will arm producers with the necessary knowledge to position their farms accordingly. This will be especially critical once carbon credit markets mature beyond the speculation stage in the United States.

Source of Funding: USDA

Scope of Impact: Multistate Research (MT, ND, SD, CO, and WY)

Activity: Wildlife Management

Impact/Accomplishments: Research in Montana has demonstrated that prairie dogs have a considerable impact on plant succession in mixed grass prairies. Ground squirrel damage to alfalfa in Montana is estimated at \$5 million per year. Losses are also occurring in other forage crops and on rangelands. Control methods with great potential to reduce crop losses for Montana farmers are being tested. Many landowners in Montana would like sportsmen to hunt their land to help control wildlife populations. Similarly, many hunters are looking for places to hunt. A website was developed (DoeCowHunt.Montana.edu) to help connect landowners and hunters. In the first year over 10,000 visitors entered the site and over 400 registered. Projects have been implemented to develop, test, and demonstrate techniques to prevent deer and elk from entering critical agricultural fields. One producer in Yellowstone County is saving from \$5,000 to \$8,000 per year from decreased elk and deer damage.

Source of Funding: Hatch, State and USDA

Scope of Impact: Regional Integrated Research and Extension

Activity: Grazing to Manage Invasive Plants

Impact/Accomplishments: Sheep grazing is a valuable tool to manage invasive plants on rangelands. Efforts are focused on leafy spurge and spotted knapweed. Controlled grazing was utilized to manage weeds on approximately 70,000 acres of weed-infested rangeland in Montana. These projects involved 892 landowners and about 16,000 ewes plus their lambs from 26 Montana sheep producers. Data from 31 plot sites suggest that strategic or controlled grazing with sheep can provide land managers an economical alternative to herbicides with lower environmental costs. Strategic grazing with sheep reduced the percentage of leafy spurge present by an average of 70%.

Source of Funding: Hatch, State and USDA

Scope of Impact: Regional Integrated Research and Extension

Activity: Rangeland Ecology

Impact/Accomplishments: 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 the findings of this work.

Source of Funding: Hatch, State and USDA

Scope of Impact: Integrated Research and Extension

Activity: Riparian Ecology

Impact/Accomplishments: Groundwater monitoring and collection of upland and riparian vegetation biomass data indicated that thinning Rocky Mountain Juniper and Ponderosa pine stands in the Missouri Breaks has led to significant changes. Controlled burns increased groundwater levels in about half of the sites measured. Biomass production in burned and unburned riparian and upland plant communities exhibited patterns similar to those noted in groundwater elevations. It is reasonable to assume that the lack of continuity in response among the four burned units is due to differences in geologic material or stratigraphy because all four burn sites had similar forest communities. Mule deer appeared to select feeding sites based on certain shrub species rather than nearness to unburned escape cover. This suggests that presence of the more palatable browse species determined deer use more than proximity to escape cover. Results from this study have been used to generate funding for additional study sites in southwestern and southeastern Montana, with the primary goal being to identify the role of surficial geology in riparian response to prescribed fire. Initial results from this study will be used as part of the training workshop for federal fuel management and natural resource personnel.

Source of Funding: Hatch, State and USDA

Scope of Impact: Integrated Research and Extension.

Activity: Grazing Behavior - Summer

Impact/Accomplishments: Low-cost cattle grazing strategies are needed for improved stewardship of riparian ecosystems. Identifiable and stable social dominance hierarchies appear to exist in rangeland cattle. Habitat use patterns of the cows are influenced by their social rank. One possible strategy is to cull from a herd those cows that spend a disproportionate amount of time grazing in riparian habitats. This strategy is being evaluated with a 155-cow herd on foothill rangeland in southwestern Montana. Improved knowledge of how social structure affects habitat use will better enable range and livestock managers to distribute animals into underutilized areas of rangelands, and to alleviate conflicts with other resources uses and values.

Source of Funding: Hatch, State and Smith-Lever

Scope of Impact: Integrated Research and Extension

Activity: Grazing Behavior - Winter

Impact/Accomplishments: Cattle may graze foothill rangelands in northern latitudes as an alternative to feeding hay. However, winter winds may increase weight loss and lower body condition. Diurnal activity patterns for cattle vary greatly from day to day and are correlated with weather changes. A thermal balance model is being developed, including net radiation, ambient temperature, cattle surface temperature, latent and sensible heat loss, conduction, storage, and metabolic heat, which identifies environmental conditions when cattle gain heat from and lose heat to their winter environment. Once refined, this model will incorporate different orientations and activity patterns, and will provide insight into metabolic requirements, weight change, and reproductive efficiency under different winter conditions. The model suggests that cattle benefit considerably from solar radiation during winter, which reduces their need to increase feed intake or to use endogenous reserves. Winter grazing, where feasible, can help lower feed costs for beef cattle producers.

Source of Funding: Hatch, State and USDA

Scope of Impact: Integrated Research and Extension

Activity: Sustaining Wildlife Habitat on Western Ranches

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

Source of Funding: Hatch, State and USDA

Scope of Impact: Multistate Regional Research

Activity: Wildlife-Livestock Interactions

Impact/Accomplishments: Interest in the relationships between beef cattle and elk is fueled by an appreciation of the fact that both beef cattle and elk are vital components of the economy and heritage of the Rocky Mountain West. Because ranching enterprises make major contributions to wildlife habitat, the economic viability of ranching enterprises is important to the preservation of elk and elk habitat. Our studies suggest that management of habitats used in the spring by elk will be important to the success of efforts to address cattle/elk problems. The economic impacts of elk on beef enterprises depend on several factors that can vary across ranches. Elk impacts on beef enterprise profits are closely associated with efficiency of resource use by cattle, i.e., ranches with lower unit costs of production lose more money by providing forage for elk compared to ranches with higher production costs. Attempts to validate an elk habitat suitability index (HSI) model and a cattle HSI model to determine if they were reliable resource management tools were not successful. The failure of these tools is likely linked to inaccuracies in GIS-based landcovers and (or) flawed modeled relationships among habitat variables and habitat use by elk and cattle.

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

Scope of Impact: Integrated Research and Extension.

Key Theme – Soil Quality

Activity: Microbial Bioremediation

Impact/Accomplishments: Organic contaminants exist in soils in a variety of microenvironmental situations. It is likely that microorganisms that degrade these contaminants have specialized into ecologically distinct populations that function best under given sets of microenvironmental conditions. Molecular methods targeting contaminant-degrading microorganisms are being used to track such populations to see if they vary with soil conditions in contaminated soils. By understanding the population biology of contaminant-degrading microorganisms, we should be able to better predict how to use microbes in bioremediation efforts.

Source of Funding: State and USDA

Scope of Impact: Multistate Research (MT, ID, ND, SD, WY, and UT)

Key Theme – Water Quality

Activity: Irrigation Water Management

Impact/Accomplishments: Agriculture is the most significant user and consumer of water in Montana. In the changing demographic climate of Montana, more and more competitors are seeking rights and uses of Montana's surface and groundwater. In some

locations, irrigation water right allocations far exceed crop needs, whereas in other areas of the state, allocations and allotments are significantly less than that necessary for optimal plant production. An understanding of the relationship between surface and groundwater quantity and quality, plant water requirements, and crop production is essential to the sustainability of Montana's irrigated crop industry and the future health and vitality of Montana's water resources. Cooperative projects with the U.S. Bureau of Reclamation, the Montana Association of Conservation Districts, and organized watershed management groups are leading to better public understanding of methods for balancing competing interests, while supporting traditional agricultural practices in Montana.

Source of Funding: State, BOR and CD

Scope of Impact: State Specific

Activity: Montana Water Quality and Human Health

Impact/Accomplishments: More than 90 percent of Montana's rural farm and ranch population and a large majority of the rapidly growing suburban population of Montana depend on unregulated groundwater and private wells for their domestic water supplies. At the same time, suburban housing developments are placing increasing demands on soil and land resources for household waste disposal and supplying domestic water. Educating small landowners and the transitioning population about the interconnectedness of the landscape with the water resources of Montana has become a major effort in the past decade. As part of a six-state regional team effort and cooperative with public health, county extension offices, and state environmental protection and conservation district offices, grass roots sampling, testing, research and educational efforts are underway to help Montana citizens learn how to protect the preserve the state's water resources and protect citizen health.

Source of Funding: USDA

Scope of Impact: Multistate Integrated Reseach and Extension

Activity: Coal Bed Methane Production on Montana's Landscape

Impact/Accomplishments: America's growing emphasis on energy self-sufficiency and domestic production, along with innovations in energy extraction, have lead to a rapid growth in exploration and development of the coal bed methane industry in Montana and neighboring states. Understanding the balance between coal bed methane development and extraction, and natural resources is a key focus of a major research/education efforts. Understanding the nature of coal bed methane water, its safe and beneficial use on the landscape are also essential to sustainable and socially acceptable development of this energy source. Water extracted from coal seams, in order to allow methane recovery, has the potential in some cases to have adverse impacts downstream whereas in other cases, this water can become a valuable resource to enhance agriculture and downstream water uses. Field and greenhouse studies are examining plant species adaptations, salt and sodium extraction potential, enhanced livestock forage production, and chemical and physical impacts on soil and subsequent crop production, range productivity, and riparian zones.

Source of Funding: USDA and DOE

Scope of Impact: Multistate Integrated Research and Extension (MT and WY)

PROGRAM 9. ECONOMICS AND SUSTAINABILITY OF PUBLIC AND PRIVATE LANDS

Key Theme - Land Use

Activity: Crop fallow techniques to sequester carbon dioxide in soil

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 and National

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

Executive Summary

The future of Montana's agricultural economy depends upon most efficiently maximizing net returns per acre or per animal unit. The development of value-added end-use products or lower energy alternatives such as biofuels, plastics, pharmaceuticals, and other petroleum-derived products has the potential to further expand our agricultural product base. Montana can provide alternatives in a biobased economy through the exploration of new crop and livestock enterprises and activities that reduce our dependence upon imported energy.

Montana exports approximately 85% of its raw commodity products and their improved quality will increase demand in the global marketplace. Currently, Montana's wheat is marketed predominately in the Pacific Rim where its high quality is recognized. In the future, it will become 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 will continue to have an increasing impact on agriculture, the properties of food, and our 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 and enhancing quality. A biobased economy will provide in-state manufacturing, product development, rural development, and jobs.

Total Goal 5

Funding - \$480,310

FTE – 12.1

Key Theme - Biobased Products

Activity: Institute for Biobased Products

Impacts/Accomplishments: The Institute for Biobased Products was established with state and federal funding. A biobased product and technology program will facilitate product development, value-added commodities, food safety, marketing, and science-based risk assessments of agricultural and environmental technologies (e.g., biotechnology and pesticides) throughout Montana and the region

Source of Funding: State, USDA and Industry

Scope of Impact: Regional

Stakeholder Input

The Montana Agricultural Experiment Station (MAES) and College of Agriculture (COA) obtain stakeholder input on programs and research priorities, and aggressively solicit input on changes in program direction.

A permanent Dean of the College of Agriculture and Director of the Montana Agricultural Experiment Station (MAES) began employment 1 July, 2004. During the transition period preceding selection of the Dean, several new stakeholder committees, including the College Development Board, Precision Ag Research Association (PARA), and the Ag Coalition, were formed. These expanded upon the historical scope of input into our priorities. The College Development Board is composed of ranchers, farmers, bankers, conservationists, state associations, and teachers and provides direction on our activities to externally support high priority needs. These include: 1) Seven Research Centers \$1 million dollar match (state provided \$1 million and a non-state match of \$1million was to be secured in early 2005) to renovate, build and repair facilities on five out of the seven Research Centers throughout Montana and 2) Animal BioScience Complex, a new endeavor that will require \$10 to 12.5 million in private funds and approximately \$20M in other funds. This building facility will enhance the teaching and research mission of the Department of Animal and Range Sciences and other departments and foster new research partnerships.

PARA is external to MAES, charges its own dues, and conducts quarterly meetings throughout Montana with members and selected professionals. MAES scientists routinely participate with this group and NRCS to provide training and expertise in GPS, GIS, and remote sensing with geospatial applications. PARA and MSU have secured a number of USDA, NASA and industry grants to initiate collaborative projects on their property as part of the MSU originated "Learning Groups" concept. The Ag Coalition consists of representation from the Montana Stockgrowers, Seed Trade, Wool Growers, Agricultural Business Association, Beef Council, Farm Bureau Federation, Montana Farms Union, Montana Water Users Association and Department of Agriculture. It

meets quarterly to review program priorities, new initiatives, fundraising efforts, and legislative activities.

The Montana Wheat and Barley Committee provides about \$400,000 in competitive financial support to MAES scientists annually. This financial support helps direct research programs in spring/winter wheat, barley, cereal grain quality, IPM practices, and interactions in small grains and crop rotations. The Montana Noxious Weed Trust Fund provides about \$300,000 to \$400,000 annually for community watershed cooperatives and for competitive education and research funds for MSU scientists. To focus their activities, we sought input from the Montana Weed Coordinators located in each of the 56 counties in Montana. Educators and researchers in the Montana University System were asked to respond to this research and education agenda with proposals for activities. Projects address all aspects of invasive plant management on private, public and agency lands. This has led to new state funding initiatives.

In addition, the College of Agriculture and MAES have 21 advisory committees and boards with a total of 266 members. These include the MAES State Advisory Council, Institute for Bio-based Products, Northwest and Western Agricultural Research Centers Advisory Committee, Montana Agricultural Innovation Center Board, Mint Committee, Southern Agricultural Research Center Advisory Committee, Center for Invasive Plant Management Board, Center for Invasive Plant Management Science Advisory Council, Northern Agricultural Research Center Advisory Committee, Montana Wool Growers Advisory Committee, Montana Beef Advisory Committee, Central Agricultural Research Center Advisory Committee, Eastern Agricultural Research Center Advisory Committee, Animal Biosciences Complex board, Western Triangle Advisory Committee, Foundation Seed Advisory Committee, Undaunted Stewardship Guidance Council, Montana Seed Growers Association Board, Thermal Biology Institute Scientific Advisory Board, Variety Release and Recommendation Committee, Potato Certification Board, and Montana Beef Network Advisory Committee. Members of these committees represent farmers and ranchers, tribal councils, county extension agents, financial organizations, communities, scientists, agricultural educators, private citizens, small businesses, conservation groups, reservation groups, and agricultural organizations. The College of Agriculture, along with its MAES faculty, responds to input from these stakeholders and state/national/international trends by evolving their programs.

Each of the seven research centers hold annual field days for the presentation of research and to collect input on new research directions. These field days are attended by agricultural clientele and the general public. Nearly 800 individuals had direct contact with project leaders through these activities in 2004.

Stakeholder input during 2004 was collected in county- and reservation agent-sponsored stakeholder input meetings. These meetings were held on all reservations and in the 56 counties. The meetings were organized by county and reservation extension agents under the direction of the Director of Extension. Meetings were advertised via news releases, newsletters, individual letters and announcements at group meetings. Extension agents were instructed to use county profile information to make sure that the people invited to the sessions would reflect the diversity of the area. The advertising and meeting invitations included the statement "Extension agents will also collect input on the research conducted through the Montana Agricultural Experiment Station."

As a result of the stakeholder input meetings in each county and reservation, MAES received ten specific suggestions with regard to research. These were:

1. Need higher yielding solid stem winter wheat
2. Study hemp as food and fiber source
3. Better marketing of Research Center work
4. More crop research in general
5. New ag product and crop research to expand ag products and markets
6. Research on rodent control
7. New crop developments
8. Test plots for winter and hull-less barley varieties
9. Explore alternative crops
10. Develop new crops.

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

A survey of stakeholders was completed in 2001 and results from that stakeholder input are still shaping MAES direction and priorities. The purpose of the survey was to collect input from a representative group of stakeholders in Montana. Questions in the survey were based upon the areas of emphasis in the strategic plans of the College of Agriculture/Agricultural Experiment Station and the Extension Service.

The return rate of usable surveys was very good at 30% and respondents were from all 56 counties in the state. The percentage response and distribution of respondents lend credibility to the results. Age of respondents significantly influenced priorities for some areas. Older respondents tended to rate the priority of teaching/research areas lower and the priority of extension areas higher. Means of priority responses tended to be between 1.4 and 1.8, indicating that the mean rating for most areas was between "above average" and "high". Sixty seven percent of respondents rated education as high priority, while only 5% rated education as below average or low priority. A safe and secure food system and agriculture/environment both received 57% high priority ratings. Other areas of research that received responses in the high priority rating were natural resources, livestock production and management, crop production and management, range production and management, noxious weed management, animal and livestock diseases, and nutrition and health. These results will likely continue to influence MAES research priority areas into the next decade.

Program Review

Hatch Projects are subject to a rigorous review at the department level, followed by a peer review, with final approval at the Director's level. The MAES Director's Office has oversight of this review process. The peer review committee, selected by the Director after consultation with department heads, includes the principle investigator's department head, MAES administrator, one department peer reviewer and two additional faculty external to the PI's department. Seminars are presented to the review committee and to faculty in general, whose input is encouraged. The seminars are announced to the public on the web so any interested citizen could attend. Reviewers are requested to provide written recommendations on the following items: relevance and importance

of the project; relation of the project to previous research; objectives; approach and methods; scientific and technical quality; resources; environmental, economic, and/or social impacts. The responses are presented to the PI during a subsequent meeting with the MAES administrator and department head. The PI is required to revise the project as recommended by the reviewers and to resubmit the project proposal to the MAES administrator and department head for additional review and semifinal approval. The approved project is submitted to the Director for final approval. Projects that do not meet expectations will not be approved and action upon them will be deferred until all of the key elements listed above have been met.

Multistate Research

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

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

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

Sustainability of wildlife habitat on ranches is becoming very important. Research is being conducted on elk and cattle habitat use patterns in Montana and Wyoming. Interest in the relationships between beef cattle and elk is fueled by an appreciation of the fact that both beef cattle and elk are vital components of the economy and heritage of the Rocky Mountain West. Because ranching enterprises make major contributions to

wildlife habitat, the economic viability of ranching enterprises is important to the preservation of elk and elk habitat. Foraging niche overlap among Rocky Mountain elk, Rocky Mountain mule deer and cattle was studied for 2 years on 37,000 ha of non-forested foothill and mountain habitat. Cattle use in summer and fall had > 60% foraging niche overlap with elk in spring, indicating that, in spring, elk foraged in many of the same places (largely sagebrush grassland) and ate diets similar in botanical composition to what cattle did during summer and fall. Foraging niche overlap also was high (41-51%) between elk in winter and cattle in summer and fall. Therefore, if competitive or complementary relationships existed between elk and cattle, these interactions most likely occurred on sagebrush grasslands where cattle use in summer-fall was followed by elk use in winter-spring.

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

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

Despite recent advances in reproductive technology, cattle and sheep producers are still faced with the persistent problem of low fertility. Indeed, recent work indicates that the fertility of domestic ruminants, even under optimal conditions, is about 50%. Only one of every two natural or artificial inseminations results in the birth of a healthy calf or lamb. The poor fertility of domestic species is reflective of cumulative loss due to poor fertilization efficiency, high embryo mortality, and spontaneous abortion. The knowledge gained through W-12 Reproductive Performance in Domestic Ruminants, will lead to the development and implementation of new management protocols and/or pharmaceutical and nutritional regimens that will increase the fertility of domestic ruminants in the Western region by increasing conception and reducing embryo and fetal loss. We 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.

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.

Integrated Research and Extension Activities

Most Montana State University College of Agriculture faculty have dual appointments involving two of the three functional areas (e.g., 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 which are not officially credited. MAES and the Montana 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, conservation, and agency stakeholders.

Since 1994 management of sugarbeet diseases has been a major focus of research and extension education programs. These programs have lead to grower implementation of

effective, environmentally friendly, economical controls for 4 chronic diseases and one new disease. Management of the chronic diseases, Fusarium Yellows, Cercospora leaf spot, Rhizoctonia Crown and root rot and Aphanomyces root rot has increased grower profits on more than 88,000 acres in MT.

Fusarium Yellows is common on more than 40,000 acres. In 1994 only one resistant variety was available to growers and this had a yield potential 15-20% less than high yielding varieties in the absence of disease. MAES research developed highly efficient methods to identify resistant germplasm and work with seed and sugar companies has resulted in the identification of many high yielding Fusarium Yellows resistant varieties and the near elimination of susceptible genotypes. Extension education programs have resulted in growers using these varieties on more than 43,000 acres for control of this disease and yields have increased by approximately 12%. Thus, the impact of this work in the past 2 years has been more than \$10.3 million of additional income in Montana. Management of this disease is one of the key factors for record yields in the Billings Factory district (Western Sugar) and has become increasingly important in the Sidney Factory district where approximately 4000-5000 acres are affected.

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 4,500 acres in 2000 for control of this disease and 8,000 acres in 2002. Based on our research plot response this increased profitability by \$109 (Based on current Western Sugar Grower Contract price) per acre or \$872,000 for MT in 2002. Research used to develop the Quadris fungicide label was started here at MSU and based on our data the full label was granted in 2001. Savings continued in 2003, but we are analyzing the data.

MAES research pioneered the use of azoxystrobin (Quadris) for control of Rhizoctonia black scurf control. Based on our work in MAES research plots and in grower fields yields for the years 1994-2002 are increased an average of 12.8%. Based on the fact that Quadris was used on 3300 acres in 2002 economic returns were increased by more than \$300/A (assume 300 cwt/A yield and \$8.00/cwt) or more than \$990,000. This is a very conservative estimate since yield increases in some years are 15% and many growers have higher base yields. This research has been transferred to other states and the manufacturer of Quadris reports use on more than 150,000 acres nationwide.

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/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.

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

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	40,623	40,771	38,138	35,214	23,915
Lamb Survivability	2,529	13,523	13,207	13,621	13,694
Influence of Social Hierarchy on Distribution of Rangeland Cattle	2,587	12,224	13,128	13,648	13,734
Management Practices which influence Feedlot Performance & Carcass Characteristics of Montana Beef Calves	3,482	16,716	17,920	18,555	18,658
IPM of Montana Field and Forage Crops	652	3,084	3,883	8,036	26,816
Integrated Management of Annual Grass Weeds in Small Grain	56,708	37,687	24,107	19,722	00
Integrated Management for Spotted Knapweed infested Rangeland	11,328	9,206	9,233	17,249	21,887
Epidemiology of Arthropod-borne diseases of livestock and wildlife					2,629
Total	117,909	133,211	119,616	126,045	121,333

 Jeff Jacobsen, Director

3/31/2005

Date