ANNUAL REPORT OF ACCOMPLISHMENTS AND RESULTS

MONTANA STATE UNIVERSITY

COLLEGE OF AGRICULTURE
MONTANA AGRICULTURAL EXPERIMENT STATION

FEDERAL FISCAL YEAR 2003

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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 are being actively pursued (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 Noxious Weed Trust Fund, Private Industry, National Institute of Health, National Science Foundation, NASA, 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) will provide focused and viable science-based education, research, and extension/outreach programs essential for providing knowledge and leadership in agricultural and natural resource systems to preserve the quality of the environment, improve the quality of life, and create added-value from our resources for Montana and its people in a global economy.

Mission

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

Values

- Provide visionary and responsive leadership based on scientific knowledge.
- Develop a community of scholars and learners committed to quality and excellence.
- Create a work environment of open communication, trust, honesty, and acceptance.
- 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 the people of Montana are a primary focus of COA/MAES programs.

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

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

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

- Provide a scientific basis for developing land and water use policies and practices.
- Enhance environmental quality and improve the sustainability of natural resource systems.
- Create educational programs that address natural resource needs and use patterns.
- Develop ecosystem improvement programs that promote sustainable management practices and are consistent with enhanced biodiversity.

- Provide programs to enhance understanding of disturbed, rural, and urban landscapes.

Strengthen the Quality of Life for Montana and Its People

- Enhance the development of educational programs and delivery systems, including distance learning, which improve basic learning and life skills among Montana's people.
- Improve recruitment and retention of students.
- 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

Montana producers faced many challenges in 2003. To assist them, we were involved in a wide range of projects. These encompassed such things as experimental cattle feed to improve forage; cattle grazing in Montana climates associated with weight loss; cattle breeding programs for improved lean carcass yield; studies on the effect of mineral supplements influencing ovulation rate in beef heifers; neonatal lamb mortality; various projects on breeding ewes and cows; studies on copper and zinc levels in livers of cattle; feeding behavior and supplement delivery methods for cattle and sheep; and contributing factors to the persistence of spotted knapweed.

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

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

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

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

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

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

Projects were designed in recognition of a changing economic 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 results provide management solutions to promote the economic competitiveness and environmental health of Montana agriculture and contribute to the production of high quality agricultural products. County Extension Agents, industry and other state, federal, and non-profit groups receive the most recent information in our Research Center advisory meetings, conferences, workshops, and in-depth training programs.

In Montana and throughout the United States, the environment within which agricultural producers operate is becoming increasingly complex. Sources of this increasing complexity include the financial system, evolving marketing practices and systems, and the myriad of government programs that influence producer behavior in agriculture.

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

PROGRAM 1. PLANT AND ANIMAL IMPROVEMENT

Key Theme - Animal Genomics

Activity: Functional Analysis of Bovine γδ T Cells

Impact/Accomplishments: These studies have implications in the design of new adjuvants for the stimulation of the bovine immune system. Another area of progress has been in our functional genomics research program on bovine γδ T cells. The direct implications of this research relates to the development of new ways to stimulate the activity of bovine γδ T cells. It is thought that γδ T cells are an important natural defense mechanism against a variety of pathogens. Enhancing their activity may increase the innate resistance of cattle to mucosal and respiratory pathogens, particularly under conditions of stress associated with shipping. A goal of this work is to identify a low cost feed supplement that could be used to enhance γδ T cells.

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

Scope of Impact: State and Regional (MT, WA, MN)

Key Theme – Animal Production Efficiency

Activity: Efficiency and Sustainability of Beef Cattle Production

Impact/Accomplishment: On rugged and extensive rangelands, uneven livestock distribution limits the amount of forage available for grazing and may result in natural resource degradation. Cattle can be lured to graze previously underused rangeland by strategically placing low-moisture supplements. The value of additional grazing use often exceeds the cost of the supplement, irrespective of the nutritional benefits of the product. In addition, producers can improve livestock grazing patterns by selecting breeds that were developed in mountainous terrain. 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 can graze a pasture without damaging riparian areas and other 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: Research shows that selected crossbred cows for Montana environment can wean heavier calves and return $70 per cow per year more when compared to 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 Characteristics
Genetic Improvement of Biological Control Agents for Weed Control
Bacterial and Fungal Endophytes
Mechanisms of Plant Virus Transmission and Assembly

Impact/Accomplishments: Several projects involve the genetic modification of organisms for specific purposes. Fungal and bacterial plant pathogens specific to certain weeds have been developed as biocontrol agents. These organisms have been genetically modified to increase virulence and also reduce their visibility when the host plant is not available. Such biocontrol organisms are proving very useful in locations where chemical herbicides are not appropriate such as riparian habitats and high use areas. Grain quality in wheat and other small grains is being improved by modifying hardness genes (patented technology) and genes controlling specific steps in starch biosynthesis. The same genes involved in grain texture also have anti-fungal activity. Transformed wheat with modified hardness; increased disease resistance, and Roundup™ and Clearfield™ resistance technologies have been developed. New strains of bacteria and fungi with biocontrol properties have been developed or identified. The use of empty viral protein cages (devoid of their nucleic acid) as 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: An interaction between a soil fungus and a native grass has been shown to be one of the factors that permit the grass to grow in hot soils found in Yellowstone National Park and other such thermal regions. The 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 their application 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 extremely efficient way to locate important genes in legume crops such as pea, lentil and chickpea. Similar work in wheat is being used to locate the genes controlling qualitatively inherited trains of particular interest for breeders. Genetic information developed for one crop often can be applied to a closely related crop through comparative genomics. Such applications are being performed in wheat (using various grass models), in pea (using Medicago truncatula as a model) and in lentil (using pea as a model). The location of numerous important genes has been identified using this approach.

Source of Funding: Hatch, State, and Federal (USDA, NSF

Scope of Impact: State, Regional, and National

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 Grant, Hatch and Federal

Scope of Impact: Integrated Research, Extension and Private

Activity: New Applications for Non-glutinous Cereals

Impact/Accomplishments: Commercialization will help stabilize production and develop new industries in Montana. Using 10,000 acres of land for production, the value at the farmgate will be $7.5 million. Value-added products derived from production and byproduct sales will add an estimated $18.9 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: New Applications for Hulless Oats and Legumes

Impact/Accomplishment: Commercialization will help stabilize production and develop new industries in Montana. Using 40,000 acres of land for production, the value at the farmgate will be $10.3 million. Value-added products derived from production and byproduct sales will add an estimated $20.6 million per annum. A farmer-owned cooperative has been established to develop these products. Market contacts are through locally owned cereal manufacturers.

Source of Funds: Hatch, Federal, and Private Funding

Scope of Impact: Integrated Research and Private Collaboration

Activity: Development of Products for the Equine Industry

Impact/Accomplishment: The equine industry is increasing in the western United States by 6 percent per year. All growth is essentially in non-working or traditional horses. Development of feeds specific for horse classes (athletic, geriatric and brood mare, as examples) are new markets for Montana producers. The new hay developed has a relative feed value of 150 (alfalfa has an RFV of 100). The equine industry, as a whole, in the United States has an economic value comparable to the U.S. petroleum industry. New products include a identity-preserved hay blend specific for horses and a supplement designed to be compatible with this hay. Other products include a hoof moisturizer and protectant, 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: Cultivation practices for the production of 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: The value-added high oleic safflower oil is higher in monounsaturates than olive oil and lower in saturates than olive oil. The product is grown on 50,000 acres, processed and marketed locally by the safflower oil processing plant, Montola Growers, Inc., in Culbertson, Montana. The safflower meal is utilized by the area livestock industry. The high quality Montola safflower oil has market potential in birdseed, cosmetics, infant foods, lubricants, in dietary food preparation, and as a feed additive for livestock.

Source of Funding: 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. This research 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 in developing countries. This work has determined that it is cost effective to manage wild oat infestations using site-specific technology only when less than 60% of fields are infested. 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, MI)

Activity: Fertilizer Use Efficiency

Impact/Accomplishments: Crop yield and quality are improved through the judicious use of fertilizer materials and manures. Statewide research is conducted in farm fields and at research centers to determine the response of new varieties and new crops in Montana. This research helps to optimize fertilizer use, minimize negative impacts on the environment, and improve net returns. Fertilizer guidelines are published with this information and disseminated throughout Montana.

Source of Funding: Montana Fertilizer Committee

Scope of Impact: State Specific

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

Impact/Accomplishments: New varieties of 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, SD)

Key Theme – Animal Health

Activity: Temporal and Spatial Distribution of Culicoides Vectors of Bluetongue

Impact/Accomplishments: Light trapping of adult midges indicated that the primary vector of bluetongue is present in parts of eastern and southwest Montana. A more comprehensive study will be initiated 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 from the tongue to the brain 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: Previously, we have shown that macrophages can destroy this parasite and recent results show that infection in a mouse model results in macrophage infiltration of the reproductive tract tissues. We have also shown that direct macrophage exposure to trichomonads leads to increased production of NO and COX-2, markers of macrophage activation. These results are consistent with the hypothesis that innate immune responses and inflammatory responses are directly triggered by trichomonads. The results also suggest innate immunity is likely to be important in destruction of *T. foetus* during infection. 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, 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

Scope of Impact: State and Regional

Activity: Innate Defense Mechanisms in Cattle

Impact/Accomplishments: Two inflammatory mediators that are implicated in regulating bovine neutrophil function in inflammatory events are interleukin-8 (IL-8) and platelet-activating factor (PAF). Interestingly, IL-8 and PAF can elicit different responses in neutrophils, depending on the cellular environment. For example, in an *in vivo* model of mastitis in cattle, IL-8 does not seem to attract neutrophils, while IL-8 is strongly chemotactic for bovine neutrophils *in vitro*. Conversely, the same study suggested PAF was implicated in the recruitment of neutrophils *in vivo*, whereas it was not chemotactic for neutrophils *in vitro*. Currently, little is known about the mechanisms behind these differential responses; however, there is some evidence that extracellular matrix (ECM) proteins can have complex modulating effects on neutrophil responses to these agents. To investigate this issue, we characterized functional responses (intracellular calcium, actin polymerization, degranulation, adhesion, and oxidative burst) of bovine neutrophils adhered to selected ECM proteins (collagen IV, laminin, fibronectin, thrombospondin, heparan sulfate proteoglycan [HSP]) in response to interleukin-8 (IL-8) and platelet-activating factor (PAF). Neutrophil adhesion to ECMs altered responses to PAF and IL-8, although some functions were more responsive to modulation. The most susceptible function was reactive oxygen species (ROS) production. ROS production in response to PMA and TNF-α was differentially supported by various ECMs, and PAF and IL-8 "priming" had strikingly different effects, depending on the ECM present. While both PAF and IL-8 inhibited TNF-α-induced ROS production in neutrophils adhered to collagen, fibronectin and laminin, PAF strongly enhanced ROS production in HSP-

adherent cells. This study illustrates how neutrophils can integrate multiple stimuli, resulting in complex modulation of their functional response.

Source of Funding: Hatch, USDA, and State

Scope of Impact: National

Activity: Innate Defense Mechanisms in Bison

Impact/Accomplishments: The majority of studies on NADPH oxidase function have been performed on human cells, several laboratory animals, and a few domestic livestock species. In contrast, almost nothing is known about NADPH oxidase function in wild ruminant species. Thus, we also characterized bison neutrophil function and found unique differences that may allow bison neutrophils to respond to the distinct host defense challenges bison encounter. We also extended this work by cloning and sequencing the full-length genes for all five of the bison NADPH oxidase components $p22^{phox}$, $p40^{phox}$, $p47^{phox}$ and $p67^{phox}$, and $gp91^{phox}$. When compared to other species, the deduced amino acid sequences of the bison homologs were most similar to those of bovine, but were less similar to those of the other species sequenced to date. Interestingly, a bison $p40^{phox}$ alternative splice product was isolated, which was similar to that observed for human $p40^{phox}$ in that the cDNAs contained sequence from intron eight. Consistent with the high degree of similarity between bison and bovine sequences, immunoblot analysis showed that the bison homologs migrated similarly to their bovine counterparts. Overall, these studies show that the bison and bovine NADPH oxidase genes are highly conserved between these two species, despite their divergence from a common ancestor over 1 million years ago.

Source of Funding: Hatch, USDA, and State

Scope of Impact: National

Activity: Innate 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. Because rabbits represent an established model for studying a number of important disease processes that involve NADPH oxidase activity, we carried out studies to clone and sequence all five rabbit leukocyte NADPH oxidase genes. Comparison of the rabbit sequences with those of other species showed that, with the exception of $p67^{phox}$, the rabbit phox proteins were highly conserved. In contrast, rabbit $p67^{phox}$ had a very divergent C-terminus and was 17 amino acids longer than any other known $p67^{phox}$ homolog. This was surprising, given the high degree of conservation among all of the phox proteins previously sequenced. To evaluate the functional consequences of this difference, wild-type rabbit $p67^{phox}$ and a mutated rabbit $p67^{phox}$ missing the C-terminal 17 amino acids were expressed and analyzed in a cell-free assay. Our results show that both the full-length and truncated rabbit $p67^{phox}$ proteins were able to support oxidase activity, although the truncated form reproducibly supported a higher level of activity than full-length $p67^{phox}$. These studies contribute to

our understanding of the nature of the leukocyte NADPH oxidase in different species and will be valuable in future research using the rabbit inflammation model.

Source of Funding: Hatch, USDA, and State

Scope of Impact: National

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 ~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 a coccidian parasites. Currently, sporozoite and early-fast growing libraries have been constructed and are undergoing sequencing. Our plan is to integrate the SAGE data into the NIH-sponsored Toxoplasma DB (http://ToxoDB.org/) such that tags are displayed on an assembled 12X genomic coverage of this protozoan pathogen.

Source of Funding: Hatch, State, and NIH

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

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

Impact/Accomplishments: Our project is aimed at increasing the efficiency of targeted mutagenesis in bovine cells, which could, in the future, be used to initiate modified breeds of animals. We have produced pure lines of bovine embryonic fibroblast cells (BEFs) from a purebred breed of dairy cattle (American Holstein) and from a genetically distant breed (Montana beef cattle, out-bred, with a high contribution of Angus). We also produced a genomic DNA library in lambda-phage from the American Holstein BEFs. Using a DNA clone from this library, we are constructing model vectors for targeted mutagenesis. Differences in targeting efficiency between the two cell lines will be correlated to the number of DNA sequence differences between the cell lines at the targeting locus. We will then introduce specific mutations into the targeting vector and measure the effects of these on targeting efficiency in the two cell lines. Our goal is to measure how critical it is to use isogenic vectors for targeting mutations into bovine cells.

Source of Funding: Hatch, USDA, and State

Scope of Impact: National

Activity: Pathogenesis of and Immunity to Bovine Shipping Fever

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

Source of Funding: State

Scope of Impact: National

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

Impact/Accomplishments: Population densities of *C. sonorensis* were monitored in 2003 and it was determined that three generations occur during the 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 indicted 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 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: Effect of Calf Scours on Weaning Weight and Economic Impact on Montana Producers

Impact/Accomplishment: Beef cattle health and performance records were analyzed from 3,637 calves over a 14-year period for impact of scours on calves. Calves contracting scours weighed 19 pounds less at weaning with average reduced income per calf of $34.84 when cost of treating was included. Research has shown importance of management, especially in first calf heifers, to reduce incidence of calf scours.

Source of Funding: State, Hatch, and Private Industry

Scope of Impact: Integrated Research and Extension

Activity: Sheep Nutrition

Impact/Accomplishment: A major factor reducing profitability in sheep operations is lamb mortality. Causes of neonatal mortality are similar regardless of geographic region.

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. Lambs subjected to cold stress at birth show an immediate and positive response to safflower supplementation of the ewe during late gestation and colostrums intake. Positive response to late gestation supplemental vitamin E on lamb survival does not enhance immune function. Additionally, although Zn supplementation increases serum vitamin E levels, high levels of dietary zinc may have a negative impact on immune function. Lambs receiving colostrums were more cold tolerant than those receiving no colostrums prior to a cold challenge.

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

Scope of Impact: Integrated Research and Extension

Activity: Sheep Reproduction

Impact/Accomplishment: Mass selection for reproductive rate in ewes does not alter the mating behavior of male offspring. Research is underway to identify specific genes controlling litter size. If genes are discovered, this could lead to a gene test that would allow producers to more efficiently select for litter size.

Source of Funding: Hatch and State

Scope of Impact: Integrated Research and Extension

Activity: Wool Quality

Impact/Accomplishment: Currently, objective measurements of wool are the standard for selling wool. However, that technology is designed for measuring whole clips rather than individual animals. 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 when 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/Accomplishment: 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 un-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 and numerous pest problems can be minimized.

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

Scope of Impact: Integrated Research and Extension

Activity: Beef Cattle Nutrition – Concentrates

Impact/Accomplishment: 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 indicate that barley and corn have similar feeding values in high concentrate diets. In addition, 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/Accomplishment: Barley harvested as hay is a significant source of winter forage for livestock producers 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. MT 981060 has superior feeding value for backgrounding steers and is scheduled for release by the Montana Agricultural Experiment Station. These new barleys increase livestock producers bottom line profits, since they can feed locally-grown barley and decrease imported corn purchases. Crop barley producers have an expanded market for their barleys.

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

Scope of Impact: Integrated Research and Extension

Activity: Beef Cattle Nutrition - Minerals

Impact/Accomplishment: Adequate dietary trace minerals are an essential component to growth and sexual development in males. 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/Accomplishment: 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/Accomplishment: 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: 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 different for different calving seasons. Morbidity of beef calves can be significantly improved by implementing a weaning protocol that includes viral vaccinations, supplemental crude protein, vitamins and trace minerals. A feeder-calf certification program has been implemented for beef quality-assurance trained producers based on best management practices for enhancing calf health. Central to this networking approach is the exchange of information from the producer to the end user (feedlot, packing plant).

Source of Funding: Hatch, State, 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 yield potential and crop quality are superior to levels experienced in traditional mid-western soybean production areas. Added benefits would include rotation-related pest suppression in rotation crops as well as reduced nitrogen fertilizer use. A projected 25,000 acres of soybean would have a minimum economic impact of $ 7 million to the local economy. Computer-based information technology has been implemented to assist in dissemination of research center results and recommendations to the public. The center currently possesses full time internet connectivity and is equipped with an on-site server system. Web access at

http://www.sarc.montana.edu currently 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/Accomplishment: Potential impact on both livestock and annual crop production. Winter triticale has resistance and/or tolerance to some diseases that infect early seeded winter wheat. This provides for a wider period of forage utilization than is available with winter wheat. Winter triticale forage varieties have the potential to 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: Potential impact on both livestock and annual crop production. Winter pulses have the potential to 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: Natural Protection to Crops from Applications of Glyphosate

Impact/Accomplishments: The impact of this research will provide an alternative to genetically modified (GMO) crops using the same herbicide system. Currently, 90+ % of the corn, soybeans, and cotton, and 80+% of the canola grown in North America are GMO crops. By providing a seed treatment, other crops can be used in a glyphosate herbicide management system. In addition, the use of GMO-derived resistance could be made obsolete, providing an environmentally friendly alternative with no genetic resistance transfer to non-GMO crops or weeds.

Source of Funds: Hatch and Federal

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 positively influence spring wheat yield and quality. Diverse crop rotations and no-till planting can be used to effectively manage disease and weed problems in spring wheat production in Montana. Legume and oilseed crops left sufficient post-harvest residues for protection of soil from wind and water erosion. Differences in insect numbers were recorded among the various crops. Legumes for the most part had the fewest pest problems while wheat following fallow had the highest number of potential pests. Plant diseases were less in no-till than conventionally tilled plots. Fusarium crown rot was found in higher levels in wheat produced with conventional tillage than wheat in zero tillage systems.

Source of Funding: Hatch 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. MSU is investigating agronomic constraints for chickpea, winter lentil and winter pea production. As a result of specialty crops research at MSU, constraints to chickpea production in the US Northern Plains region have been well communicated to farmers resulting in shifting acreage from chickpea to pea and lentil. When favorable economic circumstances return for chickpea, our research efforts have developed production packages with acceptable risk. Pea and lentil production in Montana is 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, SD)

Key Theme – Emerging Infectious Diseases

Activity: Monitoring West Nile Virus Vectors in Montana

Impacts/Accomplishments: Mosquito populations were monitored from trap sites located in 22 counties in the state during 2003. The primary vector, *Culex tarsalis*, was captured in each county but not all trap sites indicating the ubiquitous nature of this rural species in the state. Trapping efforts along major river drainages showed the predominant mosquito species were floodwater species early in the summer; populations of *Cx. tarsalis* increased during the summer peaking in late July and early August. Of 634 pools of mosquitoes assayed for WNV, 143 or 22.5% were positive. The areas with the highest number of positive mosquito pools included counties along

the Milk River in northern Montana and along the Yellowstone River in the eastern part of the state.

Source of Funding: Centers for Disease Control

Scope of Impact: State and Regional

Activity: Emerging Infectious Diseases and Center for Bison and Wildlife Health

Impact/Accomplishments: Emerging infectious diseases represent a growing threat to public and animal health. A potential major source of new and spreading infections is the interaction of livestock and wildlife, which are in close association in Montana. Many infectious organisms, which have reservoirs in wildlife and livestock, are also considered potent biowarfare agents. Therefore, it is essential that we begin to develop an understanding of these diseases and identify mechanisms to prevent their spread. The Center focused on wildlife health will carry out investigations on infectious diseases affecting wildlife.

Source of Funding: State, Hatch, and USDA

Scope of Impact: National

Activity: Mucosal Distribution of the Chronic Wasting Disease (CWD) Agent

Impact/Accomplishment: These studies can identify mucosal sites from which the CWD agent is shed during infection. Knowledge of CWD transmission is necessary for developing strategies to prevent spread of CWD in free ranging and captive cervids.

Source of Funding: DOI

Scope of Impact: National

Activity: Biomarkers of Neuroendocrine Function in Chronic Wasting Disease (CWD)

Impact/Accomplishment: Identification of altered host biomarkers of endocrine and neuroendocrine function in blood or saliva from CWD infected cervids could be used to develop a preclinical test for CWD.

Source of Funding: DOI

Scope of Impact: National

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. About 7,500 acres were mapped in Montana and Wyoming in 2003. Improved mapping will lead to more focused and economical control measures in the short term and improved plant biodiversity in the long term and greater weed resistant plant communities.

Source of Funding: BLM, NWTF, and NPS

Scope of Impact: Multistate Research and Extension (MT, 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. Results of monitoring systems are used to alert producers for these insect pests via the internet and in Extension programs. Improvements have been made in the cutworm monitoring program that now results in the production of the Northern Great Plains that predict army and pale western cutworm activity. This program has been expanded to eight states and one province. A risk model has been developed that improves the ability to weight factors that influence expected risk of cutworm infestations on <cutworm.org>.

Source of Funding: Hatch, Smith Lever, and State

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

Activity: Biological Control of Leafy Spurge

Impact/Accomplishments: Previous research has shown that the 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: Biological Control of Dalmation Toadflax

Impact/Accomplishment: Infestations of Dalmatian toadflax continue to rank among the most serious pests affecting rangeland and agricultural production in the region. The

prevalence of this weed on rangeland limits the amount of money that can be justified for conventional weed management. These infestations often occur in areas in which it is impossible or undesirable to apply herbicides, and herbicides have comparatively little impact on this species. Thus, effective and environmentally safe methods of weed management, such as biological control, are being developed for long-term management of weeds on lands of low economic return. Geostatistical approaches are being used to document the establishment and suppressive impact of the stem-mining weevil, *Mecinus janthinus*, on Dalmation toadflax populations throughout Montana. This switch from qualitative to quantitative documentation of success has long been needed in weed biocontrol in general. Additional research focuses on documenting the primary and secondary metabolic impacts of this weevil species on Dalmation toadflax at multiple field sites. The research clearly shows that this species causes significant decreases in primary physiological processes, while altering secondary metabolic outputs. A comparative study using an earlier ineffective biocontrol agent shows less significant changes, indicating that monitoring of these processes may be quite applicable to upstream screening of potential bioagents abroad. Using an analytical tool that could help quantify potential impact may prove to be very important for agent screening. Additional efforts are continuing on establishing numerous insectary sites for this stem-mining weevil throughout Montana. This coming summer is the first year of a long-term study, where we are anticipating being able to redistribute Montana-produced individuals of this stem-mining weevil to other Dalmation toadflax infestations within the state.

Source of Funding: Hatch, NWTF, and State

Scope of Impact: State and Regional

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 Montana State University insect quarantine facility, Bozeman, MT. 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 Whitetop

Impact/Accomplishments: Host specificity testing has been initiated for the eriophyid mite, *Aceria drabae*, which induces compact, leafy galls that stunts the plant or prevents flowering. Two mite shipments were received from the USDA-ARS-EBCL station in Thessaloniki, Greece for testing in 2003. Approximately 40 plant species (including 6 *Lepidium* species) plus numerous varieties of economic *Brassica* have been tested to

date. The mite appears to be highly host specific, only infesting its natural host *Lepidium draba*.

Source of Funding: Hatch and State

Scope of Impact: State, Regional, and International

Activity: Biological Control of Field Bindweed

Impact/Accomplishments: Field bindweed, *Convolvulus arvensis* (Convolvulaceae) is one of the most aggressive, perennial weeds of grain producing areas of North America. To control this weed the leaf galling mite *Aceria malherbae* (Acari: Eriophyidae) has been utilized. The phenology and spatial distribution of the mite were followed for a three year period (2000 - 2002) in central Montana. Stems of field bindweed emerged late in May and continued to emerge until mid-July. Thereafter, numbers generally declined due to senescence caused by dry conditions. In contrast, the number and percent of mite infested stems increased during the summer. No significant declines in stem densities were observed, although densities varied within the season depending upon moisture, as well as among years. Leaf production and galls generally increased during the summer. Greater numbers of galls were observed on leaves in the upper stem crown. In 2000, mean mite populations per gall increased during the season, whereas in 2001 & 2002, populations peaked in July and then decreased. Mites dispersed to root buds during the drier parts of the summer, but were also located on buds throughout the season. Both bindweed stems and infested stems were spatially aggregated within plots. This aggregation, although somewhat consistent from year to year, varied throughout the season and among years. Weak associations between stem densities and the presence of infested stems were noted. These associations did not reflect the intensity of mite infestation. Slight microhabitat differences may exist which would influence the success of the mite to overwinter and to repopulate plants the following year. Monitoring of previous releases indicated that the mite successfully overwintered at three sites located in Philips, Richland, and Yellowstone counties. One additional release of *A. malherbae* was made in Yellowstone County during 2003.

Source of Funding: Hatch and State

Scope of Impact: Regional

Activity: Biological Control of Russian Knapweed

Impact/Accomplishments: Host testing has been completed for: *Urophora kasachstanica*, *Urophora xanthippe* (flower gall flies - Diptera: Tephritidae), and *Aceria sobhiani* (stem mite). Both flies appear to be host specific, therefore a biological assessment for the release of the two *Urophora* species was finalized and reviewed by the Technical Advisory Group on the Biological Control of Weeds. The work on *Aceria sobhiani* was discontinued due to genetic bottle necks within the lab population of the mite and concerns regarding its host range. In addition, the only known population of the mite in Central Asia has been destroyed. *Aceria acroptiloni* (flower mite) was collected from Uzbekistan and limited rearing and host specificity tests were conducted. In 2002 a population of a *Galeruca* leaf beetle (Coleoptera: Chrysomelidae) was located by U. Schaffner (CABI) in Uzbekistan. This defoliating beetle was reared through one

generation in the quarantine lab. Eggs were obtained from lab reared adults but upon hatch all of the larvae died for reasons unknown.

Source of Funding: Hatch, State, and USDA

Scope of Impact: State and Regional

Activity: Biological Control of Tansy Ragwort

Impact/Accomplishments: Tansy ragwort is a recent invader in the northwestern portions of Montana. Biological control has been utilized to limit the spread and density of this weed. Biotypic differences in the phenology and host specificity of several populations of the tansy ragwort flea beetle, *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae) for use in Montana were studied in Switzerland over the past three years. DNA analysis indicated that the Swiss population of the beetle is very similar to established North American populations introduced from Italy (which have failed to establish in Montana). Nine native North American Senecio and Packera were tested in open field and in no-choice greenhouse studies to determine the specificity of the flea beetle. None were utilized by the Swiss population. Approximately 18,000 eggs and 70 adult beetles were released in Montana during 2002/2003. Although we observed plants that were infested, no adults were located during the summer of 2003, probably due to the dry, hot conditions impacting plant populations.

Source of Funding: Hatch and State

Scope of Impact: State, Regional, and International

Activity: Biological Control of Rush Skeletonweed

Impact/Accomplishments: Two collections of rush skeletonweed roots infested with *Bradyrrhoa gilveolella* (Lepidoptera: Pyralidae) were made near Lake Prespa in northwestern Greece. Roots were sent or hand carried to the Insect Quarantine Laboratory located at Montana State University. Approximately 57 adult moths were reared from the first collection from northern Greece. From these adults we obtained less than 3,400 eggs. Egg viability was estimated at 82%. The resulting larvae were used for field releases, establishing a laboratory colony, and for diet and feeding studies. Viable eggs were also sent to the Nez Perce Biocontrol Center to start a field insectary. The second shipment of roots was received in September 2003 and the larvae from this shipment were transferred to plants for additional rearing in the quarantine lab.

Releases were made in 2003 at four sites in southern Idaho: Banks, Garden Valley, Goodrich, and Idaho City. Approximately 1,020 larvae were placed on plants at these field locations. Sites were revisited on 20 September 2003 and ten plants were inspected for the establishment of larvae. Larvae were located at two sites. Hot temperatures during the release of the larvae may have contributed to the poor establishment at the other two sites. These sites will be revisited in 2004. An additional release of *Bradyrrhoa*, using eggs obtained from laboratory rearing, was made in October 2003 near the Salmon River.

A few infested plants were placed near Garden Valley, ID in November 2002. Plants were removed in September 2003 and dissected. Although few in number, nearly all the

larvae pupated and emerged as adults. This indicates the likelihood that *Bradyrrhoa* will be able to survive the Idaho winters.

A laboratory colony is being maintained at MSU and at the USFS Forestry Science Laboratory, Bozeman. We hope to continue the colony so that additional moths may be released in 2004. To augment the rearing of the moth, work on the development of an artificial diet began. On preliminary diets, larvae fed for extended periods and more mature larvae completed their development to emerge as adults. Studies were also initiated to investigate the impacts of larval feeding on the root.

To determine habitat associations of *Bradyrrhoa gilveolella* in Europe, a total of nine sites were surveyed in Greece, six in Bulgaria, and eight in Idaho. Aspect, slope, elevation, average *C. juncea* plants per area, presence of *B. gilveolella*, and other site parameters were recorded for each site visited. A total of six surveyed sites in Europe contained *B. gilveolella.* Soil samples were also taken at each site. Data analysis for the European and Idaho sites will be conducted this winter.

Source of Funding: Hatch and State

Scope of Impact: State, Regional, and International

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 Sugar Beet

Impact/Accomplishments: Development of plants resistant to common diseases and the understanding of the pathogens are two important goals. *Cercospora* leaf spot in sugarbeet has been effectively controlled by a combination of partially tolerant germplasm and use of biocontrol agent Bac-J that is now under commercial production. An understanding of the genetics of mating types in *Ustilago hordei* is being explored to identify methods for controlling this 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 endophylic 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, State, Region, and Nation

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

Impact/Accomplishment: The sawfly resistant winter wheat cultivar Genou was released. Wheat stem sawfly causes up to $30 million in crop losses annually. The demand for the previously released solid–stemmed winter wheat varieties Vanguard and Rampart seed

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: Nutrient Management and Agronomic Practices for Dryland Malting Barley

Impact/Accomplishment: Montana dryland grain producers are being asked to increase malting quality, barley production for the new International Malting Corporation plant currently being built in Great Falls. Recent research indicates that production techniques need to focus on quality rather than yield potential and that nitrogen fertilization has marked effect 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; however, research continues on plant population and nutrient interactions for acceptable malting barley 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/Accomplishment: 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/Accomplishment: This project initiated canola and rapeseed variety evaluations in 1986, three years prior to private industry initiating contract production in the state and providing support for research. Canola acreage has stabilized around 30,000-50,000 acres in Montana.

Source of Funding: State, Hatch, and Private Industry

Scope of Impact: Integrated Research and Extension

Activity: Research to Control Kochia Infestations in Small Grain Production

Impact/Accomplishment: Kochia is a severe weed problem in all of Montana's dryland cropping systems. Recent research resulted in new, effective methods to control kochia by using post harvest management strategies. Recommendations based on this research are presented in a new MontGuide (#200213 "Post harvest kochia management in small grains". All 500 copies of the first printing sold out within 2 months of release. Furthermore, the MontGuide is available on the web and has been frequently downloaded.

Source of Funding: State, Hatch, and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Introduction of Haybet Awnless Hay Barley

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

Source of Funding: State, Hatch, and MWBC

Scope of Impact: Integrated Research and Extension

Activity: Air Drill Evaluation

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

Source of Funding: State, Hatch, and MWBC

Scope of Impact: Integrated Research and Extension

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

Impact/Accomplishment: The sawfly resistant cultivars 'Choteau' spring wheat and 'Genou' winter wheat were recently developed and released. Both offer agronomic and quality improvements over other sawfly resistant varieties. Both varieties will save up to $30 million in crop losses due to sawfly, and demand for seed is exceptionally high.

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/Accomplishment: Busch Agricultural Resources, Inc., (BARI), Cargill, Inc., and Coors, Inc. have increased malt barley production from none in 1998 to 500,000 bushels in 1999, 2M bushels in 2000, 4M in 2001, 8M in 2002 to 18M in 2003, to enable MonDak producers to become preferred suppliers of malt barley and to increase economic returns. A new 1.5M bushel malt barley handling and storage facility was built by BARI and put in 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 sprinkler and flood irrigations and dryland production.

Durum varieties selected for and adapted to production in Montana will improve the yield and quality of durum produced. Pasta production and durum mills in North Dakota and Montana have proved to be successful, and are 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, 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 2000 acres yielding 6 T/acre of alfalfa has added $600,000 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, 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. This research demonstrated that early cutting, an important cultural control, can be improved by addition of a raking step to the harvest process. As a result, a savings up to $15 per acre was calculated for alfalfa hay production due to decreased pesticide need for alfalfa weevil control. With 1.7 million acres of harvestable alfalfa hay in the state, if this technique saves an insecticide application on 10% of the total acres, a savings of $2 million can be realized each year.

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, NE)

Activity: Reducing Traditional Pesticides-Replacement with Effective/Economical Biopesticides

Impact/Accomplishments: We investigated the efficacy and costs of biopesticides for the management of forage and seed crop insect pests including alfalfa weevil, pea aphid, cereal aphids and lygus bugs. Novel chemistries such as insect growth regulators and new botanical products were tested in 2003 for their effectiveness in controlling pests and conserving natural enemies and pollinators. Alternatives to classical pesticides improve management, decrease energy inputs, and expand the choices available through IPM practices.

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

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

Activity: Elucidating Mortality Factors of Alfalfa Leafcutter Bees

Impact/Accomplishments: In western North America, managed populations of the leafcutting bee *Megachile rotundata* are used to maximize seed yield in alfalfa seed production. 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: Smith-Lever and State

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

Activity: Wheat Stem Sawfly Management

Impact/Accomplishment: The wheat stem sawfly, a perennial small grain pest in Montana, cannot be managed by conventional agricultural practices (e.g., burning, tillage, swathing, insecticides). Thus, there is an urgent need to develop new tools for its management. Recent advances in the understanding of sawfly ecology are providing tools for development of innovative management strategies for this pest. Research efforts have now identified numerous chemical odors that are used for sawfly mating and for location of host plants. In particular, an attractant compound, *cis*-3-hexenyl acetate, has been found to synergize the activity of key pheromonal compounds successful trapping experiments. Research this past summer has suggested that nonanal was a

key a pheromonal attractant for female wheat stem sawflies, and activity was synergized by the addition of *cis*-3-hexenyl acetate, while male sawflies responded to a pheromonal combination of 9-acetyloxynonanal and hexadecanal synergized by *cis*-3-hexenyl acetate. In addition, the amount of *cis*-3-hexenyl acetate released by different wheat varieties has been shown to be critical in determining wheat stem sawfly infestation levels in laboratory and field experiments. We have already applied this approach to the concept of optimized trap strips, using semiochemical and agronomic traits, to plant wheat that will retain the wheat stem sawfly, and protect a growing crop. The trap strip can be harvested as green forage for sawfly control. We believe these trap strips could be a critical component in an integrated biorational sawfly management program. A second component of this integrated approach is biological control. In 2003, we initiated a pilot scale effort to innoculatively establish efficacious braconid parasitoids on six Montana farms. On four farms we established parasitoids where there were none previously. On the other two farms we augmented an existing population of these parasitoids. These natural enemies of the sawfly are endemic to Montana and are attracted to unique ketone odors produced by infested plants. Wheat varieties vary in the amount of these ketones that are produced, therefore this is a new tool that can be used by wheat breeders to promote biological control. Detailed plans are underway to conduct a multiyear monitoring of these newly-established parasitoid populations, so that we can document the changing rate of sawfly suppression over several generations.

Source of Funding: Hatch, State, and USDA

Scope of Impact: State and Regional

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

Impact/Accomplishment: Wheat stem sawfly causes up to $30 million in crop losses annually. Sawfly resistant cultivars are continually being evaluated. The demand for solid stem varieties or traits tolerant to sawfly attack is exceptionally high and varietal development and evaluation is an important focus of the program. We are striving to develop new varieties (8 to 10 years start to finish) that will maintain yield and quality characteristics without use of insecticides.

Source of Funding: Hatch, State, and MWBC

Scope of Impact: Integrated Research and Extension

Key Theme – Precision Agriculture

Activity: Application of GIS and GPS

Impact/Accomplishments: Research on applications of geographic information systems (GIS), global positioning systems (GPS), sensors and remote sensing technologies such as yield monitors, satellite imagery, variable rate application equipment, tracking technologies, and field navigation devices, farmers and ranchers have new opportunities to incorporate precise, site-specific information into land management decisions.

Source of Funding: State, Hatch, MWBC, and Fertilizer Advisory Committee

Scope of Impact: Integrated Research and Extension

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 and applications of geographic information system (GIS), global positioning systems (GPS), sensors, remote sensing technologies, yield monitors, satellite imagery, climate information, variable rate application equipment, 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, WY)

Program 3. Agricultural Finance, Marketing, and Policy

Key Theme - Adding Value to New and Old Agricultural Products

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

Impact/Accomplishment: Answered producer and policy maker-questions with findings: Wholesale-retail margins for beef and pork and 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. Consumer response to GMO-free labels on branded milk exceeded 50% of market sales. The pre-outbreak program of vaccinating all cattle herds for brucellosis with tests of 25% random selection dominated other vaccinations/testing programs. Impacts included:

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 in Montana and U.S. Agriculture

Impact/Accomplishment: Developed a new method to simulate carbon supply curves for the adoption of reduced fallow and conservation tillage practices. Compared this new method to results from farm-scale analysis conducted for Montana. Estimated field-scale carbon rates using the Century ecosystem model. Used these data to derive carbon supply curves at the sub-MLRA level. Impacts include: 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/Accomplishment: Research addressed risk management and crop insurance policy, the honey program, grain markets, segregation programs, and the importance of biotech labeling policies. The mix of publications indicates that the 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 1200 farmers, agribusiness leaders, and policy makers in the four state region of Montana, North Dakota, South Dakota and Wyoming. The benefits accruing to farmers and ranchers from these project results have therefore been very substantial but difficult to measure.

Source of Funding: Hatch and State

Scope of Impact: Montana, North Dakota, South Dakota, and Wyoming

Activity: Agricultural Finance and Farm and Ranch Management

Impact/Accomplishment: 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: Montana, Regional, and National

Activity: Externalities in Agriculture: The Economics of Pollination and Honey Markets

Impact/Accomplishment: The causes and consequences of the federal honey program were analyzed. Work continued on a paper providing an empirical analysis of pollination markets, "An Empirical Analysis of Honeybee Pollination Markets," presented in seminars at economics and agricultural economics departments at Clemson and the University of Maryland. Research results were presented at the annual meetings of the Oregon and Washington Beekeepers Association in Hood River, Oregon in November. Dissemination of economic thinking on pollination markets was made to professional beekeepers and others directly concerned with agriculture and the beekeeping industry. Dissemination of results to non-agricultural audiences communicates the importance of pollination in agriculture and the role of markets in coordinating its provision.

Source of Funding: Hatch and State

Scope of Impact: Regional and National

Activity: Impact Analysis and Decision Strategies for Agricultural Research

Impact/Accomplishment: 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 justifying agricultural research programs.

Source of Funding: Hatch and State

Scope of Impact: Regional and National

TOTAL GOAL 1 Funding- $9,967,415 FTE- 289.4

GOAL 2. A SAFE AND SECURE FOOD AND FIBER SYSTEM

Executive Summary

The development of new varieties and the quality 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. The science of plant breeding is responsible for approximately one-half of the dramatic yield gains experienced for most of our major crops over the past few decades. Additionally, genes for resistance to major insects and diseases have been incorporated into successful crop cultivars. The basis for plant improvement through breeding is the exploitation of genetic variability. In order for this variability to be accessible to plant breeders, plant collections must be developed, catalogued, and characterized. Finally, once superior varieties have been developed, it is vital that pure and healthy seed stocks be maintained throughout the seed production and commercialization process. Another source of important genes is the endophytes that

live in association with plant species. Characterization of these species has led to the identification of medically and agriculturally important compounds.

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

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 their own seed in a replant situation or a large seed company involved in state, regional, and international shipments.

Source of Funding: State and 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 may be the first major genetically engineered crop to be marketed and grown in Montana. Although this spring wheat is not grown commercially in Montana, considerable discussion among the public 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 current, commonly used herbicides 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

TOTAL GOAL 2 Funding- $951,425 FTE- 11.1

GOAL 3. A HEALTHY, WELL NOURISHED POPULATION

Executive Summary

Human nutrition studies and the use of medicinal plants can impact the health and nourishment of people. The effects of improved food product content labeling on consumer purchases of dairy products are being investigated. Initial results indicate that credible and accurate labeling about bST content and organic and non-organic milk products leads to important changes in consumer purchases and, by implication, improved consumer choices. The FDA has set requirements for labeling of the products.

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

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

Source of Funding: State

Scope of Impact: National

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 with their endophytes which have multiple impacts on our society by virtue of the development of new knowledge, national and international patents that have and will be licensed to pharmaceutical, agricultural and industrial based companies.

Source of Funding: Hatch and State

Scope of Impact: National

TOTAL GOAL 3 $581,371 FTE- 3.8

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, interactions with agricultural practices and natural resources are commonplace and often complex. Pests, the soil-plant-water-air continuum, wildlife, livestock and other agricultural enterprises interact in complex ways. When one also considers the additional interactions of the human species, it is intriguing to study agricultural systems and the environment.

A survey of hunter management strategies used by ranchers in Montana has been completed. Findings led to the development of landowner/hunter education programs

aimed at landowner concerns. A project currently underway includes a study attempting to identify prescriptions to use livestock grazing to improve habitat for elk. Elk and cattle habitat use patterns are being monitored.

IPM seeks to optimize grower profitability and natural resource sustainability through development, selection and implementation of appropriate pest management tactics that are economically sound and environmentally acceptable. Cropland weeds are the major pest impacting Montana cropland agriculture. Developing integrated weed management systems requires the study of weed biology, herbicide efficacy, and crop performance. Field and greenhouse studies were utilized to quantify these relationships and develop management strategies for the numerous weeds impacting small grain systems.

The movement of chemicals through soils under different water conditions can negatively impact water quality. Water shortages, increased multiple use pressure for water resources, and surface water runoff all speak to efficient uses of irrigation water. Field and laboratory experiments were conducted to evaluate the calibration of approaches with TDR to provide real-time estimates of solute (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.

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. IPM seeks to optimize grower profitability and natural resource sustainability through development, selection and implementation of appropriate pest management tactics that are economically sound and environmentally acceptable. IPM systems are dynamic and the application of IPM is site-specific in nature; selection of individual tactics is determined by the particular crop-pest-environment complex. IPM research and education programs need 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 management of cattle grazing in concert with riparian habitats, wildlife, and clean water. Characterization and understanding of the complex interactive components will lead to improved soil, plant, and water resources in ecosystems.

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

In Montana and throughout the U.S., the relationship between economics and the sustainability of ecological systems has become one of the critical issues in modern agricultural and environmental policy. The sustainability of alternative land uses is equally critical for public and private lands. Because private and public lands comprise common ecological resources (e.g., river systems, wildlife) it is also important to study these lands together. Understanding how the various land uses (e.g., farming, ranching, timber, recreation, mining, development, and subdivision) are determined is crucial in determining the sustainability of these lands. In order for farmers, ranchers, forestland companies, and public land mangers to adapt to changing conditions it is essential that they be provided with information in the link between economic decisions, government programs, land use, and sustainability. Economic analysis of these issues can be an essential component in this discussion and analysis.

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, Canada)

Key Theme - Integrated Pest Management

Activity: Insect Quarantine Laboratory

Impact/Accomplishment: The primary objective of the MSU Biological Control Containment Facility is to facilitate the importation, augmentation, study, and release of potential agents for the biological control of noxious weeds of regional importance. During 2003 sixteen shipments representing nine arthropod species and one plant pathogen were received in quarantine to be assessed for their suitability as biological control agents or for rearing for field release. These included: *Aulacidea subterminalis* (hawkweeds), *Spurgia capitigena* (leafy spurge), *Bradyrrhoa gilveolella* (rush skeletonweed), *Aceria acroptiloni* (Russian knapweed), *Aceria* sp (yellow starthistle), *Aceria draba* (hoarycress), *Longitarsus jacobaeae* (tansy ragwort), *Thamnurgus euphorbiae* (leafy spurge), and *Cephus fumipennis* & *Collyria* sp. (a parasitoid for wheat

stem sawfly). The micro-containment laboratory was utilized by the Department of Plant Sciences & Plant Pathology. Various strains of pathogens have been brought into the containment lab to determine their suitability as biological control agents of leafy spurge and Canada thistle. This facility will assist in the identification and implementation of additional biocontrol agents.

Source of Funding: State and Industry

Scope of Impact: State, Regional, and International

Activity: Regional Cutworm-Monitoring Program

Impact/Accomplishment: A regional cutworm-monitoring program has been in place for more than 10 years. Activity of adult pale western and army cutworms are monitored using pheromone traps to indicate relative activity of each species in an area and provide a prediction of cutworm larvae and damage the following spring. Correlations between trap catches and larval densities and critical weather data are being developed for a regional forecasting model. Because extensive larval cutworm damage can occur rapidly in the spring, cutworm moth catches reaching or exceeding economic thresholds in the fall can be used to alert producers in those areas about potential cutworm problems the following spring. 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 at Western Triangle Ag Research Center showed increased moisture conservation; improved stand establishment in dry years; increased winter survival; decreased air and water pollution; decreased soil erosion; decreased production costs; and increased crop yield. Grower adoption of no-till chem-fallow continues to be enhanced by this research activity. Stand establishment for canola has been far more successful with no-till than tillage systems because no-till maintains moisture closer to the soil surface.

Source of Funding: 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, a greenhouse gas 300 times as potent as CO_2. 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, WY)

Activity: Wildlife Management

Impact/Accomplishment: Contrary to other studies, research in Montana has demonstrated that prairie dogs have a considerable impact on plant succession in the mixed grass prairies of Montana. Damage by ground squirrels to alfalfa in Montana is estimated to be 5 million dollars per year. Losses are also occurring in other forage crops and on rangelands. Control methods are being tested which great potential to reduce crop losses for Montana farmers. 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/Accomplishment: Sheep grazing is being evaluated and demonstrated as a tool to manage invasive plants on rangelands. Efforts are focused on leafy spurge and spotted knapweed. In 2003, controlled grazing was utilized to manage weeds on approximately 70,000 acres of weed-infested rangeland in Montana. These projects involved 892 different landowners, and about 16,000 ewes plus their lambs from 26 different Montana sheep producers. Data from 31 plots 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/Accomplishment: Successional patterns of sagebrush communities are being researched in relation to fire recovery under a wide variety of conditions. Investigations continue on the effects of herbivory on several shrub types, and the nutritional relationships of different sagebrush taxa with a variety of foraging histories. Natural resource agencies are adapting policies based on the findings of this work.

Source of Funding: Hatch, State, and USDA

Scope of Impact: Integrated Research and Extension

Activity: Riparian Ecology

Impact/Accomplishment: 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/Accomplishment: Low-cost cattle grazing strategies are needed for improved stewardship of riparian ecosytems. 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/Accomplishment: 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. Research has shown that 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: Wildlife-Livestock Interactions

Impact/Accomplishment: 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, UT)

Key Theme – Water Quality

Activity: Irrigation Water Management

Impact/Accomplishments: Agriculture - in the form of food production and irrigation - is the single 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 in Montana, 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 supplies. 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, and educational efforts are underway to help Montana citizens learn how to protect the preserve the state's water resources and protect citizen health. We have greatly enhanced our www presence with facts on water quantity and quality.

Source of Funding: USDA

Scope of Impact: State and Regional

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 effort spearheaded by MSU faculty. 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, 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

TOTAL GOAL 4 Funding- $3,757,964 FTE- 121.5

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

Executive Summary

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

Montana exports approximately 85% of its raw commodity products. Improved quality of existing commodity products will increase demand in the world marketplace. Currently, Montana's wheat is marketed predominately in the Pacific Rim and is recognized in this market for its high quality. In the future, it will be increasingly important to add value to raw agricultural commodities and processed food products before they leave the state. The revitalization of agriculture and rural communities in Montana is essential for the state's economic sustainability and competitiveness in the global marketplace. Advances in biotechnology and information technology are and will continue to have an increasing impact on agriculture, the properties of food, and the ability to manage the environment. Montana producers must address production from a precise systems perspective that reduces input costs and minimizes environmental impacts while optimizing yield and enhancing quality. A biobased economy will provide in-state manufacturing, product development, rural development, and jobs.

Key Theme - Biobased Products

Activity: Institute for Biobased Products

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

Source of Funding: State, USDA, and Industry

Scope of Impact*:* Regional

TOTAL GOAL 5 Funding- $803,549 FTE- 12.6

Stakeholder Input

The Montana Agricultural Experiment Station (MAES) and College of Agriculture (COA) use multiple approaches to obtain stakeholder input on programs conducted, research priorities implemented, and actively solicits input on changes in program direction.

Currently, a national search is underway to find a permanent Dean of the College of Agriculture and Director of the Montana Agricultural Experiment Station (MAES) with a start date of July 1, 2004. During this period of transition, several new stakeholder committees were formed that expand the historical scope of input into our priorities: College Development Board, Precision Ag Research Association (PARA), and the Ag Coalition. The College Development Board consists of ranchers, farmers, bankers, state associations and teachers. They provide direction on our activities to externally support high priority needs: 1) Research Centers (7) $1M dollar match (state provided $1M and non-state match of $1M must be secured) to renovate, build and repair facilities on 5/7 Research Centers throughout Montana, and 2) Animal BioScience Facility which is a new endeavor that will require $8-10M 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 foster new research partnerships.

PARA is an external group to MAES that charges their own dues and conducts quarterly meetings throughout Montana with members and selected professionals. MAES scientists routinely participate with these landowners and NRCS to provide training and expertise in GPS, GIS and remote sensing. PARA and MSU have secured a number of USDA, NASA and industry grants to initiate collaborative projects on their property as part of 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 and the Department of Agriculture. We meet quarterly to review program priorities, new initiatives, fundraising, and legislative activities.

The Montana Wheat and Barley Committee provides competitive financial support to MAES scientists on an annual basis (~$400,000). This financial support helps to 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 watershed cooperatives in communities, education and research funds to MSU scientists on a competitive basis (~$300,000 to $400,000 annually). To focus their activities, we sought input from the Montana Weed Coordinators located in each of the 56 counties in Montana. This research and education agenda was sent to all educators and researchers in the Montana University System to respond to with proposals and activities. Projects address all aspects of invasive plant management on private, public and agency lands.

In addition to the above groups, the College of Agriculture and MAES has 21 advisory committees and boards with a total of 266 members. These include the MAES State Advisory Council, Institute for Bio-Based Products Board, 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 Facility 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. These members represent farmers and ranchers, tribal councils, county extension agents, financial organizations, communities, scientists, agricultural educators, private citizens, small businesses, reservation groups, and agricultural organizations. The College of Agriculture with its MAES faculty respond to input from these stakeholders and state/national/international trends by evolving their programs. For example, the Agricultural Education and Agricultural Operations Technology Division was recently moved back to the College of Agriculture from the College of Education, Health and Human Development as a result of recommendations from a study group of stakeholders.

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 public in general. In 2003, over 740 individuals had contact with project leaders through these activities.

Stakeholder input during 2003 was collected during county and reservation agent sponsored stakeholder input meetings. These meetings were held in all 56 counties and reservations. 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 invitations to the meetings 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 on hemp as food and fiber
3. Better marketing of work being done at stations
4. More crop research
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.

The MAES will respond to these stakeholder inputs via consideration at research planning meetings of scientists, advisory groups, and administrators. Clearly, many of these activities are underway, but are not known by these stakeholders.

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 stakeholder 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 total number of estimated households in Montana as of July 1, 1998 was 346,000. (Ref. www.census.gov/populations/estimates/housing). The sample size (subjects) for this survey was 6,000 households. A proportional stratified random sampling technique was used to select households, thus insuring that the sample represented the diversity of Montana. This random selection procedure identified 6,000 households with addresses in 312 cities and towns. Households were located in each of the 56 counties in Montana.

Statistical analyses were conducted according to procedures available in the Statistical Analysis System (SAS, 2000). Analyses of variance determined whether gender, race, employment, location (farm vs. city), income level, county, and linear regression (covariate) on age of respondent were important sources of variation. Frequency distribution graphs were used to present a visual summary of responses to each question.

The return rate of usable surveys was very good at 30% and respondents were from all 56 counties in the state, both of which 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, while rating the priority of extension areas as 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”. Most respondents (67%) rated education as high priority, while only 5% rated education as below average or low priority. Both a safe and secure food system and agriculture/environment were rated highly by respondents with both areas receiving 57% of high priority ratings. Other areas of research that received the most 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 have influenced research priority areas during the last two years of MAES planning and will continue to do so, most likely into the next decade.

Program Review

Hatch Projects are subject to a very strenuous review beginning at the department level, followed by a peer review with final approval at the Director's level. The MAES Director's Office is responsible for oversight of the review process. The peer review committee, selected by the Director after consultation with department heads, includes the principle investigator's department head, MAES administrator, one department peer reviewer and two additional faculty external to the PI's department. Seminars are presented to the review committee. Seminar schedules are also made available to all faculty and their attendance and input is encouraged. There are public announcements so any interested citizen could attend. Reviewers written recommendations are on the following items: relevance and importance; relation to previous research; objectives; approach and methods; scientific and technical quality; resources; and environmental, economic, and/or social impacts are complied and provided to the PI during a meeting with the MAES administrator and department head. The PI is required to revise the project as recommended by the reviewers. The project is then resubmitted to the MAES administrator and department head for additional review and approval. After the project has been approved by the MAES administrator and department head, it is submitted to the Director for final approval. Any projects that do not meet the expectations will not be approved and deferred until all of the key elements listed above are met.

Multistate Research

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

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

In conjunction with the states of Alaska, CA-Berkley, CA-Davis, CA-Riverside, New Mexico, and Oregon, MAES faculty participated in W-147, Managing Plant Microbe Interactions in Soil to Promote Sustainable Agriculture. Soilborne plant pathogens are

responsible for many acute and chronic diseases of crop plants that can result in severe losses for growers. Economic losses to soilborne pathogens are estimated at 50-75% of the attainable yield for many crops. Yield failures resulting from acute diseases such as vascular wilts, take-all of cereals, Phymatotrichum root rot, Verticillium, and Phytophthora may be even more severe and have destroyed entire agricultural industries. About 90% of the major diseases of the principle crops in the United States are caused by soilborne plant pathogens. It has been estimated that the monetary losses to soilborne diseases is in excess of $4 billion/year. While a number of biocontrol agents are now available commercially, problems with production, storage, delivery, reliability, efficacy, establishment and understanding the mechanisms of action have prevented most biocontrol products for plant disease control from becoming established in mainstream agriculture. We believe that tremendous progress has been made in the field of biological control of plant disease and this project has been a major contributor to this progress. Members of this research group seek to find environmentally friendly solutions for management of plant pests. Towards this goal, we are examining both basic and applied research areas.

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

An evaluation of the effectiveness of livestock distribution practices on grazed watersheds was a part of a three-state project including Montana State University, University of California, Davis, Oregon State University and USDA-ARS, Burns, OR. Ongoing research from this project has shown the potential to manipulate cattle grazing 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 grown in eastern Montana at

this time and the sugarbeet industry provides many jobs both in beet production and the processing, refinement, and marketing of the sugar. The Lower Yellowstone River Valley consistently produces the highest quality sugarbeets in the United States.

New approaches for maintaining quality of cereals and oilseeds from harvest to delivery, while preserving environmental quality and consumer safety, must be developed and implemented if the U.S. is to remain at the forefront of the world's major producers. NC-213, Marketing and Delivery of Quality Cereals and Oilseeds, research activities will continue to advance scientific knowledge and generate new technologies and methodologies. Outcomes will be published in scientific journals and extension delivery of information will be achieved using multiple media approaches. Some technology advances will be transferred to the industry through patents to enhance commercialization opportunities. New varieties to expand market opportunities and add value to cereals and oilseeds will be developed and released.

Despite recent advances in reproductive technology, cattle and sheep producers are still faced with the persistent problem of low fertility. Indeed, recent work indicates that the fertility of domestic ruminants, even under optimal conditions, is about 50%. That is, at best, only one of every two natural or artificial inseminations results in the birth of a healthy calf or lamb. The poor fertility of domestic species is reflective of cumulative loss due to poor fertilization efficiency, high embryo mortality, and spontaneous abortion. The knowledge gained through W-12 Reproductive Performance in Domestic Ruminants, will lead to the development and implementation of new management protocols and/or pharmaceutical and nutritional regimens that will increase the fertility of domestic ruminants in the Western region by increasing conception and reducing embryo and fetal loss. We also expect that our collaborative work will result in the development of effective methods of estrous synchronization and, thereby, facilitate the use of artificial insemination in breeding programs of beef cattle and sheep on the Western range. Additionally, we expect that our efforts will result in the development of effective and efficient methods of immunocastration for use in male and female calves and lambs.

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

Through cooperation with the University of Wyoming and 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. 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.

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.

High-Value and Alternative Crop Production for Eastern Montana was involved in close collaboration between research and extension faculty at the MSU Eastern Agricultural Research Center in Sidney, MT and the NDSU Williston Research And Education Center in Williston, ND. An MSU faculty member serves as the superintendent/director of both of these research centers. Approximately 42,500 acres of sugarbeets were grown in the MonDak region. A conservative value of $900 per acre generated more than $38 million in sugarbeet payments to this region's economy. Investments in sugarbeet research has supported the expansion of the Holly Sugar Corporation and the expansion of the sugarbeet acreage from 35,000 to 48,000 acres with a phase II expansion to 80,000 acres scheduled over the next five years. Additionally, the local Holly Sugar Corporation processing plant has 400 employees with an annual payroll of $4 million. The sugarbeet processing plant also annually spends $5.3 million in commodity purchases, $4 million in freight expenditures, and $3.6 million in fuel expenditures. Sugarbeets are the high value cash row crop grown in eastern Montana at this time and the sugarbeet industry provides many jobs both in beet production and the processing, refinement, and marketing of the sugar. The Lower Yellowstone River Valley consistently produces the highest quality sugarbeets in the United States.

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

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

fulfilling the bioeconomic model damage function objective of optimizing *A. cylindrica* management in winter wheat.

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

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

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

Integrated Research and Extension Activities

Most Montana State University College of Agriculture faculty have dual appointments involving two of the three functional areas (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, but are not officially credited for these activities. MAES and the Montana Cooperative Extension Service are assessing future joint appointment needs. At this point, the research and extension efforts are on target to reduce input costs, manage land and water resources effectively and efficiently for crop, range, 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 different chronic diseases and one new disease. Management of the chronic diseases, Fusarium Yellows, Cercospora leaf spot, Rhizoctonia Crown and root rot and Aphanomyces root rot has increased grower profits on more than 88,000 acres in MT.

Fusarium Yellows is common on more than 40,000 acres and in 1994 only one resistant variety was available to growers and this variety had a yield potential 15-20% less than high yielding varieties in the absence of disease. MAES research developed highly efficient methods to identify resistant germplasm and work with seed and sugar companies has resulted in the identification of many high yielding Fusarium Yellows resistant varieties and the near elimination of susceptible genotypes. Extension education programs have resulted in growers using these varieties on more than 43,000 acres for control of this disease and yields have increased by approximately 12%. Thus,

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

Cercospora Leaf Spot. This disease would reduce growers profits by $70-165 per acre on more than 60,000 acres in Montana if no fungicides were applied for control. MAES research at the Eastern Agricultural Experiment Station demonstrated to both growers and the sugar companies that control of this disease was required to maximize economic return and that a weather-based disease prediction program could potentially reduce fungicide use as compared to calendar spray programs. In 1994, less than 20% of the acres were sprayed for control and by 1997 this increased to over 99% in the Sidney factory district (Holly Sugar) and to 20-25% in the Billings Factory district (Western Sugar). In 1997, the weather-based Minnesota Prediction model for Cercospora Leaf spot infection and loss was implemented in 4 sites and validated for Montana conditions. In 1998, through the use of extension education programs the weather-based prediction model was used on 17% of acres and in 1999 67% of acres were using this model to predict the need to spray. By 2000, extension education programs resulted in scouting for Cercospora and weather based forecasting being used on 100% of the acres in MT. Extension pathologists trained growers and both Coop and sugar company personnel on scouting and weather-based disease prediction and they implemented the scouting and weather monitoring program. This resulted in saving an average of 1 spray on 50,000 acres and 2 sprays on 30,000 acres with no loss in disease control in 1999 and 2 sprays on 77,000 acres in 2000. This resulted in saving more than $1.8 million in 1999 and $2.3 million in 2000, 2001 and 2002, respectively, as compared to a calendar based spray program. In Cercospora research, we demonstrated that use of a moderate level of resistance would allow growers to save 1-2 sprays compared to that needed on susceptible varieties without reducing yields. This data has been used by the Holly Sugar-Sidney Factory district to require new approved varieties have a moderate level of Cercospora resistance (KWS score less than 5.0). The impact of this work is that approximately 50,000 acres would receive one less spray @$15 per acre = $750,000. In 2002, all susceptible varieties (KWS scores > 5.5) have been eliminated from the approved list since the more resistant varieties have given equal yields with 1-2 fewer applications of fungicide. This should save growers in the Sidney Factory district $940,000-$1.8 million in fungicide and application costs in 2003.

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

Aphanomyces Black root rot. This disease is both difficult to identify and to control. MAES research identified this as a significant problem for Montana growers in 1994 and this project began a research effort to develop control strategies. Control is difficult because resistance is incomplete and there are no varieties adapted to Montana. The fungicide seed treatment Tachigaren is moderately effective in reducing seedling losses

but must be used with pelleted seed due phytotoxicity. In 1995 several promising rhizosphere inhabiting Bacilli were identified that provided control equal to Tachigaren. These were tested in production fields in 1996-2002 the result of this research is the identification of MSU 341-16-5 a Bacillus pumilis strain that provides better control of Aphanomyces than Tachigaren, better control of Pythium and Rhizoctonia than the standard seed treatment Apron-Thiram and does not have to be used with pelleted seed. In 28 location years of data using commercially treated seed, this isolate provided higher final stands and an average of 670 lbs/A more extractable sugar per acre than the standard seed treatment Apron-Thiram or Apron-Thiram -Tachigaren. This isolate will be developed commercially.

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

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

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

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

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

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

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

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

implemented. This program is a cooperative effort between the Montana Stockgrowers Association and Montana State University. A systems approach was implemented which allows for source and process verification of calves from the ranch in Montana to the feedlots in other states and provinces and eventually to the packing plant. Information collected throughout the production chain is shared among all the owners of the cattle. MT beef producers were surveyed to determine record keeping, health management, marketing strategies, and perceptions of industry issues. Results showed that Beef Quality Assurance (BQA) producers kept more records (cowherd inventory, description, calf birth weights, vaccination, feed) than non-BQA producers. More BQA producers followed recommended health management procedures than non-BQA producers. Ninety-seven percent of BQA producers vaccinated in the neck compared to 87% of non-BQA producers. Results of this survey are being used to better determine the extension programming needs of MT cattle producers.

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

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

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

invasion and sustainable weed control. This information is important in developing integrated weed management programs that are affordable and result in plant communities that meet land owner and managers land-use objectives, increased productivity, and ecosystem health.

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

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

Actual Expenditures **Title of Planned Program/Activity**	**FY 2000**	**FY 2001**	**FY 2002**	**FY 2003**	**FY 2004**
Ecology of Phyllosphere & Rizosphere Mico-Organisms & their Role in Biological Control of Plant Diseases	40,623	40,771	38,138	35,214	
Lamb Survivability	2,529	13,523	13,207	13,621	
Influence of Social Hierarchy on Distribution of Rangeland Cattle	2,587	12,224	13,128	13,648	
Management Practices which influence Feedlot Performance & Carcass Characteristics of Montana Beef Calves	3,482	16,716	17,920	18,555	
IPM of Montana Field and Forage Crops	652	3,084	3,883	8,036	
Integrated Management of Annual Grass Weeds in Small Grain	56,708	37,687	24,107	19,722	
Integrated Management for Spotted Knapweed infested Rangeland	11,328	9,206	9,233	17,249	
Total	**117,909**	**133,211**	**119,616**	**126,045**	

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Jeff Jacobsen, Interim Director Date