

V(A). Planned Program (Summary)

Program # 4

1. Name of the Planned Program

Global Food Security and Hunger: Plant Improvements, Genomics, and Products

Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
201	Plant Genome, Genetics, and Genetic Mechanisms			10%	
202	Plant Genetic Resources			10%	
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants			10%	
204	Plant Product Quality and Utility (Preharvest)			10%	
205	Plant Management Systems			10%	
502	New and Improved Food Products			5%	
701	Nutrient Composition of Food			5%	
702	Requirements and Function of Nutrients and Other Food Components			5%	
703	Nutrition Education and Behavior			5%	
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources			10%	
723	Hazards to Human Health and Safety			10%	
903	Communication, Education, and Information Delivery			10%	
	Total			100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	72.9	0.0
Actual Paid	0.0	0.0	72.7	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	1890 Extension	Hatch	Evans-Allen
0	0	562114	0
1862 Matching	1890 Matching	1862 Matching	1890 Matching
0	0	2929705	0
1862 All Other	1890 All Other	1862 All Other	1890 All Other
0	0	2806945	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

COA/MAES are recognized as leaders in the development of new cultivars of wheat and barley that are sought by global buyers. An aggressive plant breeding program ensures development of higher yielding, disease- and insect-resistant wheat and barley cultivars. Many new cultivars are licensed with partnering companies, thus ensuring that Montana stakeholders receive maximum benefit from research discoveries. In 2014, Montana planted a total of 5.9 million acres of all wheat, making it the fourth highest state for planted wheat acres in the country. As such, the majority of reporting in this area is housed within COA/MAES plant breeding advancements:

Winter Wheat: Montana planted 2.5 million acres of winter wheat in 2014, up from 2.0 million acres planted in 2013. Montana is ranked fifth for winter wheat planted acres in the United States, according to the USDA National Agricultural Statistics Service, Montana Field Office. The top four varieties listed below account for almost half of the total winter wheat planted in Montana for 2014: Yellowstone, Judee, Decade and Genou. Each of these varieties were developed by the Montana Agricultural Experiment Station (and the station's and university's subsequent wheat breeding programs) and sold as commercial seed to producers.

Spring Wheat: In 2014, Montana producers planted 2.95 million acres of spring wheat, unchanged from 2013. The state remains the second largest spring wheat producer in the country, according to the USDA National Agricultural Statistics Service, Montana Field Office. The top four varieties account for over fifty percent of all Montana's 2013 spring wheat acreage: Vida, Redder, Choteau and Mott. Vida, Choteau were both developed by MAES and sold as commercial seed to producers.

Durum Wheat: Montana producers planted 450,000 acres of durum wheat in 2014, down from 505,000 acres planted in 2013. Montana ranks second for durum acres planted in the United States according to the USDA National Agricultural Statistics Service, Montana Field Office. The top four varieties account for three quarters of the total durum wheat planted in Montana in 2014: Divide, Mountrail, Lebsock, Alzada.

Plant breeding, genetics, and genomics projects tend to be long-term with little change from year to year. Primary emphasis of the winter wheat breeding program is the development of improved cultivars adapted to Montana's climatic conditions and cropping systems. Research is ongoing to develop germplasm with excellent end-use qualities and resistance to important pest and environmental stresses. Researchers

continued to evaluate more efficient screening, selection, and breeding strategies and procedures to maximize efficiency and genetic progress in winter wheat breeding. Research projects continued to develop new hard red spring wheat cultivars for Montana producers, contributing to the science of wheat breeding and genetics, and improve end-use characteristics.

The broader impacts of MSU research are a larger food supply for the world, an improved ability of Montana farmers to compete in a global marketplace, and a strengthening of export markets for U.S. wheat. The primary output of the wheat improvement program is release of improved winter wheat cultivars. Cultivar performance data is disseminated to wheat producers via the internet, traditional extension bulletins, and in popular farm press publications.

Barley cultivars with improved feed quality could provide sustainable seed and grain markets for regional grain producers, and provide marketing advantages to regional beef producers. Research is being conducted on the development of lines for the malting, feed, and ethanol industries. The development and distribution of high quality, drought tolerant barley cultivars that provide the highest production potential remained priority of barley breeding programs in 2014. We have increased our understanding of the genetic control of traits like winter hardiness, feed quality, malting quality, and drought tolerance. Our multi-state barley research focuses the disciplines of plant breeding, genetics, plant pathology, cereal science, molecular biology, and genomics for barley improvement in Idaho, Montana, and North Dakota. We recently released four feed, forage, and malt barley cultivars that fit Montana's production environments and that provided added-value to Montana barley growers and to growers throughout the Northern Plains. MSU is developing multiple pest-resistant dryland alfalfa cultivars with good agronomic traits for Montana. In addition to alfalfa projects, efforts have been made to develop new grass cultivars suitable for Montana.

As the climate changes, the need for drought resistant cultivars of Montana crops increases. Therefore, researchers continue discovering and evaluating new crops and cultivars of spring wheat, winter wheat and barley suitable for a warmer and drier climate.

Several new camelina products are being developed for use in bread, as soil amendments, and to produce omega-3 rich beef and pork. We anticipate that new high-tocopherol lines of safflower will add value to producers in eastern Montana and western North Dakota and provide a more nutritious product.

Another scientist within our Department of Microbiology and Immunology is studying food quality and metabolic parameters that influences the development and progression of fatty liver disease (FLD) which impacts tens-of-millions of Americans and can progress to liver cirrhosis. This proposal is aimed at understanding the genetic, metabolic, and systemic physiological processes that underlie FLD. The goal is to understand the pathways leading to FLD and eventually design dietary, food-source, or food supplement protocols that might eliminate or abrogate the physical manifestations of FLD. This work will test whether simple shifts in the nation's food supply or in the USDA's nutritional recommendations might be effective at reducing FLD in the U.S. From an agricultural perspective, this might mean that subtle shifts in production may increase the general health of Americans.

Researchers are exploring different crops that deliver specific value-added products to consumers. The research involves identifying consumer needs not met by current crops. Scientists intend to continue

development of camelina, timtana, proatina and montina, and expand marketability and profitability to farmers. The impacts of Proatina and Timtana products have been considerable in the health food market, because they are gluten free and part of a \$2.5 billion annual market. Acreage of production has risen each year. The laboratory and analytical chemistry resources devoted to this project are a key reason why these products are on the market and contributing to the general health of the gluten intolerant and gluten sensitive population, now comprising about 6 percent of the population.

Again in 2014, COA/MAES communicated information on plant breeding and genomics advances through classroom activities, field days, cultivar trials, news releases, presentations at county and state meetings, and conventions:

- Release germplasm, new cultivars, and new genomics tools and techniques
- Conduct strategic planning with state agricultural groups
- Write technical and non-technical publications
- Develop value-added, agriculturally based end-use products
- Establish biobased product and food science education and research programs
- Enhance partnerships among faculty across the Montana university system, producers, agricultural industry, and other educational institutions across the region
 - Provide ways to enhance agricultural production practices to enhance product quality
 - Develop research summaries and fact sheets

2. Brief description of the target audience

- Domestic and foreign buyers of quality wheat
- Farmers, colleagues, and stakeholders
- Grain associations, Montana Department of Agriculture, Montana Wheat and Barley Committee, grain elevators, and state commodity groups
 - Seed companies
 - Crop and livestock producers in Montana
 - State agricultural advisory committees
 - Economic development groups
 - Participants in extension and commodity group meetings, conventions, conferences, and field days
 - State of Montana, Montana Department of Agriculture, BLM, USFS, and other government entities

3. How was eXtension used?

COA and MAES researchers worked closely with county extension agents and outreach coordinators to disseminate timely and accurate information regarding the evaluation and procurement of research advancements made in plant sciences, genomics and products. Many of these research projects were spoken of during MAES field days, throughout MSU/COA's seven research centers across the state.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	25000	15000	1500	1500

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year: 2014
 Actual: 2

Patents listed

201400394 Egan Wheat
 201300353 Wheat, durum, 'Silver'

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	200	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of foreign trade teams at MSU

Year	Actual
2014	13

Output #2

Output Measure

- Number of research citations

Year	Actual
2014	200

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of new or improved cultivar recommendations provided to Montana producers to maintain dominance in small grain markets
2	Integration of new molecular techniques into breeding projects to improve outcomes
3	Average per bushel yield increase of Montana grains while maintaining product quality
4	Number of elite lines of wheat and barley screened for agronomic and quality characteristics
5	Planted acreage percentage increase per year of new MSU-released small grains in Montana
6	Number of new food products created from Montana crops

Outcome #1

1. Outcome Measures

Number of new or improved cultivar recommendations provided to Montana producers to maintain dominance in small grain markets

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	4

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Small grains are an extremely important component of Montana agriculture. Continual development of spring and wheat varieties for Montana farmers remains a central and critical role of MSU's wheat breeding programs. Producers need to be growing varieties that are highly desired for their traits and economic return - so that Montana producers can remain dominant in small grain markets. Montana crop producers want products suitable to domestic and export markets. They want wheat varieties that can thrive under harsh growing conditions and are more insect and disease resistant.

What has been done

New spring wheat varieties have been developed and applied for commercial release to the public. One variety, Egan, is the first variety for Montana with resistance to the orange wheat blossom midge. The second line, Silver, is a new durum variety, that underwent variety performance testing and yielded strong results. Two high-amylose dry pea varieties were released; Amigo and B10-10.

Results

A variety is eligible for recommendation when a minimum of 16 location-years of performance data is obtained from the MAES statewide performance trials. The Egan line is soon to be commercially available to Montana producers. Results and resistance effectiveness of Egan have been published in several popular articles in the press, and journal articles have allowed reporting the results to fellow wheat breeders. Several public presentations were given state-wide during MAES Field Days. Wheat breeding is a long-term endeavor. New crosses, the evaluation of genetic materials, and variety performance will be posted on the department website. Dissemination of varieties has been accomplished through the established seed growers program

and over one million acres were evaluated and tested. Extensive testing for agronomic traits and end-use quality in the statewide trails provides data for the Montana Agricultural Experiment Station to consider potential release of an experimental line as a new variety.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
502	New and Improved Food Products
903	Communication, Education, and Information Delivery

Outcome #2

1. Outcome Measures

Integration of new molecular techniques into breeding projects to improve outcomes

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	60

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Wheat breeding is a long-term endeavor. Making new crosses, and evaluating genetic materials generated from previous crosses takes time and often requires the integration of new molecular techniques into breeding projects to improve outcomes. Identifying novel genes for climatic and pest and disease resistance for wheat breeding is a long-term goal that sees consistent, albeit slow, results. This genre of scientific work directly translates to sustaining Montana's agricultural economy and new food products for the global market place.

What has been done

Tested the effect of a subset of the new alleles upon wheat milling and baking quality; evaluated priority crop core subsets and other selected germplasm with morphological descriptors; identified

accessions with desirable economical traits, applied molecular marker techniques to assess diversity, detected duplicated accessions; identified taxa that were difficult to classify; determined relative impact of major genes that control polyphenol oxidase on Asian noodle quality; proteomic analysis of leaf senescence, functional analysis of candidate genes by virus-induced gene silencing.

Results

Identifying successful and desirable traits ultimately transfers to recommendations seeding rates, crop rotations, nutrient management, and irrigation rates that will provide more information to growers for informed decisions about which varieties to grow and how to best manage their crop. New cultivars depend on a diverse source of genetic variability. Agronomic yield and end product quality of cereal crops such as wheat are the two most important factors affecting farmer income.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
903	Communication, Education, and Information Delivery

Outcome #3

1. Outcome Measures

Average per bushel yield increase of Montana grains while maintaining product quality

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	12

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

For the crop year of 2013, the total value of all wheat was 1.3 million, with an 11.8% increase in average bushel yield increase of Montana grains, while maintaining product quality. Montana planted a total of 5.90 million acres of all wheat in 2014, making it the fourth highest state for

planted wheat acres in the country.

What has been done

Investigators with the COA and MAES continued developing hard red spring wheat varieties for farmers and the wheat milling and baking industry. Montana planted 2.5 million acres of winter wheat in 2014, up from 2.0 million acres planted in 2013. Montana is ranked fifth for winter wheat planted acres in the United States, according to the USDA National Agricultural Statistics Service, Montana Field Office. In 2014, Montana producers planted 2.95 million acres of spring wheat, unchanged from 2013. The state remains the second largest spring wheat producer in the country, according to the USDA National Agricultural Statistics Service, Montana Field Office.

Results

Variety lines produced by the Montana Agricultural Experiment Station represented about 60% of the states' wheat growing acreage and were the top four spring and wheat lines produced by MAES in 2013. The top for spring wheat lines were Vida; Montana producers planted 599,200 acres of Vida this year, accounting for 20.3 percent of the total acres planted; Choteau -212,200 acres accounting for 7.2 percent of Montana's seeded spring wheat. Winter wheat lines were; Yellowstone -accounting for 19.8 percent of the state's planted acreage with 494,000 acres seeded; Judee - 285,900 acres of the variety, which accounts for 11.4 percent of the total winter wheat acreage in 2014; Decade - 261,700 acres planted in 2014, or 10.5 percent of Montana's total acres and Genou - 164,500 acres of the variety, which accounts for 6.6 percent of the total winter wheat acreage in 2014.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems
502	New and Improved Food Products
903	Communication, Education, and Information Delivery

Outcome #4

1. Outcome Measures

Number of elite lines of wheat and barley screened for agronomic and quality characteristics

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	10

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

The need for high quality grains increases as the world population grows, and global buyers are looking to Montana as an international leader in the development of new small grain cultivars. Global traders want high quality wheat to enhance food production in breads and noodles, and they are looking for disease and insect resistant plants with high yield potential.

What has been done

Researchers determined the agronomic and economic impact of various crop sequences in dryland crop production in Montana and screened for key agronomic and horticultural traits such as general adaptation, phenology and growth potential. Two new varieties underwent seed increase and purification in 2013 and they are under consideration for potential release. These include Egan and two new dry-pea varieties.

Results

Researchers planted the intrastate yield trial at eight locations with yields averaging 58 bu/acre. Seven hollow-stem, one solid-stem, and one "Clearfield" experimental lines were selected for further testing and seed stock purification. Twenty lines were selected for additional testing, and a 49 entry yield trial was planted and harvested and twelve solid stem lines were retained in upper level sawfly trials. 856 lines were evaluated for agronomic potential, 99 harvested, with 60 then selected for preliminary yield testing. These included four hard white and three two-gene "Clearfield" lines. They also screened for reliable grain yield and the plants ability to retain green leaves after heading. Winter wheat investigators added 284 crosses to the germplasm base, emphasizing disease resistance and adaptation traits. Extensive testing for agronomic traits and end-use quality in the statewide trials provides data for the Montana Agricultural Experiment Station to consider potential release of an experimental line as a new variety.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)

205 Plant Management Systems

Outcome #5

1. Outcome Measures

Planted acreage percentage increase per year of new MSU-released small grains in Montana

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	5

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Montanans place a lot of trust in Montana State University as a leader in small grain agriculture, and nowhere is it more evident than in seed selection. Producers each year request the latest information and seed options available, so they remain competitive and successful in a global grain market.

What has been done

There was a nice percent decrease from year 2012 to 2013 in the planted acreage difference of total wheat in the state of Montana. This does not reflect MSU-released small grains. Montana planted 2.5 million acres of winter wheat in 2014, up from 2.0 million acres planted in 2013. MAES and the COA released "Silver Durum," and two Clearfield hard red winter wheat varieties, "War Horse" and "Colter." All of them were recommended in 2013 to districts throughout Montana.

Results

Field crop revenue for Montana in 2013 totaled \$9.5 million with wheat being the most significant. Montana producers seeded 2.1 million acres of winter wheat last fall for the 2013 crop year, down 200,000 acres or nine percent below the 2012 winter wheat planting of 2.3 million acres. The MSU variety "Yellowstone" continues as the highest yielding winter wheat line ever developed at MSU. "Judee" and "Bearpaw" solid stem semi-dwarf cultivars were released in the fall of 2011 and are expected to soon replace "Genou." "Genou" and "Yellowstone" have increased their yield per acres by 2.8 bu/acre and 6.7 bu/acre since 2007. Spring and durum wheat production were both up as was barley.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems

Outcome #6

1. Outcome Measures

Number of new food products created from Montana crops

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Discovering new ways to use products increases global food security and keeps consumers engaged. Consumers continue to want more local food options, and they are more interested in how and where it was grown. Consumers continue to want more local food options, and discovering new ways to use products increases global food security and keeps consumers engaged.

What has been done

MSU researchers conducted studies on genes important to cereal grain quality and agronomic traits. New food products include: Two high-amylose dry pea varieties: Amigo and B10-10. A third line with higher amylose content and higher yields is expected to be released this spring. A fourth set of lines resistant to powdery mildew will require another year of yield trails. Pea genes resistant to the wheat stem sawfly will continue to be investigated.

Results

The primary output of MSU research breeding programs is the completion of crop quality evaluations on breeders samples, and the results of which continue to be featured in journals and

publications throughout Montana and beyond enhancing knowledge for producers and consumers alike. This then leads to the identification of varieties for desired end product quality and to recommend for growers to produce. These scientific discoveries help sustain Montana's world-wide reputation for producing high quality, hard wheat

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems
502	New and Improved Food Products
903	Communication, Education, and Information Delivery

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Other (Funding)

Brief Explanation

Montana experienced one of the driest growing seasons on record in much of Southern Montana, but overall had a successful year with the value of all wheat crops down 1.2% (\$1,395,091 in 2013) from 1.6 million in 2012 .according to USDA NASS, Montana Field Office. The all wheat season average price decreased from 8.15 per bushel (2012) to 6.87 per bushel (2013). Much of these figures, like any year, is dependent upon global markets and climate changes from year to year.

The 2014 crop year faced warm and limited precipitation though out the year, but when precipitation was received hail often accompanied the storm. Montana recorded a record amount of acreage damaged by hail.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

The development of improved winter wheat lines and cultivars continues with improvements in yield, disease resistance, and tolerance advances, combined with improved stem solidness to combat sawfly. New challenges arrive, or former pests mutate to circumvent the remedies developed

to thwart their damage and renew their attack on wheat and other crop species.

Montana's spring wheat acreage during the past five years has ranged from 44 to 55 percent of the total wheat acreage planted. In 2012, spring wheat accounted for 48 percent and durum 7.8 percent of the total wheat acreages. In 2012, Montana ranked second among the wheat and durum producing states. The wheat stem sawfly, wheat rust diseases and leaf diseases including Septoria, remain threats to wheat growers in areas across Montana, and require the planting of resistant varieties.

Hard red spring wheat is grown in all areas of the state, with more than 97 percent of the acreage on dryland. The largest concentration of acreage is east of the Continental Divide along the northern tier of counties. The highest producing counties in 2012 were Roosevelt, Valley, and Toole. More than 98 percent of durum wheat is also grown on dryland, and in 2012 the highest producing counties were Sheridan, Daniels, and Roosevelt in northeastern Montana.

"Yellowstone" and "Genou" (cultivars developed by the MSU research program) are the top two planted cultivars in Montana, accounting for about one million acres in 2012.

Adoption of these cultivars by Montana wheat growers has resulted in harvest of an additional 21.5 million bushels of winter wheat over the past six crop years (2007-2012) based on production acreage and estimated yield gains over previously deployed cultivars.

Scientists developed improved winter wheat cultivars adapted to Montana cropping systems and climatic conditions. Through molecular and genetic research they discovered plants more resistant to the wheat stem sawfly and made significant strides toward introducing new rust resistant genes into Montana cultivars.

Researchers focused efforts on sugar beet and potato production and discovered biocontrol agents for different disease affecting these crops. The value of the canola crops and safflower increased significantly and producers ranked number one in the U.S. for the production of pulse crops.

The COA and MAES will continue to research and publish results for the agricultural community. New online tools provide immediate information regarding crop and seed recommendations, and researchers are working relentlessly to improve production and profitability of Montana crops.

Key Items of Evaluation

- A new germplasm, "MSUPBLB 101-10", a yellow, high-amylose dry pea suitable for conditions found on the northern Great Plains was released
- An organized collection of more than 9,000 photographs of plants, including more than 2,000 photos of grasses are maintained at www.flickr.com/photos/plant_diversity/collections. All photographs are georeferenced and tagged with taxonomic, ecological, and morphological information for ease of retrieval and use as primarily an educational tool and secondarily to document study sites
- Several new low glycemic lines of potato, one low glycemic line of naked oats, and one low glucosinolate *Camelina sativa* line for microgreens were developed
- A set of guidelines for dryland crop rotation for Montana producers is currently being developed
- "Yellowstone" and "Genou" (cultivars developed by MSU) continued to be the top two planted cultivars in Montana, accounting for about 0.934 million acres in 2012. Adoption of these cultivars by Montana wheat growers has resulted in harvest of an additional 21.5 million bushels of winter wheat over the past six crop years (2007-2012) based on production acreage and estimated yield gains over previously deployed cultivars.
- Completed complex field research experiments with nearly 1,000 experimental lines of dryland and irrigated barley.

MSU COA researchers advanced crop options for a warmer and drier climate:

Developed a new winter wheat line, "Egan" - commercially sold and patent-pending approval (see Plant Sciences and Products program area)

- Developed two new spring wheats varieties called "WB9879CLP" and "Silver" durum
- A winter wheat, "SY Clearstone"
- Increased planting of "Vida," a drought resistant variety of spring wheat which was the top choice for growers in 2012 and 2013
- MAES researchers developed and reported a new high throughput molecular marker for leaf rust resistance breeding and a new strategy for studying genes in wheat seed development.
- Researchers demonstrated two important mechanisms in plant triacylglycerol biosynthesis

pathway that were published.

- Spring wheat varieties developed by the COA/MAES program were grown on more than one million acres. The two most widely grown varieties in the state, "Vida" and "Choteau," were developed at MSU. In addition, two varieties developed by marker-assisted selection were marketed for the first time in 2012.