**Agriculture MREDI Grant**
**Quarter 2 Report**
**February 19, 2016**

**Research Center/MAES subproject of the Agriculture MREDI Grant**
**41W225 – Principal Investigator:** Barry Jacobsen; Email: bjacobsen@montana.edu

Progress towards milestones
All Research Centers have allocated space and labor for the pulse crop and cover crop variety trials. Allocation of space and labor for Durum variety /breeding line trials has been allocated at the Northern, Eastern, Western Triangle and Central Research Centers.

Presentations of this grant were made at Montana Pulse Day on Dec 9th, 2015 in Great Falls, MT, at the Montana Wheat and Barley Committee meetings, at all Research Center Advisory meetings, and at Leadership Montana and Real Montana. A poster was produced and was displayed at the Montana Pulse Day.

On February 23rd, a meeting of all Research Center and campus MREDI participants will be used for final planning of the 2016 field season.

Hiring
- Phillip Hammermeister: a 1.0 FTE Research Assistant II at the WTARC was hired to assist Dr. Ondura with pulse, cover crop, durum and one Precision Agriculture site.

Expenditures
- Total Personnel Services: $24,751.91
- Total Operations: $75.84

**Pulse Crop Research subproject of the Agriculture MREDI Grant**
**41W211 – Principal Investigator:** Chengci Chen; Email: cchen@montana.edu

Progress towards milestones
- Analyzing pea samples collected from 10 locations across Montana for protein content.
- Calibrating NIR method vs. combustion method for protein measurement.
- Organizing pea/lentil seeds for statewide testing in Spring 2016.

Hiring
- A postdoc research associate, Dr. Maninder Walia, has been hired to do nitrogen fixation study starting April 1, 2016.

Expenditures
- Total Personnel Services: None to date
- Total Operations: $375.00

**Soil Microbiology and Pea Protein subproject of the Agriculture MREDI Grant**
**1) 41W212 – Principal Investigator:** Perry Miller, Email: pmiller@montana.edu

Progress towards milestones
This project requires participation from Montana yellow pea producers to both identify *management practices* and supply yellow pea samples for protein analysis. Hence the first steps are to: a) identify potential sample streams, b)

establish producer contact, c) obtain *field-specific* (to parameterize soil and weather variables) yellow pea samples grown on Montana farms, and d) identify *management practices* for yellow pea across Montana.
Subsequent steps are to: e) conduct both combustion and NIR analysis on yellow pea samples for crude protein, and f) statistically analyze how standard management practices and the Montana growing environment affect crude protein content in yellow pea. The project was initiated on January 4th, 2016, and progress regarding steps a – d are described herein while some combustion analysis has already begun.

***Establishing Producer Contact and Sample Collection—steps a – c***

We have followed various leads in hopes of efficiently sourcing pea samples from commercial sources or other labs who are already collecting pea samples for other purposes. Producer contact is being established via flyers, direct producer contact, radio/web announcements, extension agents, industry, and presentations at state and regional pulse grower meetings to 'get the word out' on this project. These outreach efforts emphasize the potential for protein as a general marketing advantage and encourage yellow pea producers to submit samples from their farms over past and forthcoming (2016) growing seasons. Below is a list of the various outreach efforts to date.

1. Flyers
    a. *Yellow Pea Protein Flyer* (see attachment 1.)
2. Direct Producer Contact
    a. Nearly 50 yellow pea producers have been contacted via phone and e-mail.
3. Radio/Web announcements
    *a.* *Yellow Pea Protein Flyer* made available on the MGGA website and MAES centers
    *b.* Study announced on the Shelby Radio Minute—Monday January 18th, 2016
4. Extensions Agents
    *a.* Extension agents in counties with reported yellow pea acreage> 20,000 are promoting the study and distributing Yellow Pea Protein Flyer to producers in their counties.
    *b.* Specific Extension agents and respective counties are:
        *i. Bobbie Roos—Daniels County*
        *ii. Bruce Smith—Dawson County*
        *iii. Ken Nelson—McCone County*
        *iv. Marko Manoukian—Phillips County*
        *v. Jeff Chilson—Sheridan County*
        *vi. Colleen Buck—Sheridan County*
        *vii. Shelley Mills—Valley County*
5. Industry
    *a.* AGT Foods, Timeless Seeds, Pro-Coop, CG Ag Consulting, and Dry Fork Ag are encouraging their producer clientele to participate in the study.
6. Presentations at pulse grower meetings
    *a.* Montana Pulse Day—Dec 9th, 2015 Great Falls, MT
    *b.* Northern Pulse Grower Association Annual Trade Show and Convention—Jan 25th, 2016 Minot, ND
7. MonDak Pulse Day—Feb 16th, 2016, Wolf Point, MT

***Identifying Standard Management—step d.***

Participating producers are asked to complete a survey regarding management of their peas when submitting their samples (attachment 2). This covers field legal location, seeding dates, nutrient management, and rotation history. Survey results will be used to identify current *standard management* and evaluate how environment (e.g. field specific growing conditions) is influencing protein.

***Looking Ahead***

To date only 21 samples have been obtained and 10 surveys have been submitted. Thus steps a – d will continue over the next year, or until an ample sample size is achieved (~1000 ideally). Simultaneously steps c, and d will be carried out as more samples and surveys are procured. A minimum of 100 samples will be needed to move forward to the final steps (e-f). Sample procurement has proven more difficult, and time-consuming (tracking down all manner of leads that ultimately require permission of individual growers) than anticipated and represents a key risk element outside the control of the principal investigators. One concern that has been voiced by some pea growers is that they are fearful that information on pea protein management factors will somehow be used against them as an additional dockage factor at the time of sale. Thus some are not highly motivated to participate in this study.

Hiring
- No additional hiring beyond research associate Mike Bestwick

Expenditures
- Total Personnel Services: None to date
- Total Operations: $300.00

**2) 41W220 – Principal Investigator:** John Peters; Email: john.peters@chemistry.montana.edu

Progress towards milestones
Pea and pulse crops are increasingly being used in agriculture because of their economic and environmental benefits. These include the reduction of energetically expensive fertilizer, improvement of soil quality, such as increased microbial diversity and breaks in disease cycles, and high return crops such as peas for human consumption. In Montana pea and pulse crops are an important agriculture staple with Montana being the county's leader in pea and lentil production since 2011. Given this, there are two objective we are working towards, 1) understand the soil microbial ecology and nutrient combinations for best possible crop productivity, temporally and geographically, and 2) identify interventions to optimize crop productivity.

***Understand the soil microbial ecology and nutrient combinations for best possible crop productivity***

1) Sequencing and preliminary analysis
    a) Samples from Post Farm and the Montana Agricultural Experimental Stations were sent to Michigan State for sequencing of 16s rRNA.
    b) Sequencing completed and preliminary analysis completed for Post Farm Samples (see Figures 1 and 2).

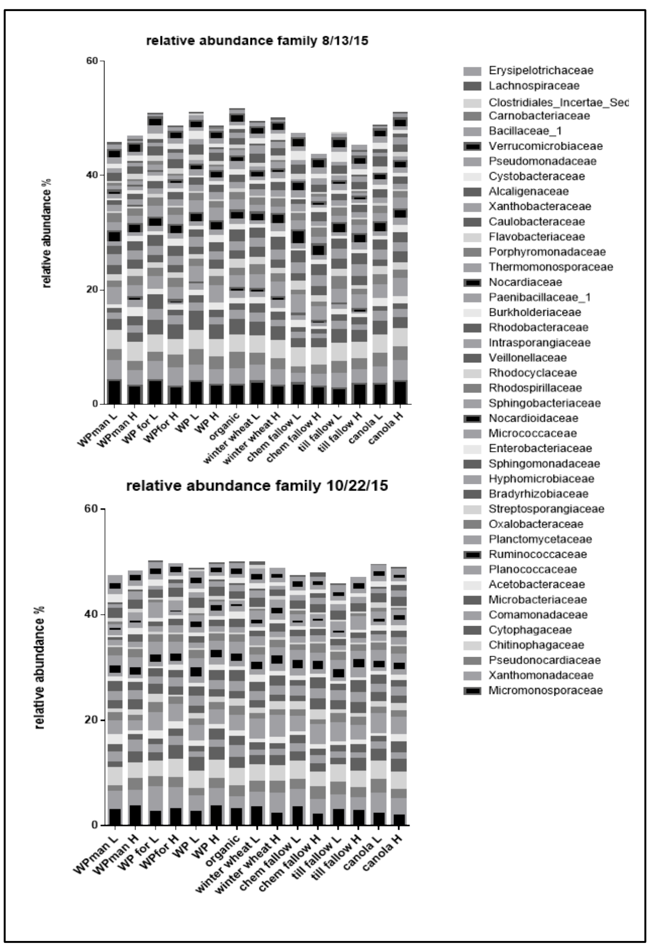


**Figure 1**. 16s sequencing shows diversity on the family level that is relatively similar between sites with small changes over time. Sites are WPman=winter pea left on site for manure, WPfor=winter pea planted for forage, WP- winter pea, organic=tilled and organic, winter wheat= winter wheat, chem fallow- left fallow and treated with chemicals, till fallow= fallow and tilled, canola=canola. H=high fertilizer, L=low fertilizer.

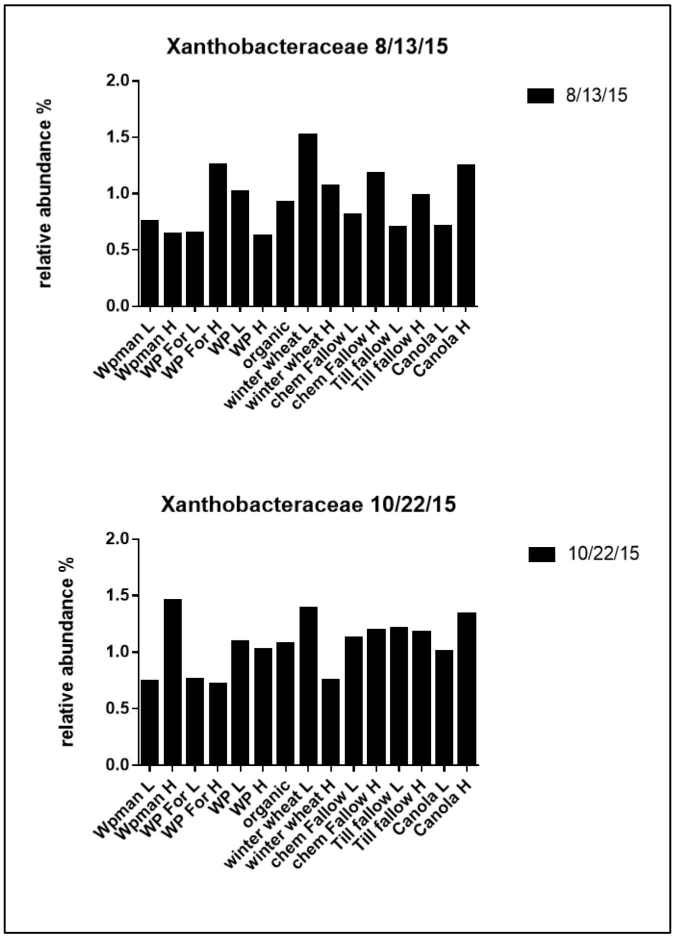


**Figure 2**. 16s sequencing of Post Farm soil at two time points shows that abundance of the family Xanthobacteraceae fluctuates over time in different rotations.

2) Chemistry
    a) Soil samples from the Post Farm and Montana Agricultural Experimental Stations were sent to the University of Idaho for analyses.
    b) Waiting for chemistry data. Expected date is mid- February.
    c) Once chemistry data is back will perform multivariate statistics with sequencing data on Post Farm samples.
3) NifH sequencing
    a) PCR using NifH primers on Post Farm samples for evaluation of nitrogen fixing bacteria in the soil. These samples will be sent off to Mr DNA for sequencing.

***Interventions to optimize crop productivity***

1) **Pot/greenhouse experiment** - Designed pot experiment to be conducted in a greenhouse using the soil sampled from the Post Farm and spring wheat inoculated with genetically modified strains of ammonia producing bacteria
    a) Objectives: 1) Are genetically modified bacteria viable as an inoculant and able to persist in the soil. 2) Will inoculated seeds lead to higher nitrogen assimilation in wheat. 3) Are bacteria endophytic or epiphytic?
        - Bacteria- *Azospirillium brasilense* HM053 and *Azotobacter vinlandii* 163.
        - Spring Wheat- variety-Duclair
        - Soil- Post Farm sites
        - Analyses- Nitrogen uptake/deficiency in plant, microbial community in soil, persistence of inoculated bacterial strains in soil and plant.

***Timeline***

1) Finish analyzing sequence data from Post Farm.
2) Do multivariate statistics on Post Farm with sequence and chemistry data.
3) Execute and analyze greenhouse experiment.

4) Plan experimental design for spring based on the above results. Have above completed by May.
5) Sequence and chemistry analysis on Statewide Study.

Hiring

- No additional hiring beyond research associates, Julie Zickovich and Justin Vetch

Expenditures

- Total Personnel Services: $24,228.12
- Total Operations: $290.08

**3) 41W213 – Principal Investigator:** Carl Yeoman; Email: carl.yeoman@montana.edu

Progress towards milestones

Several species rumen bacteria that deplete nitrate and some that also do a good job of depleting nitrite have been isolated. The two best nitrate/nitrite reducers have been identified by 16S sequencing as a Megasphaera spp. that appears most similar to M. elsdenii, the other being a Selenomonas spp. that appears most similar to S. ruminantium. They are currently assessing growth rates and looking for potential nutritional modulators of competitiveness (as potential pro- or syn-biotic additives), but both grow well in nitrate and nitrite enriched media. The plan is now to perform animal trials in the fall using these isolates.

Hiring

- No additional hiring beyond post-doctoral student, Sarah Olivio.

Equipment Purchased

- We have not been able to purchase the bioreactor, as the company upped the price on us by ~50%. We are in the process of investigating our options, including the possibility of purchasing an anaerobic chamber, as in the absence of a bioreactor, the chamber would allow us greater flexibility in performing the current set of experiments (e.g. it would enable us to use plates to assess growth and CFU).

Expenditures

- Total Personnel Services: $20,174.34
- Total Operations: $9,141.78

**Cover Crop/Grazing subproject of the Agriculture MREDI Grant**

**1) 41W214 – Principal Investigator:** Darrin Boss; Email: dboss@montana.edu

Progress towards milestones

Research Associate, Roger Hybner, is finalizing a species list and gathering seed for both the variety trial and large grazing trial. Seed finalizations and planting plans should be ready by the end of February/beginning of March 2016. Coordination with all seven Research Centers will be done on February

Hiring

- None to date

Expenditures

- Total Personnel Services: None to date
- Total Operations: None to date

**2) 41W227 – Principal Investigator**: Emily Glunk; Email: emily.glunk@montana.edu

Hiring
- None to date

Expenditures
- Total Personnel Services: None to date
- Total Operations: None to date

**On-Farm Precision Experiment subproject of the Agriculture MREDI Grant**
**1) 41W215 – Principal Investigator:** Bruce Maxwell; Email: bmax@montana.edu

Progress towards milestones
The On-Farm Precision Experiment (OFPE) Group meets biweekly to discuss progress and implementation of our project. Research technician, Phil Davis, has assembled all of the previous data from 2 fields on each of 4 farms (Figure 1). We are preparing fertilizer application prescriptions for the winter wheat fields planted in 2015. This involves considerable communication with contracted applicators as well as the farmers to determine the logistics of the application process. Prescriptions including experiments will be applied with N-fertilizer rate controllers based on software recently completed by Janette Rounds. Bruce Maxwell has focused on developing a statistical model to optimize N-fertilizer application to maximize net return between the experimental treatments in each field based on previous yield data and previous off-site experiments. Maxwell and Payn presented the OFPE project in a seminar to the MSU Department of Computer Science in December and Maxwell was invited to present the OFPE concept to small grain growers at the annual meeting of Timeless Seed in Great Falls in early February.

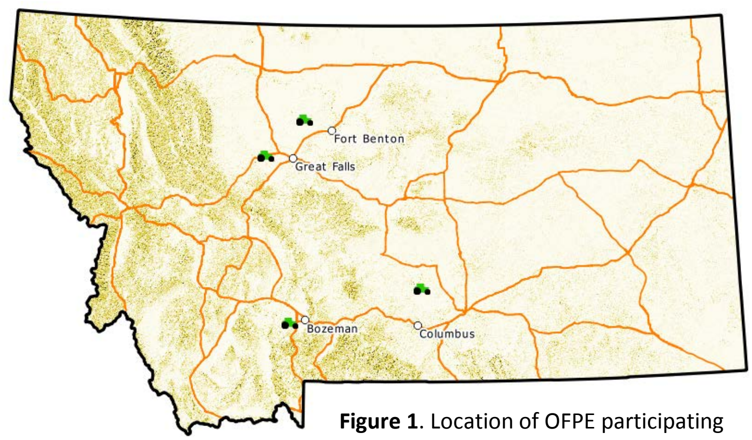

**Figure 1**. Location of OFPE participating farms in Montana.

Hiring
No new hires were made in this quarter for any of the aspects of the OFPE Project. The team managed by Payn and Izurieta has added an undergraduate student (Melissa Dale) to their team. Melissa will be working on programming interface components of the system as part of a course project. She is further tasked with extending the unified modeling language (UML) design of the database schema to allow implementation of community standard modeling interfaces (OpenMI) to retrieve information from the database. Maxwell has also recruited an undergraduate student (Paul Hegedus) funded by a fellowship from the Weed Science Society of America to work on aspects of precision weed management associated with the OFPE.

Expenditures
- Total Personnel Services: $33,780.23
- Total Operations: $1,054.41
- Total Equipment: $23,030.00

**2) 41W226 – Principal Investigator**: John Sheppard; Email: john.sheppard@coe.montana.edu

Progress towards milestones

Dr. John Sheppard is managing the team focused on designing and implementing the model calibration, yield optimization and application prescription phases of the On-Farm Precision Experimentation (OFPE) process. Over the past quarter, Janette Rounds (graduate student) has developed software that automates the division of a field into "cells" based on the width of the fertilizer application equipment. Ms. Rounds has also developed software that assigns a fertilizer rate to each cell within a field by a variety of algorithms (e.g. Figure 2). Currently, the implemented algorithms assign each cell a random fertilizer rate to ensure quality data for experiments. Moving forward, the random algorithms will be used in combination with experimental design algorithms that stratify the assignment of fertilizer rates based on different prior yields so as to maximize the area used for optimization or farmer-defined fertilizer rates, while still ensuring sufficient data.

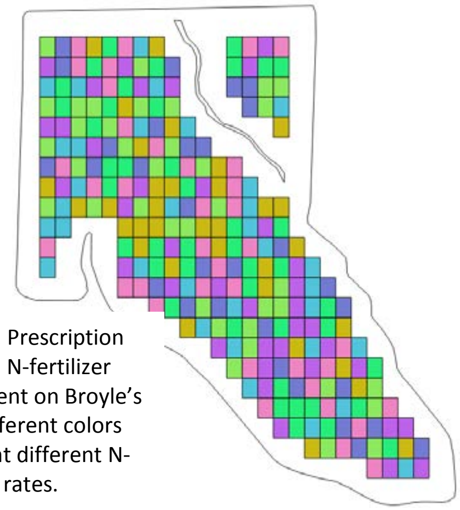

**Figure 2**. Prescription for OFPE N-fertilizer experiment on Broyle's field. Different colors represent different N-fertilizer rates.

Another major goal of this quarter was to lay the groundwork for the experimental design, calibration, and optimization algorithms. This has included evaluating various machine learning algorithms for their use in the future product, including Bayesian optimization, genetic algorithms, neural networks, and deep learning. This has also included transforming the data received from the database into a representation these algorithms can use. The "Boost C++ libraries" provide an open-source framework that includes a variety of operations and representations designed specifically for handling geometric data. By standardizing the representation used by each algorithm, the inputs to and outputs from each algorithm can also be standardized, simplifying the implementation of these algorithms and providing a framework for the future development of optimization algorithms. The next of implementation will include incorporating these algorithms into the larger OFPE product and working with the team managed by Payn and Izurieta to design the interface between the database and the experimental design, calibration, and optimization software.

Expenditures

- Total Personnel Services: $7,540.05
- Total Operations: $4,678.00

**3) 41W228 – Principal Investigator:** Clem Izurieta; Email: clem.izurieta@gmail.com

Progress towards milestones

Dr. Payn and Dr. Izurieta are managing the team focused on design and implementation of the data management and workflow technology. The system will handle transfer and storage of digital information for the data import, model calibration, experimental design, yield optimization, and application prescription phases of OFPE process.

The larger team, including Pol Llovet, Thomas Heetderks, Seth Kurt-Mason, Michael Trenk, Jenna Lipscomb, Melissa Dale, Nick Silverman, and Phillip Davis, have been meeting every other week to track project progress and address the shifting priorities inherent in a research and development project. A flexible "kanban" style project management system has been implemented to track project milestones and the tasks necessary to accomplish each milestone. MSU's "Box" cloud service is being used as a central document repository for the project, and a "Github" service is being employed to provide centralized management of code organization and revision during software development.

Implementation of the software for the "yield editor" workflow has been a milestone of primary interest over the past quarter. This workflow involves processing raw harvest data (grain flow, harvester location, time, etc.) into estimates of yield (e.g. pounds per acre). Both the raw harvest data and the derived yield data need to be imported into the database in queriable form for subsequent steps in the calibration and optimization workflows. These data also need to be available for future research on more effective optimization tools for the OFPE process, as new datasets or technology become available. The unknown nature of future enhancements to the OFPE process drive the innovation necessary for an extensible data model that is easily adapted to unforeseen data types or data with different contexts in space or time.

A substantial task necessary to complete implementation of the yield editor workflow software is a prototype schema for the database that will accept the imported data, and make it available for later queries in the workflow system. A review of database systems was conducted by Trenk, and a state-of-the-art "No-SQL" database system (MongoDB) has been selected as the foundation of the system. This selection was based on availability as open-source software, flexibility in data schema design, and efficiency in data search and extraction speeds when queried from large data sets. The hardware cluster hosting the MongoDB technology was implemented last quarter by Pol Llovet in the MSU research cyberinfrastructure group.

Mason has been leading the design of the schema (i.e. defining rules for data storage) for the database system, and the team of Trenk, Payn, Izurieta, and Mason have been conducting workshops that assess the integrity of that design as it has evolved. Integrity is assessed by manually creating data structures within the schema, and then examining the resulting structure to be sure that the desired data structures will be available or derivable when the database is queried later. The design will continue to evolve as problems are revealed by workshop activities, and new requirements are addressed with other components of the overall workflow.
The completion of the database schema has progressed to the point that Trenk has been able to begin design and implement code necessary to import results of the yield editor workflow into the database. As the designs continue to mature, Payn and Izurieta continue work to update project documentation, and have started laying out a software stack diagram for system design and code organization.

Early next quarter, the milestones for design and implementation of the calibration and optimization workflows will become a higher priority. These milestones were dependent on completion of the prototype of the database schema, so activities over the previous quarter have prepared the team to start this work in the near future.

<u>Expenditures</u>

- Total Personnel: $14,328.11
- Total Operations: $33.56

**4) Industry Match** - Dr. Nick Silverman (Adaptive Hydrology) in collaboration with Dr. Kelsey Jencso

<u>Progress towards milestones</u>
They installed the first weather station (FarmHub) and are currently testing its capabilities, robustness, and ease-of-use. Another weather station has been ordered and should be delivered before the end of February. This weather station will be installed alongside a National Weather Service station to test for accuracy. Plans are in place to order at least two more stations by the end of April for a total of four stations (one at each of the participating OFPE farms).
We have also started developing the data management system for incoming weather/soil data and processing. This system will include data retrieval, QA/QC, storage, and access to the MREDI OFPE database and model. The weather station will update online every hour and data will collected at 5 minute increments.

We have provided further support to the database, modeling, and GIS teams in the form of meetings, recommendations, and consultation on data requirements and hydrologic analysis. We have also presented the MREDI project at several conferences. Most recently we presented at the Montana Agriculture Business Alliance (MABA) conference in Great Falls on January 29th.

**Durum Quality subproject of the Agriculture MREDI project**
**41W221 – Principal Investigator**: Mike Giroux; Email: mgiroux@montana.edu

<u>Progress towards milestones</u>

- Samples selected for further testing. We have conducted most of the preliminary yield and end product quality tests on our three durum populations. From our results we selected 200 lines for larger scale yield and product quality testing in 2016. This includes 100 lines from Northern Seeds and 100 from selections out of our program. Our 100 line selections were planted as single rows in Arizona for field trial testing and to produce more seed for subsequent 2016 field trials. The selected lines will be grown in replicated plots in at least two locations in 2016 with the expectation being that a small number of lines will be selected for advanced yield trials in 2017.
- New durum populations: Advanced durum genotypes and varieties were selected and planted in the greenhouse for crossing. First crosses for these new breeding populations were completed, F1 seeds were harvested and replanted to advance to F2 and for intercrossing of some F1 groups. Intercrossing of the F1 groups was done to maximize diversity of the subsequent populations and to increase the frequency of the low cadmium trait.

***MT Interstate Durum Trials***

The 2015 MT Interstate report was completed and summarized yield of 6 experimental and 8 control lines grown at five MT and one North Dakota location. Subsamples from each of the three replicates per line per location were subjected to seed traits, milling quality, semolina quality, and mixograph performance. For statewide averages from the five rainfed experiment locations there was no significant difference between the lines/varieties tested for yield, however the highest yielding line was MT112219 (30.3 bu/ac) followed by line MT112463 (29.9 bu/ac). The check variety Mountrail had a yield of 29.1 bu/ac. Line MT101694 and Divide had lowest yield (26.5 bu/ac) of all the lines tested under rainfed conditions. Under irrigated conditions at EARC line MT101717 (81.9 bu/ac) was the highest yielding line followed by MT112444 (81.1 bu/ac) and MT112219 (77.4 bu/ac) however these lines were not significantly higher than the check Mountrail (73.2 bu/ac).

Compared to the check variety Mountrail, two experimental lines (MT112219 and MT101717) had an increased test weight which and they also had the largest average test weights of all lines tested. Other MT experimental lines had an average test weight comparable to Mountrail. All MT experimental lines had a lower grain protein content (14.7-15.3%) and individual kernel weight (32.5-35.7 mg) compared to Mountrail (15.7%; 36.5 mg), while Tioga had the highest grain protein content (16%) and Alkabo had the largest seeds (39 mg). Five out of the six MT experimental lines had an increased falling number (426.2-448.3 sec) compared to Mountrail (415.3 sec) while line MT101694 had a significantly lower falling number score (377.2 sec).

*<u>New breeding population development</u>*

Based on agronomic and end product qualities, agronomic adaptation, presence of the low cadmium trait, and germplasm groups, we selected a set of lines for intercrossing to develop new breeding populations. So, far we are advancing 21 unique populations (Table 1). The F1s from these populations are being advanced to the F2 stage to allow us to plant them in the field in 2016. Currently, we are also intercrossing among these F1 populations to maximize diversity and increase the frequency of the low cadmium trait among our populations.

**Table 1. Development of new durum breeding material for Montana**

| Cross | Generation | Unique cross # |
|---|---|---|
| AC Brigade X Alzada | F1 | 1 |
| Alkabo X AC-Brigade | F1 | 3 |
| Alkabo X Joppa | F1 | 4 |
| Alzada X Havasu | F1 | 5 |
| Alzada X Joppa | F1 | 6 |
| Alzada X Kofa | F1 | 7 |
| Alzada X Strongfield | F1 | 8 |

| | | |
|---|---|---|
| Carpio X AC-Brigade | F1 | 9 |
| Carpio X VT-Peak | F1 | 10 |
| Joppa X Alzada | F1 | 11 |
| Joppa X Orita | F1 | 12 |
| Joppa X Tioga | F1 | 13 |
| Joppa X VT-Peak | F1 | 14 |
| Mead X Joppa | F1 | 15 |
| Silver X Joppa | F1 | 16 |
| Strongfield X Alkabo | F1 | 17 |
| Strongfield X Divide | F1 | 18 |
| Strongfield X Tioga | F1 | 19 |
| VT-Peak X Alkabo | F1 | 20 |
| VT-Peak X Divide | F1 | 21 |
| VT-Peak X Joppa | F1 | 22 |

*Durum Cadmium Marker Screening*

We screened top durum cultivars that appear in our trials (Figure 1) along with some of the experimental lines (Figure 2) for the DNA marker that co-segregates with the low cadmium trait. AC Brigade, Havasu, Mead, Strongfield, and PI 330546 all carry the low cadmium gene, however PI 330546 actually contained both genes. The presence of the low cadmium trait is important since durum seed is increasingly being screened by export markets for cadmium and it seems possible in the future that high cadmium lines could be refused. Fortunately, several of the MT experimental lines grown in the interstate trials carry the low cadmium trait as do many of our lines in development. Based on these results, our intercrossing of F1s focused on incorporating the low cadmium trait into additional populations. We will also screen the rest of our experimental lines in development for the low cadmium marker so that we can use this trait in our selection process.

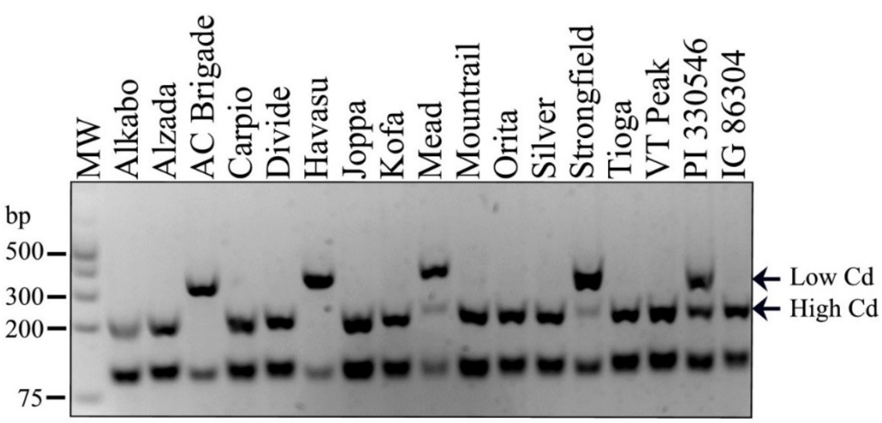


**Figure 1. CAPS screen of top durum cultivars with low Cd marker.** AC Brigade, Havasu, Mead, Strongfield, and PI 330546 carry the low cadmium marker.

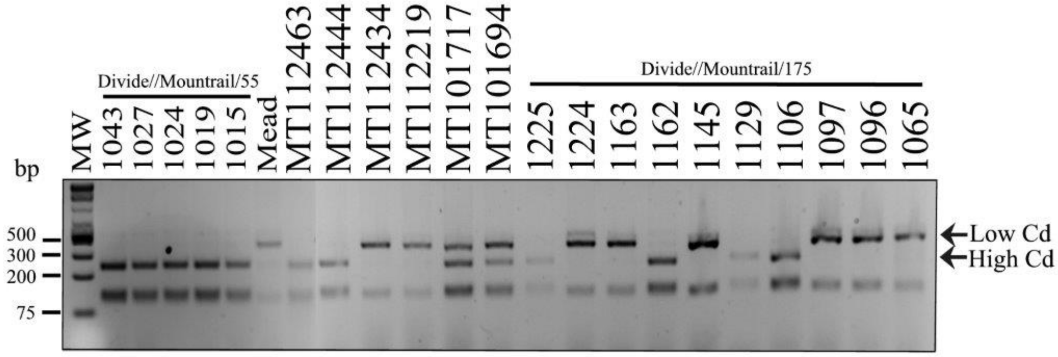


**Figure 2. CAPS screen of MT experimental lines and Divide//Mountrail/PI330546 (or IG86304) with low Cd marker.** Two of the MT experimental lines carry the low Cd allele along with several of the Divide / /Mountrail/PI330546 lines.

Hiring

- Andrew Hogg, M.S., has continued as the research associate on this project along with Kendra Hertweck, senior level undergraduate student in Plant Sciences.
- Freshman undergraduate Theodore Warthen has also been working on this project.

Equipment

- The Perten Glutomatic and the Brabender Quadrumat Jr. Durum mill both arrived and we have become actively using both for analysis of durum quality. However the Brabender Quadrumat Durum mill that arrived did not in fact meet the specifications of what was ordered resulting in our semolina yields and ash being too high.
- We do not anticipate ordering any additional equipment for this project.

Expenditures

- Total Personnel: None to date
- Total Operations: $722.72
- Total Equipment: $43,814.00

**Wheat Stem Sawfly subproject of the Agriculture MREDI project**
**41W222 – Principal Investigator**: David Weaver; Email: weaver@montana.edu

Progress towards milestones

- Flowering crop species are being grown in the greenhouse and nectar will be analyzed for sugar and amino acid content at the time of full flowering.
- Field-collected wheat stem sawfly parasitoids from our initial site have completed metamorphosis and size and fecundity measurements are now being taken in the laboratory.

Hiring

- No additional hires beyond undergraduate student, Ben Fischer.

Expenditures

- Total Personnel: $28.56
- Total Operations: None to date

**Weed Imaging/Pulse Crop Herbicide subproject of the Agriculture MREDI project**
**1) 41W217 – Principal Investigator**: Prashant Jha; Email: pjha@montana.edu

Progress towards milestones

Protocols for this project were established in Quarter 1. All hyperspectral datacubes were recorded at 240 bands per spectra. The measurements are sorted by illumination type, and labeled by the plant, herbicide resistance, and what part of the plants was photographed. “Cluster of whole plants” was the whole tray in which the plants were grow, “individual plants” was single plant individuals, and “leaves” were individual leaves picked of the plants.

Oblique Sun Direct Illumination:

- Dicamba-resistant Kochia (cluster of whole plants)
- Glyphosate-resistant Kochia (cluster of whole plants)
- Susceptible Kochia (cluster of whole plants)
- Barley/Glyphosate-resistant Kochia (cluster of whole plants)
- Wheat/Glyphosate-resistant Kochia (cluster of whole plants)
- Wheat/Dry Bean/Barley/Glyphosate-resistant Kochia (cluster of whole plants)

Diffuse Sun Illumination:

- Dicamba-resistant Kochia (cluster of whole plants)
- Glyphosate-resisant Kochia (cluster of whole plants)
- Susceptible Kochia (cluster of whole plants)
- Dry Bean/Glyphosate-resistant Kochia (cluster of whole plants)
- Barley/Glyphosate-resistant Kochia (cluster of whole plants)
- Wheat/Glyphosate-resistant Kochia (cluster of whole plants)
- Wheat/Dry Bean/Barley/Glyphosate-resistant Kochia (cluster of whole plants)

Artificial Illumination (combination of 1000 W metal halide and 500 W tungsten halogen):

- Barley (individual plants, leaves)
- Dry Bean (individual plants, top of leaves, bottom of leaves)
- Wheat (individual plants, leaves)
- Dicamba-resistant Kochia (individual plants, top of leaves, bottom of leaves)
- Glyphosate-resistant Kochia (individual plants, top of leaves, bottom of leaves)
- Susceptible Kochia (individual plants, top of leaves, bottom of leaves)
- Wheat/Barley (individual plants)

Hiring

- A post-doctoral research associate at SARC has been identified to work on this project.

Equipment

- The environmentally-controlled growth chamber at SARC, Huntley, has not been purchased yet.

Expenditures

- Total Personnel: None to date
- Total Operations: None to date

**2) 41W216 – Principal Investigator**: Joseph Shaw; Email: jshaw@montana.edu

Progress towards milestones

Our milestone for December 31, 2015 was to complete initial agricultural data collection and analysis for the use of spectral imaging to identify weeds to enable spot spraying (thereby reducing costs) and to detect and identify weeds growing amid crops. This milestone was completed as scheduled and detailed data analysis is in progress. Our primary accomplishments in the second quarter were acquiring a hyperspectral imaging system from Resonon, Inc. (a local Bozeman company), learning to use it, and applying it to the measurement of weeds in a controlled greenhouse experiment.

In December 2015 we deployed the hyperspectral imager at the Southern Agricultural Research Center in Huntley, Montana, where Dr. Prashant Jha had grown samples of several important weed species. We recorded spectral images of herbicide-resistant and herbicide-susceptible weed, primary of the Kochia species, but also of common crops such as wheat, barley, and beans, as well as combinations of Kochia with those crops. We collected measurements in a variety of lighting conditions (direct sun, indirect sun, and artificial light), and we imaged the plants in a variety of configurations (clusters of plants down to individual leaves). Figures 1-6 are photographs of the weeds and the measurement setups for direct sunlight and artificial light.

***Data Collection Set-up for the weed imaging/pulse crop herbicide subproject***

**Figure 1**. Cluster of Kochia plants.

**Figure 2**. Hyperspectral Imaging System collecting a direct sunlight image.

**Figure 3**. Cluster of Kochia plants being imaged in direct sunlight.

**Figure 4**. Ph.D. student collecting data in the artificial light environment.

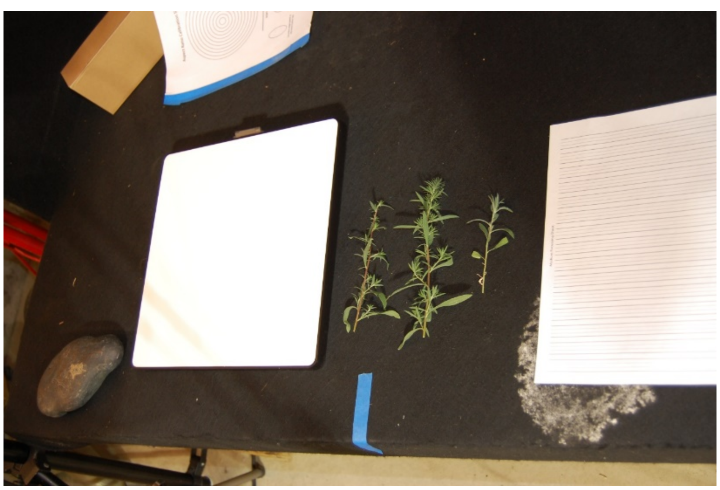

**Figure 5**. Imaging individual Kochia plants in artificial light.

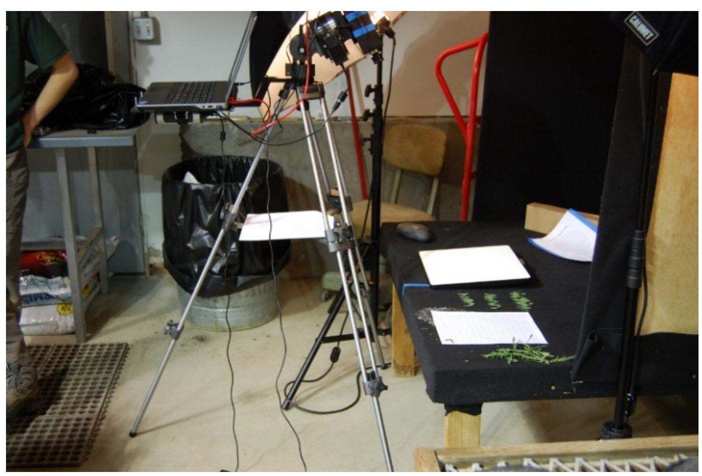

**Figure 6**. Imaging leaves of a Kochia plant in artificial light.

As a very preliminary example, Figure 7 shows spectra for Kochia in three different resistance states (see figure caption for details). The spectra exhibit prominent differences in the near-infrared region of the spectrum (750 nm to 885 nm). Each spectrum plotted is the mean of multiple spectra collected from multiple leaves and individual plants in each resistance class.

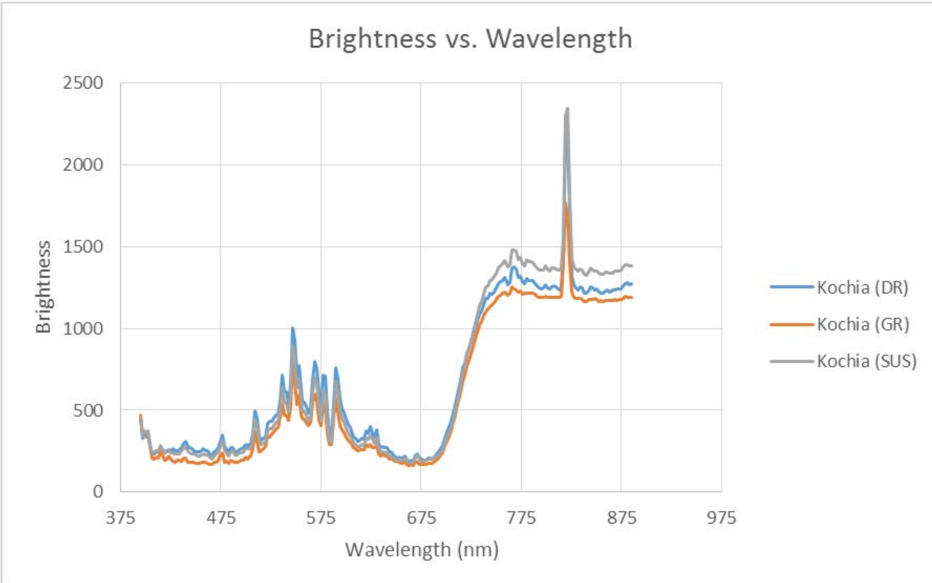


**Figure 7**. Comparison of Kochia spectra across three resistance states (DR = dicamba-resistant, GR = glyphosate-resistant, and SUS = susceptible to both dicamba and glyphosate).

Hiring

The following people continue to work on this project:

- Dr. Joseph Shaw: subproject director (to receive partial summer salary only)
- Mr. Paul Nugent: Research Engineer and Ph.D. student (partial academic year salary)
- Mr. Andrew Donelick: Ph.D. student

Equipment Procurement

- During this quarter we took delivery of a Resonon Pika IIg hyperspectral imaging system, scanning tripod, and narrow-field and wide-field lenses (Resonon is a local Bozeman optics company). The instrument was ordered during September 2015 and was delivered during November 2015.

Expenditures

- Total Personnel: $2.99
- Total Operations: $5,424.47
- Total Equipment: $16,716.00

**Film Production for the Agriculture MREDI Grant**

**41W218 – Organizer:** Eric Hyyppa; Email: eric_hyppa@montanapbs.org

Progress towards milestones

Continues to be in the pre-production phase until Summer 2016.

Equipment Procurement

- Nothing additional to date

Expenditures

- Total Personnel: $0.00
- Total Operations: $5,927.42

**Economic analysis subproject of the Agriculture MREDI project**
**41W219 – Principal Investigator:** Anton Bekkerman; Email: anton.bekkerman@montana.edu

Progress towards milestones
In the past quarter, I have continued to focus on the collection of price elasticity values that are necessary to parametrize the economic model of Montana's crop supply chain. A graduate student is currently collecting the estimates from the literature and also collecting necessary data to estimate an elasticity value in case it is not found in the literature. Part of these data include elevator-level prices in Montana and fertilizer prices, both of which have been acquired using grant funds. By the next reporting date, I will be able parametrize the model.

Hiring
- Graduate (master's) student in the Master's of Applied Economics program.

Expenditures
- Total Personnel: None to date
- Total Operations: $11,613.00

**Participatory research network subproject of the Agriculture MREDI project**

Progress towards milestones
We have now conducted five focus groups and have a sixth scheduled for late February. The research team, Colter Ellis, Mary Burrows, and George Haynes, meet regularly to discuss progress and preliminary data coding. The next phase of research will include individual interviews with producers. Colter Ellis and George Haynes have spent time training Tom Woods, a graduate student from Political Science, who has helped conduct all focus groups and is currently actively recruiting participants for individual interviews.

1) **41W224 – Principal Investigator**: George Haynes; Email: haynes@montana.edu

Hiring
- No additional hires beyond graduate student, Tom Woods.

Expenditures
- Total Personnel: $3,738.74
- Total Operations: None to date

2) **41W223 – Principal Investigator**: Colter Ellis; Email: colter.ellis@montana.edu

Hiring
- None to date

Expenditures
- Total Personnel: None to date
- Total Operations: $481.02