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Detection of Fungicide Resistant Ascochyta Blight

Project Summary

Background: Ascochyta blight is the most important foliar disease of pulse crops. The disease is composed of different species of the pathogen depending on the crop (Ascochyta rabiei for chickpea, Ascochyta lentis for lentil, and Mycosphaerella pinodes on dry pea). In Montana, growers test seed for the pathogen by submitting samples for testing prior to planting. In 2013-2014, of 35 chickpea samples, nine were positive for Ascochyta and four of those contained strobilurin fungicide (Headline) resistant isolates of A. rabiei based on a laboratory assay (44% of isolates). Of 222 pea samples, 68 samples contained M. pinodes and one was tolerant to Headline (1% of isolates). These results are extremely significant to the farming community because the most common mutation that confers resistance to this class of fungicides confers complete resistance and fungicide failures were observed in chickpea during the 2013 crop year. The mutation that confers resistance to strobilurin fungicides has the capacity to spread rapidly and we risk losing this class of chemistry for disease management. If growers can test for fungicide resistance before planting, they can take appropriate management steps including not planting contaminated seed lots or rotating fungicide chemistries for disease management. The current system of monitoring is extremely slow, taking approximately 1.5-2 months or more after sample submission.

The specific issue is preventing the loss of a cheap, effective chemical fungicide for Ascochyta disease management in pea, lentil, and chickpea. Headline and Quadris, both in the QoI (quinone outside inhibitor) or strobilurin class of fungicide chemistry are the most commonly used fungicides in pulse crops and are a major component of the newly marketed Priaxor. Loss of this class of chemistry gives us only two classes remaining, triazoles (Proline) and SDHIs (Boscalid, Endura, Xemium). There is a high risk of resistance development for SDHIs (succinate dehydrogenase inhibitors) and a medium risk for triazoles (DMI, demethylation inhibitors). Early detection of fungicide resistance is critical for implementation of alternative disease management strategies including crop rotation, use of resistant varieties, and rotating modes of action when using fungicides.

The initial purpose of the project proposal was to develop molecular testing methods for strobilurin fungicide resistance and speed up the assay significantly.

Timeliness: This project was timely because, although many North Dakota and Saskatchewan have observed fungicide resistance development for strobilurin fungicides (3-5,7), there was no monitoring for resistance development with a rapid assay that allowed growers to make decisions about their crop by the next spring planting. Headline (pyraclostrobin) is going off-patent in the 2015 crop year and there are expected to be a number of generic options on the market, decreasing chemical price and subsequently increasing growers frequency of application. Without monitoring and raising awareness now, we are highly likely to lose strobilurin fungicides for Ascochyta control in pulse crops.
The number of seed samples submitted for testing to MSU has increased significantly in recent years, in particular for chickpea and pea, which are more routinely treated with fungicide than lentils. A significant proportion of the seed samples coming in for testing contain at least 1 seed of 500 tested with Ascochyta blight. This represents a high risk of disease occurrence if we encounter favorable weather and fungicide failures.

**Previous funding:** We have received previous funding from the SCBG for fungicide resistance testing and management of Ascochyta blight in pulse crops. This is a unique and new effort. In the previous grants, we have exceeded the expectations of the proposal. In 2012, we obtained funding (Management of Ascochyta blight in lentil: $15,400) to evaluate whether field border sprays of fungicide would help slow the rate of disease and be an economically viable alternative to whole-field fungicide sprays. The answer was no, which is extremely valuable information and we have discouraged farmers from trying this approach. In 2013 we obtained funding (Evaluation of the Ascochyta/Mycosphaerella Pathogen Complex in Chickpeas, Peas, and Lentils for Resistance to QoI and DMI Fungicides: $20,250) to develop baseline data for fungicide resistance in pulse crops. We actually developed methods for four different fungicides. We added two SDHI (succinate dehydrogenase inhibitor) fungicides due to observed fungicide failures in the field in 2013. The information is being used to screen isolates of Ascochyta blight from pulse crops for fungicide resistance with a single discriminatory dose of fungicide. Screening for resistance to Headline resulted in the identification of four resistant isolates of nine total isolates recovered from chickpea. Growers were notified and they either did not plant the seed or were aware they need to rotate fungicide chemistry to avoid fungicide failures in 2014. We identified one pea isolate with reduced sensitivity and the grower is aware of the need to rotate fungicides.

**Project Approach**

**Activities:** We collected 990 isolates of Ascochyta from chickpea (10%), field pea (90%) and lentil (10%) seedlots submitted by growers in 23 Montana counties to the Regional Pulse Crop Diagnostic Laboratory (RPCDL) in Bozeman, MT., for testing during 2014, 2015, and 2016 growing seasons. This included isolates were from fields in Montana and those sent to us by Dr. Julie Pasche from North Dakota.

The 990 Ascochyta isolates were screened for strobilurin (QoI class) fungicides (Headline) resistance in an agar plate assay. Only 11 isolates of Ascochyta rabiei (from chickpea) showed resistance to pyraclostrobin fungicide (Headline). The DNA sequences of the Cytochrome b gene showed that the resistant isolates were G134A mutants. No isolates from pea and lentil were resistant to the fungicide. Greenhouse trials were conducted to determine the level of in-vivo disease control attainable with pyraclostrobin fungicide (Headline) against the resistant isolates. Disease control of resistant isolates was significantly reduced in the pyraclostrobin (Headline) treatments when compared to susceptible isolates at all fungicide concentrations (p-value < 0.001).

We have developed a TaqMan realtime duplex PCR and have used it to successfully discriminate between pyraclostrobin fungicide (Headline) susceptible (wild) and resistant (mutant) Ascochyta rabiei isolates.
Growers whose seedlots or plant samples were infected with the resistant isolates were notified and provided with appropriate management recommendations. In addition, the results from this project were disseminated via the routine extension activities, including presentations to growers, county agents, and ag professionals (~1000 contacts and talking about pulse crops); press releases, newsletter articles, radio, and television appearances, MontGuides, agalerts, etc. Also, we have a peer-reviewed publication:


A few Montana isolates of Ascochyta rabiei, the fungus causing ascochyta blight in chickpea, have been shown to have developed resistance to the commonly used fungicide class used to control its disease. The use of this fungicide group is ineffective against the resistant isolates. The good news is that we have developed a rapid test method for the mutant Ascochyta rabiei. This method is now being used by the Regional Pulse Crop Diagnostic Laboratory in Montana to test isolates of Ascochyta rabiei in from infected chickpea seedlots and plants for resistance to the fungicide class prior planting. The lab advises growers whose chickpea seedlots are infected with this mutant against the use of the ineffective pyraclostrobin (Headline) for seed treatment or foliar application. Alternative but effective fungicides are recommended. Overall, the project has given us the tool to manage ascochyta disease of chickpea and has alerted us to Ascochyta rabiei resistance development to QoI class of fungicides. Also, we have shown that the pyraclostrobin (Headline) Ascochyta resistance is presently not an issue in pea and lentil.

**Benefits to other Commodities:** Not Applicable

**Significant Contributors:** Dr. Julie Pasche from North Dakota supplied us with Ascochyta rabiei isolates from North Dakota. She provided technical inputs and reviewed our manuscript prior to publications.

The project was carried out at the Regional Pulse Crop Diagnostic laboratory, where Dr. Bright Agindotan is the manager. Dr. Agindotan directly supervised the project with Dr. Mary Burrows.

**Goals and Outcomes Achieved**

**Activities Completed:**

1. Collection of 990 pure isolates of Ascochyta each from chickpea (99) and lentil (89), and dry pea (810) from 23 counties in Montana and 1 from North Dakota (10 isolates from chickpea). The number of isolates collected exceeded the minimum proposed: 50 isolates each from chickpea and lentil and 150 isolates from pea.

2. The Ascochyta isolates were screened for pyraclostrobin (Headline) resistance in plate assay.

3. The 11 Ascochyta isolates from chickpea that showed resistance to pyraclostrobin (Headline) in plate assay were evaluated for functional resistance to the fungicide in the Greenhouse.
4. The Ascochyta rabiei isolates that showed resistance and those susceptible to the fungicide had DNA extracted from them and their cytochrome b gene amplified and sequenced to identify the mutation in the gene. The fungicide-resistant isolates were G134A mutant.

5. Duplex real-time TaqMan PCR was developed to timely identify pyraclostrobin (Headline) resistant Ascochyta rabiei. This diagnostic method is now being used at the Regional Pulse Crop Diagnostic Laboratory, Bozeman, MT. A peer-reviewed paper on the method has been published and now available for use by other laboratories in Montana and other pulse-growing states.

6. Through extension activities, growers have been made aware of the presence of pyraclostrobin (Headline)-resistant Ascochyta rabiei isolates infecting chickpea in Montana and the need to test their seedlots and diseased plants to identify if they are infected with the resistant isolates. The infectiveness of using the popular pyraclostrobin (Headline) has been emphasized and effective alternative list of fungicides have been recommended.

**Long Term Outcomes:** Not Applicable

**Major successful outcomes in quantifiable terms:**

1. We have shown that pyraclostrobin (Headline) resistance have developed in Ascochyta rabiei infecting chickpea in Montana. The resistant isolates have been confirmed in 3 chickpea seedlots from 3 counties in Montana: Daniel, McCone, and Valley.

2. Out of 891 Ascochyta isolates (from 23 counties in Montana) from lentil and dry pea, none was pyraclostrobin (Headline) resistant. Good news to growers of lentil and dry peas!

3. A rapid detection method: duplex realtime PCR has been developed and now being used by the Regional Pulse Crop Diagnostic Laboratory to screen chickpea seedlots infected with Ascochyta rabiei for pyraclostrobin (Headline) resistance. The method has been published and it is now available to other laboratories in Montana and other pulse growing states.

4. Through our extension activities, publications and presentation to pulse crop growers and other stakeholders they have been informed that mutants of Ascochyta rabiei (causing ascochyta blight in chickpea) which are resistant to pyraclostrobin (Headline) fungicide are emerging and that this commonly used fungicide is no longer effective for the management of the disease. Growers are being informed that they need to test their chickpea seedlots for pyraclostrobin (Headline)-resistant Ascochyta mutants. If the mutants are detected, pyraclostrobin (Headline) and all the QoI class of fungicides should not be used because there are ineffective against the mutants. Alternative but effective non-QoI fungicides have been recommended.

**Beneficiaries**

**Description:** Chickpea growers will benefit from avoiding potential yield loss resulting from usage of ineffective fungicide against the Headline resistant Ascochyta rabiei. The fungus causing seed yield loss through empty pods, lodging, and poor photosynthesis. The knowledge of the mutation, the rapid test now are available, and the availability of alternative fungicides will help to avert yield loss.
Extension agents and pulse plant pathologists in Montana and other pulse producing states will benefit from the detection method and the awareness of mutants and alternative fungicides for control of the disease.

**Number of Beneficiaries:** The beneficiaries are all the chickpea growers in the United States. Montana led in 2017 with 40.9% of 603,800 acreage cultivated, followed by Washington (29%), Idaho (19.5%), North Dakota (7.3%), California (2.4%), and Nebraska (0.9%). The value of chickpea in US 2016 was a $128 million. Other beneficiaries include all the exporters of chickpea in Montana and other chickpea producing States.

All the scientists working on Ascochyta rabiei in Montana and other states will benefit from the impact of this project. Lastly, crop insurance companies might benefit from reduced liabilities if they require chickpea growers to test their Ascochyta-infected chickpea for resistance to Pyraclostrobin(Headline) for insurance coverage.

**Lessons Learned**

**Insights:** It is important to inform growers immediately if detect ascochyta blight in their chickpea fields to enable them to make a prompt treatment decision.

Chickpea seedlots with Ascochyta incidence >2% are most likely to have mutant populations. Advise growers to test for Ascochyta Headline (fungicide) resistance immediately prior to selling them for planting.

**Unexpected Outcomes:** We were expecting pyraclostrobin (Headline) resistant Ascochyta isolates from lentil and pea but none of the 891 were resistant to the fungicide. Good news to the growers though.

All goals of this project were achieved.

**Contact**

Bright Agindotan  
Research Assistant Professor-PhD  
Plant Sciences & Plant Pathology  
406-994-7738  
bright.agindotan@montana.edu

**Additional Information**

**Publication**

Conference presentation


Extension presentations in Montana

- Burrows, M. 2/22/2017. Healthy Seed, Healthy Start: The Importance of Seed Testing in Preventing Diseases of Pulse Crops. 400 attendees. Field Crops Disease Summit; Top Crop Manager. Saskatoon, SK.
Evaluating generational resistance to Potato Virus Y in potato

Project Summary

Background:

Potato Virus Y (PVY) is the most important virus disease of potatoes worldwide, and an important pathogen of Montana’s Seed Potato crop. PVY is an aphid and tuber transmitted pathogen resulting in decreased yield and quality of potatoes. Seed potatoes are produced in a limited generation flush-out system where the earliest generation (nuclear) is derived from tissue culture stocks, which are maintained disease free in sterile culture, and after 4 successive generations in the field (G1-G4), the potatoes cannot be recertified as seed and must be sold for commercial production. Limited generation seed potato production systems limit the proliferation of tuber borne diseases, such as aphid transmitted viruses including Potato Virus Y (PVY), Potato Virus A (PVA), and leafroll. While the overall virus disease in certified seed potatoes is reduced by this system, we have observed that the nuclear generation is more susceptible to aphid transmitted virus infection and environmental stress. Initiating new plantings from tissue culture is extremely expensive and labor intensive. Virus-infection of nuclear generation plantings results in a potential loss of G1 seedlots. Our data demonstrate that a 0.1% infection rate in G1, is an indication that the entire lot will not be suitable for G2 planting in the following year, resulting in the loss of an entire crop year for the seed potato grower. When using a 10X planting multiplication factor, losing 1 acre of G1 results in the loss of 10 acres of G2. A second, more promising, observation from our field studies is that later generation potatoes (G2-G4) are more resistant to PVY. The goal of this project is to identify the mechanisms of late generation (G2-G4) resistance to PVY in order to develop strategies that reduce loss of early generation seed lots.
**Timeliness:**

In 2013, Montana growers experienced a significant increase in PVY in nuclear and Generation 1 (G1) potatoes in specific varieties. Growers that experienced significant amounts of PVY in their G1 potatoes will not be able to plant G2 for those varieties in 2014, and these effects will be amplified in lost production in successive years. Due to the increase in PVY from 2013, some early generation seed of specific varieties will be in very short supply. 49% of G1 Alturas, 30% of Norkotah, 39% of Norkotah Colorado 3, and 39% of Norkotah Texas Line, and 25% of Umatilla exceed planting tolerances for certification as G2 in 2014. When G2 becomes limited, growers will either have to buy seed from another Montana Certified seed grower or plant G3 to produce G4 which is often discounted in contracts, reducing the growers profit. Growers have employed numerous management options to reduce virus in their seed plots and some are still struggling. To address this problem, we performed studies aimed at better understanding the mechanism(s) of generational resistance. We hypothesize that discovery of these resistance mechanisms will lead to the development of strategies to limit infection in early generation potato plants.

**Previous Funding:**

This project does not build on a previous project.

**Project Approach**

**Activities:**

Experiments were performed to test whether seed type and growth conditions (i.e., sterile vs. field grown) impacted PVY incidence. Systemic acquired resistance (SAR) is a plant immune response that is induced by pathogens and resistance-inducing agents. Resistance-inducing agents are effectively used to limit fungal pathogens, and we hypothesized that they may also limit PVY infection. To test these factors, potato plants (cultivars Russet Burbank and Norkotah Colorado 3) were grown from multiple seed types (i.e., plantlet, minituber, and Generation 3 tuber (G3)) and mechanically inoculated with PVY strain Wilga.

Potato cultivars differed in incidence of PVY infection after mechanical inoculation. The cultivar Russet Burbank had a lower incidence of PVYN-Wi infection (mean of 41%) than the cultivar Norkotah Colorado 3 (mean of 63%) when data from plantlets, minitubers, and G3 tubers was analyzed together (P-value 0.0069). PVY incidence varied by seed type for Russet Burbank but not for Norkotah Colorado 3. Russet Burbank plants had a lower incidence of PVYN-Wi infection than Norkotah Colorado 3 plants grown from both minitubers (P-value 0.04), and G3 tubers (P-value 0.01. However, plants grown from Russet Burbank and Norkotah Colorado 3 plantlets did not significantly differ in incidence (P-value 0.82) (Figure 2.1).

Potato seed type affects incidence of PVYN-Wi infection in Russet Burbank. Plants grown from Russet Burbank plantlets had a significantly higher incidence of PVYN-Wi infection than plants grown from Russet Burbank G3 tubers (P-value 0.03). However, plants grown from Norkotah Colorado 3
plantlets did not have significantly higher incidence of PVYN-Wi infection than plants grown from Norkotah Colorado 3 G3 tubers (P-value 0.82).

To determine if SAR-inducing agents could lower the risk of infection by PVY, Russet Burbank and Norkotah Colorado 3 plants were grown from three seed types in the presence or absence of SAR-inducing compounds. SAR inducing compounds tested were applied to plants 5 days pre-inoculation: Resistance-inducing agents tested in this study were compost tea (Kimm Seed Potatoes, Manthattan, MT), Bacillus mycoides isolate J (BmJ, Montana State University, Bozeman, MT), acibenzolar-S-methyl (Actigard ® Syngenta, Basel, Switzerland), and phosphorous acid (Phostrol ® Nufarm, Melbourne, Australia). Plants were inoculated with PVYN-Wi (Wilga) and the percentage of plants infected (incidence) with PVYN-Wi was measured at 2, 3, and 4 weeks post-inoculation. In gene regulation, qPCR studies on 2 pathogenesis related proteins it was found that Beta-1,3-glucanases (a PR-2 protein) were consistently upregulated in plants that were treated with Phostrol, in both infected and uninfected plants. B-1,3-glucanases have been implicated in multiple roles in the cell, including defense against viruses. PR-1 was also tested but the results were inconclusive. This may be due to use of a housekeeping gene as a control that wasn't suited for this assay. This work is ongoing with a new housekeeping gene as a control and new potato samples.

Laboratory technician Eileen Carpenter and Graduate Student Elisa Boyd traveled to Stewart Grays lab at Cornell during the fall of 2014. They learned techniques on aphid transmission of PVY in Dr. Gray’s lab.

Dr. Zidack presented the data gathered from this project in an oral presentation at the WERA meeting in March of 2017.

**Benefits to other Commodities:** Not Applicable

**Significant Contributors:**

Graduate student Elisa Boyd under the direction of Michelle Flenniken and Nina Zidack demonstrated that there are quantifiable differences in PVY susceptibility between potatoes planted from different seed types. There is also a difference in susceptibility of the two varieties we tested and between those varieties, there were differences in seed types. Nina Zidack has seen this demonstrated in grower fields and worked with Flenniken and Boyd to design experiments to test the hypothesis that seed types from different generations of potatoes have differ in their susceptibility to PVY. This has implications for how seed potato growers manage their early generation potatoes in the field because it is demonstrated that plants initiated in sterile culture are more susceptible to PVY, and that additional measure need to be taken to protect them from infection. Michelle Flenniken contributed expertise in molecular biology which enabled Elisa Boyd to quantify virus inoculum and PVY titers in plants. Through this research we have an indication that Phostrol is a product that could be used to increase these plantings resistant to PVY. This data provides the basis for actual field application which will be tested in subsequent projects.
Goals and Outcomes Achieved

Activities Completed:

Initially a number of experiments were performed to optimize inoculum preparations including purification of preparations and standardization of titer by quantification using qPCR.

Determine differences in generational and varietal susceptibility of potato to PVY - Replicated greenhouse experiments were performed to assess the differences in susceptibility of 2 different cultivars of potato (Russet Burbank and Russet Norkotah CO3) and 3 different plant types including plants grown from tissue culture, plants grown from greenhouse produced minitubers and plants grown from G3 field grown tubers.

Evaluate commercial biological control agents and known plant defense inducing compounds for induction of resistance to PVY - Replicated greenhouse experiments were performed to test different potential inducers of resistance to PVY. Compounds tested were Phostrol, compost tea, BmJ (Lifegard), and Actigard. Phostrol appeared to have the most significant effect so additional experiments were performed with both Russet Burbank and Russet Norkotah CO3 plants grown from plantlets.

Identify mechanisms (regulated genes) of PVY resistance in later generation potatoes - Samples were collected from all of the treatments in both the first set of experiments on cultivar and generation age, and the Phostrol inducing treatments. All samples were stored at -80C. During the winter of 2017 it was determined that the DNA had degraded in these samples to the point that RNAseq analysis would not be successful. qPCR was run on some newly collected samples from Phostrol treated plants and more analysis will continue.

Long Term Outcomes:

We have identified that plants initiated from sterile culture are more susceptible to PVY and that this is consistent with observations by seed potato inspectors in the field. We have also shown that the resistance inducing product Phostrol reduces infection of PVY in Russet Burbank, the most widely grown cultivar in the United States. One interesting aspect is that Russet Norkotah CO3 does not seem to be induced which has implications for whether or not this management tool would be effective in other cultivars. In order to give growers practical management recommendations on use of this product, more research will need to be conducted on the effect of cultivar in response to this product.

Major successful outcomes in quantifiable terms:

In 3 replicated experiments, we showed that Russet Burbank plants grown from G3 tubers had 69% less infection that plants grown G3 tubers. This information is important to pass on to growers because it has implications for how they manage their nuclear plantings of seed potatoes. We also have indications that Phostrol reduces PVY infections by 66%. Phostrol is a product that is already
registered for use on potato so it is something that could be implemented without any special registration. This is very significant when it comes to implementing a product for pest management.

Interesting trends were observed in plants treated with Phostrol (phosphorous acid). Russet Burbank plantlets treated with phosphorous acid had lower percent infections at four weeks post inoculation compared with the non-induced control in experiments 1, 2, 3, and 4. Specifically, Russet Burbank plantlets at four weeks post inoculation, treated with phosphorous acid resulted in 66.7% lower infection in experiment 1, a 77.3% lower infection in experiment 2, a 30% lower infection in experiment 3, and a 75% lower infection in experiment 4 compared to the non-induced controls. The cultivar Norkotah Colorado 3 has a higher incidence of infection than Russet Burbank. This trend was observed in experiments 1 and 2. In experiment 1, Russet Burbank non-induced controls had 30% infection and the Norkotah Colorado 3 non-induced controls had 60% infection at four weeks post inoculation. In experiment 2, the Russet Burbank non-induced controls had 75% infection and the Norkotah Colorado 3 non-induced controls had 100% infection.

Together, the preliminary studies performed to date suggest that treatment of Russet Burbank plantlets with phosphorous acid reduced PVY infections, however, due to an insufficient number of replications the results are statistically non-significant and thus additional experiments are required to validate these initial findings. We expect that additional replications of these experiments will result in significant findings.

Benefits

Description:

This information has been presented to Montana Seed Potato growers at the growers meeting at the Annual Seed Potato Seminar which is held every November. As Director of Seed Potato Certification at MSU, I also incorporate these research findings into my recommendations to producers. The results were published in the American Potato Journal which is a well respected journal widely circulated among potato practitioners throughout the US and the world.

Number of Beneficiaries:

This information has been presented to Montana Seed Potato growers which includes 52 family farm operations. Since the information is publicly available in a refereed publication, seed potato practitioners in the 13 seed potato producing states have access to this information and can incorporate the findings into their management recommendations.

Lessons Learned

Insights:

One of the biggest challenges was standardizing inoculum for the experiments. If the inoculum level was too high, it was not possible to record differences between treatments. If the inoculum level was too low, you could not get statistical separation between treatments.

Unexpected Outcomes:
One unexpected outcome was that Russet Burbank and Russet Norkotah CO3 had differential expression of the age related resistance. Russet Burbank G3 had significantly less infection than plants grown from tissue culture but in Russet Norkotah CO3, both plant types had the same amount of infection. This has implications for the difficulty in managing highly susceptible cultivars at all growth stages.

Outcomes Not Achieved:

We were not able to complete the RNAseq analysis on the samples that had been saved from previous experiments. The RNA had degraded to the point that they were not able to be analyzed. Any future experiments that we do with potato and RNAseq analysis we will process the samples and send them off for sequencing much more quickly. We were able to get some useful information on gene expression for qPCR.

Contact

Nina Zidack
Dir MT St SeedLab-PhD
Plant Sciences & Plant Pathology
nzidack@montana.edu
406-994-6110

Additional Information
None

Evaluation of Montana-grown “Superfood” Fruits

Project Summary

Background:

The opportunities are ripe to expand small-fruit production in Montana. Demand for small fruits is growing in the state and nationwide. In part, the growth in demand is due to an increased interest in healthy eating. Berry-based nutraceuticals and antioxidant-rich, superfoods have captured public attention and represent a growing market. In addition, Montana food processors have expressed a strong interest in incorporating these fruits into their products. However, current production of these fruits is low. Producers lack the basic information concerning which types and varieties are adapted to grow in Montana and the economic potential of these crops. The project produced research-based recommendations addressing the productivity and marketability of these new crops. We tested over 50 varieties of small fruits including Dwarf Sour Cherries, Saskatoons, Currants, Aronia, and Haskaps at four sites across the state. The mid-term goal is to provide this information to producers and consumers. Our findings were communicated to over 1300 consumers, fruit-growers and fruit-buyers through workshops, field tours, and publications in a variety of media. The ultimate
goal is to increase both the supply and demand for Montana fruits and contribute to the growth of this niche market.

Timeliness:

Markets for high-antioxidant fruits are rapidly expanding. Several of the fruits can be grown in Montana’s climates and labor markets. Cold-hardy, machine harvested berry production is increasing rapidly in similar areas in Canada and Northern Europe. For example, over 12,000 acres over Aronia are currently harvested in Poland. Across the border in Canada (Alberta, Saskatchewan, and Manitoba), saskatoon production has increased to 400 growers that produce over 20 million dollars in crop value each year. Haskap (also known as Honeyberries) acreage has also expanded dramatically in Canada and Northern Europe with over 1000 acres reported in Canada alone. Montana fruit growers can begin to take advantage of these markets with research and outreach.

Previous Funding:

The project was not built upon a previously SCBG-funded project.

Project Approach

Activities:

The project has four goals: 1) evaluate the productivity and profitability of cold-hardy, high-antioxidant fruits in Montana climates and markets; 2) increase producer awareness of and interest in these fruits; 3) increase producer knowledge about the best management practices for these fruit; and 4) establish relationships with producers to begin to grow these fruits (i.e. increase acreage in production). The project has reached these goals. The project activities and outcomes completed to achieve the outreach goals and production goals are described below.

Producer awareness and knowledge has increased substantially as a result of the project. We have presented information generated from the project at over 20 workshops and field tours reaching over 1300 individuals. The project has also been featured in several newspaper and magazine articles and television news stories. We have also shared project results and management recommendations through the WARC website (http://agresearch.montana.edu/warc/warc_research/fruit/Fruitindex.html) and several pamphlets. The project has also sent growers to the Saskatchewan to visit Haskap growers/processors and to attend the University of Saskatchewan Fruit Field days. We will continue to provide growers and nurseries with updated information regarding producing cold-hardy, high antioxidant fruits as the project has been funded for another three years. Project personnel have also provided direct assistance in nearly all current and prospective growers in the state.

The acreage planted to these fruit types has increased 30-fold during the project. Prior to 2015, there was less than an acre in production of all fruit types in this study. Currently, there are over 11,000 plants (or around 15 acres) planted or will be planted by next year in commercial plantings. Based on grower surveys, this acreage is expected to continue to grow. We are engaged with these
growers to identify and address their needs as well as to facilitate networks among growers, processors, and consumers.

**Benefits to other Commodities:**

The project only benefited specialty crops, specifically small fruits and berries.

**Significant Contributors:**

Dr. Zach Miller, Bridgid Jarrett, and staff at WARC managed and analyzed fruit trial at the site, lead outreach efforts. Dr. Miller also is co-mentoring at Master’s student on the project, Durc Seltzer, with Dr. Mac Burgess. Durc Seltzer managed fruit trials at MSU-Bozeman and assisted Brent Sarchet with trials in Helena. Durc has also led efforts to evaluate nutrient and antioxidant content in fruit grown in the trials. The project’s trials at Flathead Valley Community College were managed by Heather Estrada and Julian Cunningham. All site managers also hosted field days and workshops and provided their expertise to current and potential growers. Dr. Pat McGlynn, Flathead Co. Extension, organized volunteer labor for the Kalispell site and assisted in outreach.

**Goals and Outcomes Achieved**

**Activities Completed:**

The project has four goals: 1) evaluate the productivity and profitability of cold-hardy, high-antioxidant fruits in Montana climates and markets; 2) increase producer awareness of and interest in these fruits; 3) increase producer knowledge about the best management practices for these fruit; and 4) establish relationships with producers to begin to grow these fruits (i.e. increase acreage in production). The project has reached these goals. The project activities and outcomes completed to achieve the first goal are described below.

Trials were established in 2015 at four locations in Montana to evaluate cultivars of Haskaps, Aronia, Red and Black Currants, Dwarf Sour Cherries, and Saskatoons. The test orchards are located at the Montana State University Horticulture farm in Bozeman, two private farms near Helena, the Flathead Valley Community College Horticultural farm in Kalispell, and the MSU-Western Agricultural Research Center in Corvallis. At each location, cultivars were planted in three plant set in each block with three blocks per site. Location of fruit species and cultivars within species were randomized using a split-plot design. Data on winter hardiness (plant survival, damage), pests, and fruit production were collected in 2016 and 2017 (second and third years after planting).

All cultivars were adequately cold-hardy. No significant winter mortality or injury was observed. While two winters at four sites is a small sample, the winter of 2016-2017 was colder than average with low temperatures of -20 to -30 degrees Fahrenheit at all sites. Most plant losses were due to transplant shock and small mammal damage (e.g. plants excavated or girdled). Both of these factors were associated with use of weed barrier/landscape fabric.

Cultivars differed in yields and fruit quality. In the second year after planting, Haskaps, Currants, and Aronia produced small crops (<0.25 lbs. per plant) and no fruit was produced in Dwarf Sour Cherries.
and Saskatoons. Much larger and more consistent yields were obtained in the third year and we were able to identify cultivars that are better suited for commercial production. Results from that year from WARC are used below to demonstrate these findings. Among fruit types, Haskaps, Currants, and Aronia produced the largest and most reliable yields over the first two harvests. All plants produced crops in the third year and yields ranged between 1.2 and 5.4 lbs. per plant.

In Haskaps, six of the fifteen cultivars were not suitable for commercial production either due to poor flavor, small berry size and yields, un-even ripening, or the habit of dropping fruit prior to ripeness. Third years Haskap yields ranged from 0.1 to 4.4 lbs. per plant. Haskap cultivars ripen at different times from late June and mid-July. We evaluated berry flavor in a taste test among two sets of cultivars those that ripened early and those that ripened later. Indigo Gem had the best flavor (and highest yields) among early ripening Haskaps. All late ripening cultivars had good flavor, but the appearance and flavor of Aurora was generally preferred over the other cultivars.

Currant yields ranged from 0.1 to 5.4 lbs. per plant among cultivars. Recommended cultivars are Tahsis, M12, and Whistler. These cultivars ripened evenly, had large berries, and produced yields that were five to seven times greater than the commercial check cultivar (Titania). Two cultivars (Tofino and Blackcomb) do not appear to be suitable for commercial since they ripen unevenly.

Dwarf Sour Cherries require several seasons to bear fruit. 2017 was the first year that any fruit was harvested, so results are preliminary. Two cultivars that have just been released, Romeo and Juliet, and were planted in 2016 produced a crop in the second year which we did not see in any other cultivar. 11% of Juliet and 67% of Romeo plants produced fruit in the second year. The fruit is sweeter than the other sour cherries and the flavor of fresh fruit was preferred in taste tests. Carmine Jewel and Lutowka Rose cherries produced reliable crops (mean yields=0.7 and 1.3 lbs. per plant, respectively) in their third year in the ground. The other cultivar, Crimson Passion, has not produced fruit at any site.

Aronia cultivars have been productive and have the advantage of not being preferred by birds, unlike all other fruit types in our trials. We have leveraged this project to gain additional grant funds to study health impacts of Aronia with scientists at MSU.

Saskatoon production has been hampered by pests. Around 70% of the crop was lost due to Saskatoon sawfly this year. Growers will need to manage for this pest. We will evaluate pest control practices for sawfly next year.

The goal to increase producer knowledge of potential of these fruits and best management practices was achieved but the methods of measuring the performance were changed slightly. Pre and post surveys were delivered to differing audiences so the results could not be formally compared to measure change in knowledge. The pre-project survey was delivered to people who attended small fruit workshops and at farmers markets in 2015. This sample included growers, consumers, and gardeners and was made up of 139 Montana residents from 12 counties. However, growers (either commercial or hobbyists) were a minority (14 to 26% reported growing fruit species in our project). This survey did establish that current production and knowledge was low and interest in growing and
purchasing these fruits was relatively high. Most respondents had heard of currants (87%), juneberries (85%), and Aronia (70%) but most had not heard anything about honeyberry/haskap (40% had “heard of”) or dwarf sour cherries (42%). Also most people had not tasted many of these fruits. Approximately 80% had not consumed honeyberries or dwarf sour cherries. Fifty seven percent had never tasted Aronia. Slight majorities had consumed currants and juneberries (69 and 52 %, respectively).

The post survey included only commercial berry growers. We interviewed all commercial producers that we are aware of (19 farms/orchards)of the berries and small fruits included in this produce in Montana. All reported gaining knowledge because of this project. Most (84%) had participated in project outreach, either through attending workshops or individual consultation. All of those growers reported gaining knowledge from the project’s activities.

**Long Term Outcomes:**

Determining ideal small fruit and berry cultivars for the high-antioxidant fruit market for Montana growers is a long-term goal. We have made progress in identifying cultivars that are not well suited for commercial production. The project has identified the major pests for these fruits (primarily birds, rodents, and deer) and successful means of managing these most of these pests.

Currently, the major challenge identified by growers is access to markets and harvest costs. The project has facilitated connections between growers and processors and has educated consumers, but more work on this front is needed. We plan to evaluate cultivars harvest efficiency in mechanized harvest in the next phase of the project.

**Major successful outcomes in quantifiable terms:**

Production of high-antioxidant fruits in Montana has increased significantly during this project. Prior to 2015, there was less than an acre in production of all fruit types in this study. Currently, there are over 11,000 plants (or around 15 acres) planted or will be planted by next year in commercial plantings. Haskaps plantings make up the majority of the new plantings (5500 plants or about 5.5 acres) with four farms greater than one acre and several of the farms are planning on expanding. Aronia is also widely planted, with nearly seven acres (or approximately 4700 plants) planted at four farms. Saskatoons, Currants, and Dwarf Sour Cherries are currently planted on 2.5 acres at multiple farms.

These fruit orchards will provide increased agricultural revenue for the state. Conservatively, when the current plantings are mature, Haskap production is estimated at around six tons annually with a value of nearly $60,000. There will be about 11 tons of Aronia produced annually with a value of nearly $50,000.

Small-scale, backyard plantings have also increased in Montana. We surveyed seven nurseries located across the state. All nurseries located in the central and western portions of the state report
increasing interest and demand for cold-hardy, dark fruits. In just these selected nurseries, over 4000 plants (primarily Haskaps or Honeyberries) have been sold in the last few years.

**Beneficiaries**

**Description:**

The project has benefited 21 commercial fruit growers located across the state. This includes six new Haskap producers which are the first of their kind in the state, five Aronia producers, and first commercial currant orchard in the state. The project has also benefited the vineyards and wineries in the region. Many of these fruits can be made into high-quality wines. Four vineyards have established or increased plantings of the fruits in the project and the project has facilitated connections between growers and wineries. Several of the new growers are vegetable producers that are diversifying into cold-hardy fruits.

**Number of Beneficiaries:**

The project has benefited 21 commercial fruit growers located across the state. Currently, there are over 11,000 plants (or around 15 acres) planted or will be planted by next year in commercial plantings. Haskaps plantings make up the majority of the new plantings (5500 plants or about 5.5 acres) with four farms greater than one acre and several of the farms are planning on expanding. Aronia is also widely planted, with nearly seven acres (or approximately 4700 plants) planted at four farms. Saskatoons, Currants, and Dwarf Sour Cherries are currently planted on 2.5 acres at multiple farms. Many farms are expanding and we expect that new operations will start up, but even based on current plantings this represents over $100,000 annual in new agricultural sales once these plantings mature.

**Lessons Learned**

**Insights:**

The primary insight from our research is that the labor required to manage and harvest berry trials was greater than expected. To evaluate cultivar performance, deer and bird exclosure is necessary but was difficult to achieve at some sites. We have addressed these issues at the sites in the last year of the project. Two of the sites were managed organically and utilized weed fabric in the rows. This led to increased rodent damage and plant losses at both sites.

**Unexpected Outcomes:**

The project provided unexpected insights into the barriers to starting a fruit orchard and the limits to research and outreach. Growers face high start-up costs and few banks willing to loan money for a novel crop that will not produce cash flow for two to four years. Growers also face uncertainties of emerging and dynamic markets. More work is needed to educate processors and consumers to the value of these novel fruits.

**Outcomes Not Achieved:**
It was not possible to quantitatively determine which fruits would be most profitable as markets for these novel fruits are still developing and prices are dynamic. We are currently increasing our engagement with producers and processors to determine actual prices in the state and region.

**Contact**
Zach Miller  
Supt/Assistant Prof of Hort-PhD  
Western Ag Research Center  
zachariah.miller@montana.edu  
406-961-3025  

**Additional Information**
None  

**Food Safety Trainings for Group GAP**

**Project Summary**

**Background:**
Growing demand for local and regional grown farm products offers an unprecedented opportunity for sustainable small- and mid-sized farms. Food hubs and other farm product aggregators make it possible for small and mid-sized farms to gain entry to larger-volume markets that have been difficult or impossible for producers to access on their own. The wholesale supply chains have long relied on external (second or third party) food safety (e.g. GAP and GHP) audits as demonstration of product safety compliance. Over the years, these requirements have become increasingly complex and expensive to meet. These requirements constitute a present and growing barrier which hubs and their local/regional suppliers must meet in order to assure that market opportunities truly grow into all that they potentially may be. Small and mid-scale producers, those most suited to supply the hubs and buyers, generally find the cost of meeting these requirements to be disproportionately expensive. This project addressed this need in providing support to Western Montana Growers Cooperative (WMGC) and other small-scale producers in developing a Group GAP (Good Agricultural Practices) approach to on-farm food safety.

**Timeliness:**

This project is important and timely. Based on the positive results of early pilots (see report at [http://ngfn.org/groupGAPreport](http://ngfn.org/groupGAPreport)), and the clear demand and urgent need for a program of this type, USDA AMS began developing certification and training auditors in Group GAP beginning in 2015. The Wallace Center is supported eight pilot projects to feed relevant information into USDA process, to develop materials that support hubs and cooperatives to prepare for and understand the Group GAP option, and to serve as points of experience for a growing network of hubs that will pursue the Group option. Lake County Community Development Corporation and Western Montana Growers Cooperative were chosen by the Wallace Center to be one of the eight pilot projects.
**Previous Funding:**

This project builds on the accomplishments of the previous SCBG "Providing Technical Assistance to Montana Specialty Food Processors in meeting the requirements of the Global Food Safety Initiative Audits" which created a foundation of food safety expertise and knowledge at Lake County Community Development. The previous project also created a tool kit for food safety management plans for food businesses. The food safety courses conducted in the previous project are self-sustaining and will be continued through work of Montana’s Food and Agriculture Development Center program. This proposed project is specifically designed to meet the needs of specialty crop producer groups who will develop Group GAP QMS (quality management system) programs.

**Project Approach**

**Activities:**

Significant progress in on-farm food safety. Key accomplishments the last 3 years are:

- The project developed training materials, templates, and curricula for farmers based on USDA GAP standards and FSMA requirements.
- Training was provided training to all 31 Western Montana Growers Cooperative produce grower members in on-farm food safety through a combination of classes, home based learning, group on-farm training, and personal consultation.
- All 31 WMGC produce farms have developed a base food safety plan for their farm. We have trained 2 WMGC staff and 3 contractors as USDA approved Group GAP internal farm auditors. These auditors meet the same standards as USDA GAP program auditors. WMGC established a Group GAP program administered through a quality management system to GAP-certify a number of farms and the WMGC warehouse. Now in its third year of certified operation, WMGC has 9 farms plus the warehouse meeting USDA GAP/GHP standards. The farms are tending to be the larger producers who expect to benefit with access to new markets.
- Although WMGC presently does not actively market the Group GAP program, many wholesale customers appreciate that all WMGC farms have an active food safety program.

**Benefits to other Commodities:**

All the beneficiaries of the project were specialty crop producers.

**Significant Contributors:**

The project supported Western Montana Growers Cooperative staff time and training to become internal auditors. The cooperative invested time and resources in assisting their 31 produce growers in developing on-farm food safety plans. Jim Sugarek worked closely with Lake County Community Development Center (LCCDC) in designing training materials and reaching producers with technical assistance.
David Wise - contractor - worked closely with WMGC and LCCDC in outreach and communication to producers in the Gallatin Valley. He is trained in internal auditing, PSA and GAP. He provided one on one technical assistance to farmers in completing on-farm food safety plans, conducted internal, warehouse and the Group GAP QMS audits.

IOIA - Jonda Crosby - assisted the project in design on educational materials, conducting internal audits and providing one on one technical assistance to producers in completing on-farm food safety plans.

Matheson Consulting - Nancy Matheson wrote the on-farm food safety training manual and conducted several trainings throughout the state. She conducted internal audits on WMGC farms to comply with their GAP audits.

**Goals and Outcomes Achieved**

**Activities Completed:**

**Objective 1** - Development of a Group GAP QMS for Western Montana Growers cooperative with a successful USDA audit

The project assisted two food hubs - the Western Montana Growers Cooperative and the Gallatin Valley Growers, in the development of a Group GAP QMS programs. Resource materials based on USDA GAP and Food Safety Modernization Act (FSMA) were developed and provided to produce growers to assist in on-farm food safety planning. Technical Assistance was provided to producers in each region to assist to complete on-farm food safety planning. The WMGC was assisted in completing a Group GAP QMS and successfully passed and audit on their QMS.

**Objective 2** - Prepare cooperative in conducting internal and 2nd party audits to meet the needs of specialty crop producers

Supporting WMGC staff, Jonda Crosby and David Wise were certified as USDA internal auditors and perform internal audits of member producers and Coop warehouse. Outreach and support was provided to producer members. The WMGC was supported to successfully complete their USDA inspection of warehouse and 10 producers successfully passed USDA GAP audits. 2 additional producers are pursuing GAP certification in 2017 production season.

**Objective 3** Develop a Group GAP QMS toolkit and training program to deliver to Food Hubs in MT

Activities include the completion of an on-farm food safety training manual and a Group GAP QMS toolkit. An introductory workshop using the materials was held at the Montana Organic Association annual conference. LCCDC conducted outreach to Montana producers to attend the on-farm food safety training workshops that were held in Bozeman, Great Falls, Corvallis, Kalispell and Billings.

**Objective 4** Engage in a community of learning around food safety and Group GAP with the Wallace Center, IOIA, and other Food Hubs.
Activities include participating in the monthly Wallace Center Group GAP calls, participating in the statewide food safety committee, sharing resources and holding training with the Gallatin Growers, participating in a regional project with Idaho, WA and MT that will assist other food hubs in developing Group GAP QMS systems.

**Long Term Outcomes:**

No long term outcomes to report on.

**Major successful outcomes in quantifiable terms:**

Number of on-farm food safety plans completed-48

Number of farms successfully passing GAP audits- WMGC has 9 producer members who have passed their GAP audits and are certified. In 2017 production season 2 fruit orchards are pursuing GAP certification.

Number of QMS audits- WMGC successfully passed their audit for the second year. Root Cellar Foods is developing a QMS plan with the assistance of David Wise.

Number of internal audits conducted by WMGC over two years- 18 plus two internal audits on the warehouse

Group GAP Toolkit has been used by Linc Foods Cooperative and Root Cellar Foods in the development of their Group GAP QMS plans.

**Beneficiaries**

**Description:**

The Western Montana Growers Cooperative and its 31 specialty crop producer members benefited from the project. The cooperative successfully gained USDA GAP certification for the cooperative warehouse and the Group GAP QMS.

Linc Foods Cooperative (50 specialty crop producers) and Gallatin Growers(17 specialty crop producers and one food hub, Root Cellar Foods) benefited from the Group GAP QMS toolkit and the on-farm food safety trainings and technical assistance provided by David Wise.

**Number of Beneficiaries:**

Number of specialty crop producers- 98

Number of food hubs- 3

The economic impact is reflected in the success of WMGC to serve the institutional market, which holds a high bar for food safety. The cooperative sold $311,453 in produce to institutional markets in 2016. This reflects a 25% increase in sales from 2015. Linc Foods has increased their membership and expanded their distribution route to serve markets outside the Spokane region. Root Cellar Foods is
now meeting Montana State University food safety requirements with several of their produce sources operating under food safety plans.

**Lessons Learned**

**Insights:**

The project assisted producers to develop understanding and capacity around on-farm food safety. It built the capacity of a cooperative, through a Group GAP QMS program, to fully meet the requirements of the FSMA rule and exceed those requirements by pursuing GAP certification. The marketplace is looking for third party audits to insure food safety issue are met. This project empowered the WMGC to expand into new markets fully prepared to answer and meet food safety questions and concerns.

**Unexpected Outcomes:**

An unexpected outcome is the regional effect the project had and the development of new partnerships who are working together to assist small specialty crop producers in meeting food safety requirements. The regional project will continue the work in assisting in the development of Group GAP QMS programs for the Gallatin Growers and Linc Foods. Resource and training materials will be shared with project partners- Linc Foods, Moscow Food Coop, and Univ of Idaho.

**Outcomes Not Achieved:**

The goals and outcomes measures for this project were fully met.

**Contact**

Jan Tusick  
Center Director  
Mission Mountain Food Enterprise Center  
jan.tusick@lakecountycdc.org  
406-676-5901 x111

**Additional Information**

LCCDC also partnered with NCAT in holding farm tours that educated producers in on-farm food safety practices.

**Identification, Preservation, and Propagation of Heritage Orchards in Montana**

**Project Summary**

**Background:**
Montana's local food systems are largely missing fruit. The Heritage Orchard Program, fruit tree cultivar research and small fruit cultivar research (all funded through SCBG), among other programs and research efforts are all being conducted in an attempt to increase fruit production across the state and address the many food deserts in the state. There are many old orchards located across the state (living 100 plus year old research sites). Through this research we have learned about what cultivars are at these old orchards, disease resistance among these cultivars, cold hardiness, micro climates, etc. All this information is aiding us in educating clients and rebuilding fruit production in the state.

The goal of this project was to compliment and enhance previous Fruit Tree Cultivar Research by determining which cultivars will perform best given different locations across the state, and distribute that information to growers. With the Montana Heritage Orchard Program, we are identifying the cultivars that are in the historic orchards and then distributing that information to growers. The idea being that if you are a prospective grower and you are trying to figure out which cultivars to plant, you could use the information from the two programs to help you in your decision making process; the prospective grower has information on the performance of newer cultivars and 100 plus year old cultivars that still have a place in today’s orchards. The information and resources from the two programs will help new orchard owners or current orchards looking to expand more informed in their decisions, so they can hopefully be more successful.

**Timeliness:**

There is an increased need and interest in growing fruit in Montana, which coincides with the national trend for more localized food production. Until the last 6 years there has been little to no research and education efforts on growing fruit in Montana. The information we are learning about the old orchard is aiding our efforts with educating the public about growing tree fruit. Cultivars that have survived 100 plus years of growing in Montana are a starting place for rebuilding the orchards of the future. The heritage orchard program is also creating opportunities for agritourism, which is a growing segment of Montana tourism. Orchard owners have the opportunity to diversify their farm income.

**Previous Funding:**

The project complements the fruit tree cultivar research funded by SCBG.

**Project Approach**

**Activities:**

1) Built a website, [www.mtorchards.org](http://www.mtorchards.org)

2) Identified over 60 heritage orchards across the state
3) Identified the following cultivars at the orchards through DNA testing (listed most to least identified cultivar): Wealthy, McIntosh, Duchess, Wolf River, Northwest Greening, Yellow Transparent, Whitney Crabapple, and Transcendent Crabapple. We also have over 116 samples that are unique. What does this mean? These could be seedlings, mutations that could have occurred, etc. which is exciting in the pursuit to find the 'Montana Apple'.

4) Assisted landowners with preserving their trees with pruning and management advise.

5) Propagating trees for the orchard owners and the public from these heritage trees; the first trees propagated from the Chief Plenty Coups State Park orchard will be available to the public in the spring of 2018.

6) Conducted 30 workshops reaching over 1,800 individuals on a combination of grafting, pruning, fruit tree management and the heritage orchard program. Dissemination of the information was done through the workshops and over a dozen magazine and newspaper articles as well as extension publications.

**Benefits to other Commodities:**

Specialty Crops benefited only

**Significant Contributors:**

Brent Sarchet and Toby Day organized the program and continue to administer the program. Dr. Norm Weeden has conducted the DNA testing. Jay Van Voast created the website and Roger Joy from Canyon View nursery is propagating trees for the program.

**Goals and Outcomes Achieved**

**Activities Completed:**

Accomplished Objectives:

1) Built a website, mtorchards.org

2) Identified over 60 heritage orchards across the state

3) Identified the following cultivars at the orchards through DNA testing (listed most to least identified cultivar): Wealthy, McIntosh, Duchess, Wolf River, Northwest Greening, Yellow Transparent, Whitney Crabapple, and Transcendent Crabapple. We also have over 116 samples that are unique. What does this mean? These could be seedlings, mutations that could have occurred, etc. which is exciting in the pursuit to find the 'Montana Apple'.

4) Assisted landowners with preserving their trees with pruning and management advise.
5) Propagating trees for the orchard owners and the public from these heritage trees; the first trees propagated from the Chief Plenty Coups State Park orchard will be available to the public in the spring of 2018.

**Long Term Outcomes:**

The underlining long-term goal of this research in conjunction with other research is to develop the resources through research so we can educate, through our Extension work, the public on growing fruit in the effort to rebuild our local fruit production across the state. This program has contributed to long-term goal. As a side note, some of the heritage orchards are assisting in getting apples in Montana schools. This year through the program we helped organizing getting Montana apples from heritage orchards for Crunch Time, a local food event at area schools. These apples prior to our work were feeding deer and bears instead of kids.

**Major successful outcomes in quantifiable terms:**

1) Over 60 heritage orchards in the program

2) Of the 462 samples that were DNA tested, 200 of them were identified to variety (120 Wealthy, 36 McIntosh, 17 Duchess, and 27 others including Wolf River, N.W. Greening, Yellow Transparent, etc.)

**Beneficiaries**

**Description:**

Landowners especially small acreage owners, orchard owners and future orchard owners all have benefited from our research and extension efforts.

**Number of Beneficiaries:**

Through our research and teaching efforts with this program, we have made contacts with over 800 people not including those who have read stories about the program in various news outlets or that have visited the website.

**Lessons Learned**

**Insights:**

We learned that there are much more 100 plus year old orchard across the state than we originally thought. Originally, we thought there were probably around 30 or 40. We put a ton of time and effort into this program. The travel between the orchards collecting tissue samples, pruning, etc. was more than we had anticipated. This program could easily be a full-time job.

**Unexpected Outcomes:**

Unfortunately, there were many groups or cultivars that we have not yet identified. Many of these have attributes worthy of preserving and propagating. Some have much promise in use in the growing cider industry in Montana.
Outcomes Not Achieved:

We decided not to set up a smart phone application. We believed the website was sufficient until more locations want to participate in agritourism.

Contact
Brent Sarchet
Agricultural Extension Agent
bsarchet@montana.edu
406-447-8346

Additional Information
www.mtoryards.org

The Montana State University Magazine will feature the program in its upcoming issue.

Meeting Montana's Food Safety Education Needs

Project Summary

Background:
The initial purpose of the project was to proactively provide food safety trainings to small producers throughout the state. Food Safety Modernization Act (FSMA) was going to be implemented, and no agency or organization was constantly offering these trainings throughout the state.

Timeliness:
FSMA was scheduled to be enacted in mid-2015 which would radically change the food safety environment. There were random food safety trainings being offered by the Food and Agriculture Development Centers (FADC) and other organizations in the state, but nothing consistent. This project allowed for producers to plan ahead and take training as they needed them, at locations throughout the state, that they would otherwise have to travel out of state for.

Previous Funding:
This project was not previously funded.

Project Approach

Activities:
Increase understanding of rules of FSMA for Specialty Crop producers:
Accomplished - Post class surveys reported 100% had gained more knowledge about FSMA and food safety than prior to the training.

Certified in HACCP: 
Every attendee of our HACCP trainings reported that they had implemented HACCP plans

Increase Capacity of FADC in delivering TA for Food safety: 
All FADC directors attended at least one training and reported gaining knowledge.

Better Process Control (BPC) School: 
All attendees who completed the better process control school were certified after attendance.

On farm food safety plan: 
Over 75% of attendees reported having an on farm food safety plan after attending trainings.

The Food Safety Management System Planning Toolkit training was completed in year one of the project.

All trainings included in the workplan were held with an additional training offered in the spring of 2017.

In total, 61 individuals received training in 2015, 79 in 2016 and 38 in 2017

Benefits to other Commodities: 
Any organizations working with non-specialty crops were required to pay to attend trainings.

Significant Contributors: 
All of the food and ag network partners were great in sharing trainings and helping to provide outreach. Headwaters coordinated all marketing efforts, scheduled trainings, venues and did all the work to put the events together, but it was nice to have partners provide additional outreach.

Goals and Outcomes Achieved

Activities Completed:

15 trainings conducted across the state in the following communities: Bozeman, Ronan, Missoula, Livingston, Billings, Great Falls, Havre

Long Term Outcomes:

Outcomes were aimed at individual specialty crop producers implementing better food safety practices on their farms as long term outcomes are difficult to quantify.

Major successful outcomes in quantifiable terms:
While over 100 businesses were assisted over the timeframe of the grant in a variety of food safety trainings including GAP, Wholesale Success, On Farm Food Safety and BPCS the individual need for the trainings were the biggest success. 100% of attendees reported increasing their knowledge of food safety and implemented plans at their businesses.

**Beneficiaries**

**Description:**

All food and ag producers and processors that attended trainings were the biggest beneficiaries.

**Number of Beneficiaries:**

147 training attendees over the life of the project. Numerous peripheral businesses that benefitted from the increase in food knowledge across the state.

**Lessons Learned**

**Insights:**

We learned that there are certain areas that food businesses are very much in need of these trainings. Any training offered in Bozeman, Ronan or Missoula was very well attended.

**Unexpected Outcomes:**

The biggest challenge that the project faced was offering trainings in Great Falls. We repeatedly reached out to local organizations with no response. We spent more dollars on advertising in the community than anywhere else and still had no response. We assumed that the clients that these trainings and the FADC serve weren't there, or just weren't supportive of food services that every other region of the state needed. This response was definitely not something we expected given the success of trainings in all other regions of the state.

**Outcomes Not Achieved:**

None of the courses offered were recorded because none of the trainers were agreed to do so.

**Contact**

Joe Willauer  
Headwaters RC&D  
Executive Director  
406-723-4349  
jwillauer@bldc.net

**Additional Information**

None to report
Montana Sustainable Strawberry Initiative

Project Summary

Background:

The project purpose was to provide regionally specific resources for commercial strawberry production through research and outreach with an emphasis on annual production in unheated greenhouses (i.e. high tunnels). Strawberries are a profitable specialty crop that Montana producers could integrate into their existing production to diversify and fulfill niche market gaps to further enhance economic sustainability. Though demand for strawberries is high, regional production is at a nearly all time low.

Timeliness:

Strawberries are a niche, yet viable crop that Montana fruit and vegetable producers could integrate into their existing production to diversify, gain access greater markets, and further enhance economic sustainability. Strawberries have been identified as a specialty crop of high demand but relatively low production in Montana. The Western Montana Growers Coop has determined a strong potential market from its customers while a diminishing contribution from its members exists. This poses a potential niche crop for Montanans to produce thus diversifying their own production. Net returns on strawberry production have a wide range from nearly $2,000 per acre for organic matted row production, $10,000 per acre for annual plasticulture production, and nearly $40,000 per acre for annual high tunnel production. Most commercial production systems have shifted to annual strawberry production which is well suited for pest management in the organic production systems that are typical for small scale producers in the state.

Furthermore, strawberry production could be successfully integrated into high tunnels with the potential to provide earlier strawberries when demand is high and supply is limited. Many of Montana's specialty crop producers already rely on these structures as a season extension tool. The Montana NRCS Seasonal High Tunnel program has 92 high tunnels under contract across Montana, 30 of which are in Western Montana. The adoption of seasonal high tunnels by Montana producers has opened the door for new specialty crops and methods of production. Seasonal high tunnels allow for greater flexibility in crop selection and provide the opportunity for multiple harvests of different crops per season. The relatively recent integration of high tunnels as a production tool by Montana specialty crop producers further emphasizes the need for regionally specific resources and research-based guidelines.

However, producers lack information on which varieties and production systems to utilize in Montana. ATTRA's organic strawberry production guide provides a list of recommended strawberry varieties for commercial production in most states, but does not include Montana. Strawberry production research has been conducted by Utah State University but their winters are relatively mild (USDA cold hardiness zone 7a) relative to most of Montana which range from zones 5 to 4.

Previous Funding:
This project was not previously SCBG funded.

**Project Approach**

**Activities:**

Research objectives and protocols were established in the winter of 2014/2015 and field trials were conducted from the spring of 2015 until spring of 2017. There were difficulties in procuring cold-hardy, June-bearing cultivars as live plugs for late summer planting. We were able to purchase dormant crowns for three suitable varieties (Cavendish, Jewel, and Honeoye) in the spring of 2015 and produced live plugs at the MSU-Western Ag. Research Center (WARC) for subsequent plantings. We found that utilizing runners from the annual high tunnel system for plug production was the most efficient system and produced high quality starts.

Research trials were established in five locations: WARC, Corvallis, MT; Homestead Organic Farm, Hamilton, MT; PEAS Farm, Missoula, MT; Hill Top Haven Farm, Missoula, MT; and at the National Center for Appropriate Technology's Small Scale Intensive Farm Training (SIFT) site in Butte, MT. At each site, the three strawberry varieties were planted into three production systems (outdoor perennial matted row, outdoor annual, and annual-high tunnel).

Crop management and data collection at multiple sites with often limited resources and staffing was a challenge. No useable data was collected from Homestead Organic Farm. The annual-high tunnel strawberries failed in 2016 at both the SIFT and Peas Farms. Data was collected from all other sites and systems in 2016 and 2017. Data analysis is ongoing and results presented here include all sites in 2016 and WARC in 2017.

Overall, all cultivars were well adapted to climates at most sites, but there was not one cultivar that consistently performed better across sites and systems. Outdoor annual production was not consistently successful, failing in most locations and years. While annual-high tunnel yields were generally lower than the outdoor perennial matted row, the harvests were nearly a month earlier, offering a unique opportunity to market fruit when local strawberries are typically not available.

Results were shared with producers and approaches were modified based on producer feedback throughout the project. Project objectives and results were shared with 620 growers at 10 field days, workshops and tours held across western Montana.

**Benefits to other Commodities:**

The project benefits were limited to specialty crops, specifically fruit and vegetable growers.

**Significant Contributors:**

Seth Swanson coordinated the project and lead outreach efforts. MSU-WARC, directed by Dr. Zach Miller, produced strawberry starts, hosted field days, analyzed results, conducted outreach, and maintained research trial. Travis Greenwalt (owner of Hilltop Haven Farm), Laura Garber (owner of Homestead Organic Farm) and Ethan Smith (farm manager of Garden City Harvest, PEAS Farm)
maintained and monitored research trials. National Center for Appropriate Technology’s Small Scale Intensive Farm Training (SIFT) site in Butte, MT, maintained and monitored research trials and assisted in outreach activities.

**Goals and Outcomes Achieved**

**Activities Completed:**

The project made significant progress toward determining the efficacy of annual strawberry production through the field trials. All of the three strawberry varieties were well adapted for use in annual and perennial growing systems in most Montana climates. Yields at the trial in high elevation site (SIFT farm in Butte) were extremely low (<10 lbs. per 100 sq. ft.) and outdoor annual plantings failed at most sites in most years. Where these plantings did succeed, they were planted earlier (Late July/Early August) and covered with straw over winter.

The outdoor annual system did not consistently perform well. In the five sites over two years, a crop was failed due to winter kill and frosts in eight of the ten site-years. When the outdoor annual system did succeed at WARC in 2017, it produced yields of 30.6 lbs. per 100 sq. ft., more than double the yields of the high tunnel annual system (mean=14.2 lbs) but berries matured later and at the same time as the matted row that had greater yields (mean= 41.8 lbs. per 100 sq. ft.).

The annual-high tunnel system consistently provided earlier harvests. At WARC, strawberries were harvested from the annual-high tunnel system beginning in early May, more than a month before the outdoor strawberries and ended in early June, around the time harvest began in the matted row. Early strawberries should command a higher price due to limited supply and may provide a marketing advantage at farmer’s market which, in the area, typically began in May. Most farmers have similar products at these early markets (e.g. spring greens, Kale) and having strawberries at the market stand as well may help sell greater volumes of the other products.

Planting multiple varieties (e.g. all three varieties in the trials) would provide more consistent early yields. In 2016 at WARC, Cavendish produced over 78% of total yield in the first three weeks of May. Honeoye harvest peaked at the same time but yielded about 30% less than Cavendish. In contrast, the Jewel variety produced peak yields in the latter half of May and in early June when yields in the other two varieties were declining. During this four week period, yields of Jewel were 4.1 times greater than Cavendish. In 2017, we observed a similar pattern in the timing of fruit production but early yields in Honeoye were greater than Cavendish.

Overall, none of the cultivars were consistently higher yielding than the others. Rather we saw that differences in yields among cultivars varied among sites, systems, and years. For example, in 2016 at Hill Top Haven farm in the indoor annual system, Honeoye yields (mean=9.4 lbs. per 100 sq. ft.) were about two times greater than Jewel and Cavendish. In the same year and system at WARC, we observed the opposite pattern. Yields of Jewel and Cavendish (mean=34.1 lbs. per 100 sq. ft.) were 79% greater than Honeoye (mean=19.0 lbs. per 100 sq. ft.). Yet, in the next year in the same system at WARC, Honeoye yields were similar to the previous year (mean =20.5 lbs. per 100 sq. ft.), but nearly double the yields in Jewel and Cavendish.
The annual-high tunnel system did not produce yields that were greater than the outdoor perennial matted row. At WARC, yields in 2016 in the matted row were similar yields in the high tunnel annual system (mean=29 lbs. per 100 sq. ft.). In 2017, matted row yields averaged 41.8 lbs. per 100 sq. ft., nearly three time greater than the indoor annual system. At Hill Top Haven Farm in 2016, yields in the matted row were also nearly three times higher than the yields in the indoor annual system. The indoor annual system did have a smaller proportion of unmarketable fruit (mean=12.4%) than the matted row (mean=24.8%).

Quality of strawberries in the trials was typically high. Sugar content (measured as % soluble solids or °Brix) was three to four times higher than strawberries sold at local grocery stores at the same time. Based on the WARC trials, Jewel had larger berries than the other two varieties and was preferred in informal taste tests.

Annual systems did not achieve yields equivalent to perennial matted row. It may be possible to increase yields of the annual-high tunnel system by 1) planting earlier and 2) increasing planting densities. Further research is needed to improve yields in the annual-high tunnel system.

Through grower engagement we have re-evaluated the production benefits of integrating the annual strawberry system into high tunnels. Several growers were concerned that the annual-high tunnel system offered less production and potential profits relative to a fall and spring harvest of alternative crops (e.g. fall tomatoes and early spring greens). The appropriate economic comparison is between alternative crops that could be grown in the high tunnel and not between annual-high tunnel and outdoor perennial system. To address this concern, new trials were established at WARC to evaluate if annual strawberries could be established in the fall below a late season crop (Tomatoes) and provide similar yields to annual beds of strawberries alone.

The project has increased producer knowledge and has changed some practices. Project objectives and results were shared with 620 growers at 10 field days, workshops and tours held across western Montana. Surveys delivered at workshops indicated that most producers were more willing to grow strawberries and interested in annual production due to the workshops. We know of five producers that have started or have expanding their strawberry production and expect that the number of strawberry producers in the state has increased beyond this number.

**Long Term Outcomes:** None

**Major successful outcomes in quantifiable terms:**

The major successes were providing a robust, research-based evaluation of annual strawberry production for Montana climates and delivering that information to a diverse group of specialty crop producers in western Montana. Project objectives and results were shared with 620 growers at 10 field days, workshops and tours. Research results will be published in an extension guide and on WARC’s website once final analysis is completed.
**Beneficiaries**

**Description:**

The project will improve the profitability and reduce potential risk by introducing current information on annual strawberry production to the 126 small fruit and 325 vegetable producers in Montana. In addition, the project will benefit the current (92 contracted with NRCS) and all future operations that utilized high tunnels/hoop houses.

**Number of Beneficiaries:**

There are approximately 450 fruit and vegetable growers in Montana that could benefit from the project’s accomplishments.

**Lessons Learned**

**Insights:**

Successfully conducting research trials at multiple sites is logistically challenging. Providing clear and consistent management guidelines would improve the success of these trials, as would providing more resources for supplies and labor for management, harvest, and data collection.

**Unexpected Outcomes:**

We did not expect that the relative performance of the strawberry varieties would change as much site to site and year to year. This is likely due to differences in environmental conditions and management practices among sites and years. This result does provide a solid foundation on which to build future research and outreach projects.

**Outcomes Not Achieved:**

All goals and outcome measures have been achieved.

**Contact**

Zach Miller  
Supt/Assistant Prof of Hort-PhD  
Western Ag Research Center  
zachariah.miller@montana.edu  
406-961-3025

**Additional Information**

None to report.
Montana’s Bee Viruses: Identification and Transmission

Project Summary

Background:

Honey bees are important pollinators of agricultural crops that comprise much of the U.S. diet (i.e., cherries, almonds, apples, blueberries, alfalfa-, oil-, and legume seed), valued at $15 billion annually, and plant species that augment landscape biodiversity. Since 2006, the U.S. honey bee pollination force has experienced increased annual losses. The decline of honey bee pollinators is a pressing problem in agriculture that directly impacts Montana. Over the last decade, Montana commercial beekeepers have ranked 2nd-7th in the nation for honey production ($31 million in 2013) and pollination services ($22.5 million). The cause(s) of increased colony mortality are not fully understood, but it is clear that pathogens (viruses, mites, bacteria, and fungi) play a role. The majority of honey bee pathogens are viruses, including a recently discovered Lake Sinai virus (LSV) group. Preliminary data indicate that LSV infections correlate with colony health, but little is known about the pathogenicity and transmission of these viruses. The goal of this work is to determine which virus strains are present and prevalent in Montana, and to investigate the mechanism(s) of virus transmission using molecular biology techniques. This data will increase our understanding of virus transmission routes, and may lead to the development and implementation of strategies that mitigate virus infection. This project will enhance the collaborative efforts between MSU scientists, commercial beekeepers, and the Montana Department of Agriculture.

Project Purpose

The goal of this project is to identify the strains of a highly abundant virus family (the Lake Sinai viruses 1-5) circulating in Montana, and investigate the route(s) of virus transmission within and between honey bee colonies.

Understanding the route(s) of virus transmission is critical to developing and/or employing strategies to minimize virus transmission (e.g., reducing mite loads, testing queen-rearing colonies). It is also important to document which strains of this virus are currently circulating in Montana, since three of the five known strains of LSV have been associated with increased colony losses in the U.S. and Belgium.

U.S. annual honey bee losses have remained high since a dramatic increase from 18% to 32% in the winter of 2006/07 with some operations experiencing 90% colony loss. In fact, during the 2012/2013 almond pollination season, one Montana-based beekeeper lost 80% of his colonies (NY Times). Honey bees are a specialty crop with a dual role in agriculture where they serve as producers of honey and essential pollinators of numerous crops. Montana’s beekeeping industry ranked 2nd for honey production in 2013 (National Honey Board Report, NASS-USDA). The majority of Montana’s commercial beekeepers transport their colonies to California each fall to pollinate the almond groves. The almond pollination season is when the majority of colony losses occur. Colony mortality is associated with higher pathogen levels, but the specific pathogens and additional factors
responsible for these losses remain unknown. Dr. Flenniken discovered the Lake Sinai virus family during her postdoctoral research at the University of California in 2011. These viruses were the most abundant viruses detected in a 2009-2010 honey bee sample cohort obtained from South Dakota and California. In subsequent studies, LSV abundance was associated with colony mortality (Cornman, 2012; Ravoet, 2013; Flenniken, unpublished), but very little is known regarding the pathogenicity and transmission of these viruses. Therefore, it is important to better understand the current distribution of LSV strains in Montana and investigate the transmission mechanisms employed by this virus group.

The objectives of this project are:

1. Identify the strains of a recently identified virus group (Lake Sinai viruses 1-5) that are circulating in Montana-based honey bee colonies.

2. Determine the route(s) of transmission of Lake Sinai viruses (i.e., mite transmission, maternal transmission, bee-to-bee transmission).

3. Expand the number of Montana-based commercial beekeeping operations collaborating with Montana State University.

Timeliness:

The role of viruses on honey bee colony health and the distribution of viruses associated with honey bee colonies in Montana are unknown.

Viruses are one of the factors that contribute to honey bee colony deaths, and thus understanding the distribution of honey bee viruses in Montana is important to the long-term goal of reducing colony losses. This project is timely, since beekeepers have experienced increased colony losses since 2006.

Previous Funding:

For this project we interacted with and obtained samples from Montana-based beekeepers and expanded the number of beekeepers with whom we have collaborated. This SCBG project titled, "Montana's Bee Viruses: Identification and Transmission" was independent of our previous SCBG. This project focused on one recently discovered, and very abundant group of viruses, the Lake Sinai viruses 1-5 (LSV1-5).

Project Approach

Activities:

We completed the majority of our goals/targets, objectives, outputs, and outcomes for this grant. We obtained over 240 samples from ten collaborating Montana beekeeping operations during the summer and fall of 2015. We have completed all PCR diagnostic tests for the beekeeping operations from which we obtained three quality sample sets (i.e., including bees from 10 colonies with
corresponding colony health (population) estimates). We performed over 4,500 PCR tests for pathogens associated with honey bee samples we obtained in 2015 field monitoring. We augmented the results of our study by testing for additional pathogens, including viruses (ABPV, BQCV, CBPV, DWV, IAPV, KBV, SBV), microsporidia (N. ceranae), and trypanosomatids (C.m./L.p.). Since LSV infection may have correlated with other infections, it was important to expand our testing beyond a single virus family in order to better understand the landscape of bee viruses associated with commercially managed operations in Montana.

We also augmented our sample set by testing for the Lake Sinai viruses in Varroa destructor mites parasitizing honey bee colonies in the Gallatin Valley, since mites were not obtained from collaborating beekeepers throughout the state (due to low mite counts in some bee colonies, and lack of time or resources in other operations). These mites did not test positive for the four most common honey bee associated Lake Sinai viruses in Montana (i.e., LSV1-4), but potentially had Lake Sinai virus 5 (another strain of the virus). Since mites transmit honey bee viruses, it will be interesting to further understand the potential implications of different LSV strains in mites and honey bee colonies. Our results indicated that bee-to-bee transmission of LSVs is a major route of transmission, and that this group of viruses may be less correlated with mite infestation (as compared to Deformed wing virus, which has a strong association with mite infestation), though more studies are needed since it is difficult to draw major conclusions from one year of sampling. LSVs have been detected in mites, thus mites likely transmit these viruses, but the data on LSV replication in mites is inconclusive and requires further investigation (i.e., in some cases PCR data indicates replication, but in the majority of samples the replicative intermediate form of the virus is not readily detected in mites).

We determined that the most prevalent viruses circulating in honey bee colonies managed by Montana-based beekeeping operations in 2014-2015 were Black queen cell virus (BQCV), Deformed wing virus (DWV), and the Lake Sinai viruses (the focus of this study). Specifically LSV3 was the most prevalent followed by LSV2, LSV1, and LSV4, but the percentages varied by sampling date and with specific beekeeping operations, indicating the importance of obtaining samples on exact dates, particularly if/when correlating pathogen load with colony health.

Benefits to other Commodities:
Not Applicable

Significant Contributors:

Montana Beekeepers provided bee samples
Michelle Flenniken, Project Director - coordinated and analyzed data
Katie Daughenbaugh - coordinated study, helped contact beekeepers throughout study, performed PCR analysis, and directed undergraduate and graduate student research assistants, assembled data
Undergraduate and Graduate Student Research Assistants - obtained samples from participating beekeeping operations, performed molecular pathogen diagnostic tests (i.e., pathogen specific PCR)
Goals and Outcomes Achieved
Activities Completed:

Project Activities included (1) establishment of collaborative projects with Montana-based commercial beekeeping operations to obtain honey bee samples, (2) perform pathogen-specific PCR-based pathogen diagnostics and virus sequencing analysis, (3) obtain mites and bees during different developmental states for LSV analysis in order to investigate routes of transmission, and (4) development of a Honey Bee Pollinator Center at MSU, although funds from this grant were not used for this site.

We completed the majority of each of the Project Activities (listed above), specifically:

(1) Our goal was to obtain 3 samples from the same colonies in ten different Montana beekeeping operations—we successfully engaged 10 beekeeping operations and for seven of them we obtained complete samples sets; for the other three we obtained two sample sets. Overall, we obtained over 240 samples from ten collaborating Montana beekeeping operations during the summer and fall of 2015.

(2) We performed over 4,500 PCR tests for pathogens associated with honey bee samples we obtained in 2015 field monitoring and are done with PCR analysis. We sent out over 20 data reports to collaborating beekeeping operations.

(3) We examined virus (LSV) prevalence in a limited number of mite samples and did not obtain samples of bees in various life stages (i.e., egg, larvae, pupae, young adult < 3 weeks old, older adult). We identified additional strains of LSV in Montana – there are over seven different genome variants of LSV.

(4) We advanced the development of MSU’s Honey Bee Research Site and Pollinator Garden and held several events at the site during the summer of 2016. During the life of this grant Dr. Flenniken gave several public lectures on the importance of bee health to Montana agriculture (e.g., Café Scientifique March 2017, MSU Science Roadshow 10x10 Talks March 2017, Museum of the Rockies Nov. 2016, Bozeman Garden Club 2017) and acknowledged MDA-SCBG funding at each of these events. Laura Brutscher, a PhD student in the lab, gave a presentation at the American Bee Research Conference (Jan. 2017). Three graduate students in the Flenniken Lab (Laura Brutscher, Will Glenny, and Alex McMenamin) gave short presentations at the Pollinator Symposium in Bozeman on April 19, 2017. Dr. Flenniken shares the results of MDA funded research each year at the Montana State Beekeepers Association meeting.

(5) We analyzed virus prevalence in Varroa destructor mites (11 samples) and detected the following honey bee viruses: Deformed wing virus (DWV, 73% positive); Black queen cell virus (BQCV, 27% positive); and Lake Sinai virus (27% positive). Together this and other data indicate that LSVs may be transmitted by mite, but other routes of infection are also important.
Long Term Outcomes:

The goals of this project were completed and the data obtained will contribute to the long-term goal of better understanding the role of viruses on honey bee colony losses. We obtained good baseline data regarding the viruses currently circulating in Montana-based honey bee colonies.

This type of data is good for understanding potential future colony losses, as it provides a baseline for comparison.

Major successful outcomes in quantifiable terms:

We successfully engaged 10 beekeeping operations and for seven of them we obtained complete samples sets; for the other three we obtained two sample sets. Overall, we obtained over 240 samples from ten collaborating Montana beekeeping operations during the summer and fall of 2015.

We performed over 4,500 PCR tests for pathogens. We sent out over 20 data reports to collaborating beekeeping operations.

We analyzed virus prevalence in Varroa destructor mites (11 samples) and detected the following honey bee viruses: Deformed wing virus (DWV, 73% positive); Black queen cell virus (BQCV, 27% positive); and Lake Sinai virus (27% positive). Together this and other data indicate that LSVs may be transmitted by mite, but other routes of infection are also important.

Beneficiaries

Description:

Montana beekeepers were impacted by this project in the following ways (1) obtained data on the pathogen status of bees throughout the summer, (2) obtained information on the relationship between colony strength and pathogen load, and (3) established a collaborative relationship with scientists at MSU; these relationships are particularly important during acute incidences including large-scale colony losses.

Number of Beneficiaries:

We worked directly with 10 beekeeping operations, and shared our results with ~ 50 Montana Beekeepers each year at the Montana State Beekeepers Association meeting. There are ~ 60 commercial beekeepers that manage ~ 150,000 honey bee colonies in Montana (Ian Foley, MTDA).

In 2013 the rental fee was ~$175 per colony, thus Montana beekeepers collected ~$26.3 million for pollination services (Project Apis m.). Understanding the factors that contribute to the over 30% annual colony losses could lead to strategies that mitigate these losses and in the long-term will economically impact beekeepers, but an economic impact as a direct result of this study would be difficult to measure. We need to better understand the factors most responsible for honey bee colony losses before the economic impact of our research and recommendations can be measured.
Lessons Learned

Insights:

(1) Sample collecting needs to be improved.

The majority of samples were obtained, but we still had trouble meeting with some collaborating beekeepers and obtaining all three sets of samples during the summer collection period.

(2) Larger number of samples needed. Due to the variable distribution of pathogens in honey bee colonies and between beekeeping operations, our results were not as statistically robust as we anticipated. We can address this in future studies, by increasing our sample size or potentially by obtaining a higher number of samples from a single beekeeping operation and/or at specific dates.

We did not sufficiently budget for measuring mite mediated transmission and viruses in multiple bee life stages.

We realized that we had to test for numerous pathogens (i.e., DWV, BQCV, SBV, ABPV, CBPV, IAPV, KBV, and a trypanosomatid Lotmaria passim (formerly known as Crithidia mellificae)) - as opposed to only focusing on a single virus family, since we need to understand the context of LSV infections before being able to attribute reduced colony health to LSVs. This significantly expanded the work required prior to focusing on LSVs.

Unexpected Outcomes:

During the first year of this project we obtained less Varroa destructor mite samples than we anticipated.

Outcomes Not Achieved:

We obtained additional mite samples in the summer of 2017 and tested them for viruses, but we did not test as many mite samples as we planned.

Contact

Michelle Flenniken
Assistant Professor- Ph.D.
Montana State University
215 Plant BioScience Building
406-994-7229
michelle.flenniken@montana.edu

Additional Information

None
Northern Plains Vegetable Variety Testing

Project Summary

Background:

Montana vegetable producers need updated information about vegetable varieties adapted to our unique climate. Producers would also benefit from a consumer base better informed with regards to seasons of production and unique qualities of locally grown vegetables. Montana State University (MSU) will join an ongoing collaboration between the Northern Plains Sustainable Agriculture Society (NPSAS) and North Dakota State University (NDSU) Department of Plant Sciences to increase access to superior varieties of selected market classes of carrot, green bean, broccoli, lettuce, and cucumber suited for sale in local premium markets. First, we will engage Montana vegetable producers to identify current standard cultivars of these specialty crops and identify traits for which producers desire improved performance (e.g., heat tolerance, cold soil germination, taste, appearance, earliness). We will then perform replicated variety trials at the MSU horticulture farm in Bozeman, MT and the MSU Western Ag Research Center in Corvallis, MT, as well as daughter sites at vegetable farms throughout Montana. Data from these variety trials will be reported through the Northern Organic Variety Improvement Collaborative (NOVIC) and eOrganic through NDSU’s existing collaboration with these entities, through a field day hosted at MSU’s Towne’s Harvest Garden, and through social media. We will assess the value of the program to stakeholders through use of surveys before and after participation in these events and by soliciting feedback via social media.

The objectives of this project were:

1. Objective 1: Improve understanding and collaboration among farmers, scientists, MSU SFBS students (future farmers or food buyers), and community members regarding the differences among vegetable market classes and varieties and interactions of varieties with weather conditions of different locations and years.

2. Objective 2: Identify market classes and specific traits of local interest for popular vegetables including carrot, green bean, broccoli, cucumber, and lettuce.

3. Objective 3: Evaluate new vegetable varieties alongside those currently being produced by farmers, communicate the results of these evaluations to participatory breeding programs, farmers, and interested consumers throughout Montana and the northern Plains.

Timeliness:

This project is important and timely because growth in demand for locally produced vegetables in Montana is inspiring young farmers to start new small vegetable farms. Increased demand for a reliable supply of vegetables throughout the year and for new cultivars with specialty traits means that existing knowledge about well-adapted varieties needs to be augmented with information that can be gained from new variety trials. Many students aspire to start small-scale vegetable farms in Montana to meet local demand. Others seek to understand the challenges and benefits of local vegetable production for future roles as leaders in building community food systems.
Previous Funding:

This project was the beginning of collaboration between Montana State University (Dr. Mac Burgess) and an existing and ongoing project with Frank Kutka at Northern Plains Sustainable Agriculture Society (NPSAS) and Dr. Chiwon Lee at North Dakota State University.

Project Approach

Activities:

During 2015 replicated variety trials of Carrots, Yellow Storage Onions, Bush Type Green Beans, Romaine Lettuce, and Cucumbers were performed at the MSU Bozeman Horticulture Farm, the MSU Western Ag Research Center in Corvallis MT, and on 6 farms in western Montana.

Dr. Burgess also met personally with the 6 farmer collaborators along with many other small-scale vegetable growers and interviewed them regarding current standard cultivars of these and other vegetable species, what they like and dislike about them, and what specific traits should be investigated in the variety evaluation.

The following is a summary of desired qualities mentioned by farmers:

Carrots: uniformity of size and shape, top strength for mechanical harvest, color, taste.

Lettuce: cold and heat resistance, bolting resistance, lack of bitter taste in hot weather

Green Beans: most farmers did not want to trial green beans as harvest labor is prohibitive.

Yellow Storage Onions: size and size uniformity is important to some but not all farmers, storage ability is important. A typical issue is a high proportion of onions that do not fall over and dry down before fall frost or snow ends the growing season and inability to get onions cured for storage. This requires a new evaluation of the interaction of temperature and photoperiod on onion bulbing and maturation

Cucumbers: Earliness and consistency/duration of continued yield under trellised indoor production systems.

Montana 2015 results were shared at NPSAS meeting in Jan. Aberdeen South Dakota.

Green Romaine Lettuce: At Bozeman Salvius and Coastal Star, both Utility-patented varieties, produced the largest heads and coastal star stood out for having the best resistance to bolting. Parris Island was a notable non-patented cultivar, in 3rd place for head size. The only cultivar with serious quality problems was a forellenschluss, a speckled Romaine lettuce which experienced severe tip burn at Bozeman. This was an isolated occurrence, as this cultivar is still grown for production at the student farm at the same location without quality problems.

Onions: the Highest yielding storage onion, (Sedona F1), was also the most variable in size and the poorest storage quality, with most of the bulbs not drying down in Bozeman. Patterson, Talon, and
Copra (all F1 Hybrids) were tied for 2nd place in size and all stored well. Of the OP onions, NY early was the largest but most variable with poor storage.

Green Bean yield evaluations were inconclusive due to Provider and Jade.

In 2016 Scaled back variety evaluations trials at MSU Bozeman Horticulture farm were completed during 2016 for cucumber, and onion. Original NDSU/NPSAS multistate collaborators continued with their plan of evaluation of 6 species at multiple locations in North Dakota with renewed 2016 funding. Additional funding for this project in Montana was not received so operations were scaled back based on the lessons learned promising outcomes from the first year.

Montana 2015 cucumber yield results were shared with public attendees at July 2016 MSU Hort Farm Field Day along with personal observation of early 2016 cucumber trials for interested parties (7 people participated in personal tours of cucumber trials). Cucumber tastings were held and MSU Bozeman and Corvallis field days. There were no consistent and significant preferences among consumers for different tastes of cucumbers, but consumers did express interest in different size and shape classes of cucumbers for different uses.

In 2017 we continued variety yield trials at MSU Bozeman Horticulture farm as part of the Towne's Harvest Garden Student Farm were completed during 2017 for cucumber, and onion.

Montana 2016 cucumber and onion results and in-person inspection of 2017 trials were presented at the 2017 MSU Hort Field Day in Sept. 2017.

In 2017 the Towne's Harvest Garden student-operated CSA and Market Garden directed by PI Dr. Burgess, and the associated MSU summer course SFBS 296 embraced a new focus on vegetable variety appreciation for students and consumers. For the 2017 CSA season all vegetables supplied to the CSA customers were identified by cultivar name and a major focus of class activity was appreciation of differences among market classes.

Benefits to other Commodities:

The project did not in any way involve any non-specialty crops.

Significant Contributors:

The project partners (6 Montana farmers) performed on-farm variety evaluations of from 1-6 species and participated in survey regarding desirable properties of these crop species from the producer perspective.

Goals and Outcomes Achieved Activities Completed:

Objective 1: Dr. Burgess also met personally with the 6 farmer collaborators along with many other small-scale vegetable growers and interviewed them regarding current standard cultivars of these
and other vegetable species, what they like and dislike about them, and what specific traits should be investigated in the variety evaluation.

**Objective 2:** The following is a summary of desired qualities mentioned by farmers:

Carrots: uniformity of size and shape, top strength for mechanical harvest, color, taste.

Lettuce: cold and heat resistance, bolting resistance, lack of bitter taste in hot weather

Green Beans: most farmers did not want to trial green beans as harvest labor is prohibitive.

Yellow Storage Onions: size and size uniformity is important to some but not all farmers, storage ability is important. A typical issue is a high proportion of onions that do not fall over and dry down before fall frost or snow ends the growing season and inability to get onions cured for storage. This requires a new evaluation of the interaction of temperature and photoperiod on onion bulbing and maturation

Cucumbers: Earliness and consistency/duration of continued yield under trellised indoor production systems.

**Objective 3:** Replicated variety trials of Carrots, Yellow Storage Onions, Bush Type Green Beans, Romaine Lettuce, and Cucumbers were performed at the MSU Bozeman Horticulture Farm, the MSU Western Ag Research Center in Corvallis MT, and on 6 farms in western Montana.

**Long Term Outcomes:**

Not applicable

**Major successful outcomes in quantifiable terms:**

Green Romaine Lettuce: At Bozeman Salvius and Coastal Star, both Utility-patented varieties, produced the largest heads and coastal star stood out for having the best resistance to bolting. Parris Island was a notable non-patented cultivar, in 3rd place for head size. The only cultivar with serious quality problems was a forellenschluss, a speckled Romaine lettuce which experienced severe tip burn at Bozeman. This was an isolated occurrence, as this cultivar is still grown for production at the student farm at the same location without quality problems.

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**Beneficiaries**

**Description:**

Over the course of the 2015-2017 growing seasons this project worked directly with Farmers, MSU Students, Towne's Harvest CSA Shareholders, and attendees at MSU research and extension field days.

**Number of Beneficiaries:**

Through this project we directly impacted:

- 12 Montana vegetable farmers
- 48 MSU THG Practicum Summer students in 2015-2017
- Over 300 members of the public various extension and outreach.

**Lessons Learned**

**Insights:**

Any subjective data collection should be blind (i.e. participants should not know the names of the cultivars).

Despite fairly sophisticated approaches to experimental design and protocol, taste testing did not result in any consistent meaningful overall preferences. An interesting example is the case of lettuce, where we conducted a blind replicated taste preference experiment as a class project for a culinary marketing class at MSU. The major discovery there is that there is FAR more difference in bitterness from the base of a leaf to the tip of the leaf than there is among cultivars of lettuce. We had similar difficulties discerning differences in taste among cucumber cultivars. Many taste panel participants had no favorite, with one person saying "they all taste like cucumbers", and where individuals had strong preferences they were not consistent among panelists.

**Unexpected Outcomes:**

In interviewing producers regarding desired characteristics and interesting divide became apparent. Some producers were interested in the best-performing varieties or hybrids with little regard to seed source. In some cases these producers are interested in confirmation of their observation that a
chosen hybrid not available as organic seed is indeed superior, or wanted to know if any cultivars that are available as organic seed could match the performance (often of a single trait) of a chosen variety not available as organic seed. This request was specifically made of Mokum (F1) carrot.

Another group of producers indicated a desire not to use utility patented, PVP, or Hybrid Seed. They were more interested in identifying the best Open Pollinated or non-patented/PVP variety, generally demonstrating the viability of OP seed,

**Outcomes Not Achieved:**

The original goals were overly ambitious for the amount of funding requested and for the resources available. We should have focused on only 1 or 2 crops and a smaller number of varieties of each.

Collection of good data from On-farm research is difficult without dedicated skilled labor funded and supervised by the researcher. Even with the best of intentions during the planning phase farmers were overwhelmed by the work of collecting data.

**Contact**

Mac Burgess  
Assistant Professor- Ph.D. from Montana State University, 2012  
Office Phone: 406-994-3510  
mburgess@montana.edu

**Additional Information**

None

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**Plant Something: Montana-Grown Awareness Campaign**

**Project Summary**

**Background:**

This project was a broad-based marketing effort for the Montana nursery industry. Project goals included helping retail nurseries educate the public about proper plant choices, planting and placement of nursery stock, and the benefit of having a Certified Plant Professional in each nursery location. Certified Plant Professional (CPP) is a professional credential gained after successfully passing a challenging written exam and a plant identification exam. CPP’s have extensive plant knowledge to share thereby providing an informed purchase to the customer, providing excellent customer service, and increasing sales to the nursery.

The need addressed by the project was to educate Montana homeowners on the value and benefits of purchasing and planting Montana-grown hardy plant material along with the benefit of a Certified Plant Professional in the nursery to guide the homeowner to the best plant material for their location.
All these components worked toward the project goal of increasing the long term sustainability of Montana nursery growers and increasing sales of nursery stock at the local retail level.

**Timeliness:**

Montana nurseries were recovering from an economic downturn beginning in 2010 and this program was a broad based marketing effort to continue to help economic conditions improve. Montana consumers have an increased interest in locally grown nursery plants and this campaign offered additional resources for the consumer to Plant Something. Each participating nursery received Plant Something promotional materials to give to their customers to allow them to further educate and create more awareness about the Plant Something campaign.

**Previous Funding:**

This project was built on a previously funded project by the Arizona Nursery Association. The Arizona project had designed Plant Something promotional materials which Montana was able to alter to include Montana’s contact information. In addition to taking place in a different state, the project differs from the Arizona project by the additional focus on the Certified Plant Professional program added into this project.

**Project Approach**

**Activities:**

MONTANA GREEN EXPO - Plant Something was promoted in the Montana Nursery & Landscape Association (MNLA) Booth at the Montana Green Expo in January 2015, 2016 and 2017.

PROMOTIONAL - Promotional items including blade banners, plant stakes, information brochures and posters of the ads were personalized for Montana and distributed by mail, personal delivery, and made available at the Expo booth for participating retail garden centers to receive.

CERTIFIED PLANT PROFESSIONAL - The Certified Plant Professional Exam is comprised of a written exam of 100 questions and a plant identification exam. To achieve the Certified Plant Professional designation a student must pass both exams with a minimum score of 75.

Over the grant period a total of 53 applicants took the exams with 15 applicants taking the exam at multiple locations for a total of 38 individual applicants taking the exams. 17 applicants passed both exams to become Certified Plant Professionals. The goal was to have 10 participants in each year of the grant. We exceeded the goal with an additional 8 applicants.

CPP STUDY MANUAL - In late 2016 Montana State University-Bozeman (MSU) and MNLA worked together to begin to update the current study manual. Three MSU professors reviewed and updated portions of the manual. The Department of Agriculture also provided some updated information.

WEBSITE - Initially one page was added to the current MNLA website to introduce Plant Something at [www.plantingmontana.com](http://www.plantingmontana.com). In 2016 a website was created for Plant Something Montana - [www.plantsomethingmontana.org](http://www.plantsomethingmontana.org). This website includes how to videos, planting resources, and a
list of all MNLA member retail nursery and landscape businesses in Montana. Unfortunately, the web designer failed to add tracking information to the website so we do not have data on the number of visits to the site. Tracking information has now been added as of October, 2017.

ADVERTISING - Four new ads were created for the Plant Something promotion. Ad sizes included ¼, ½ and full page digital ads plus Facebook ads. These ads not only benefitted Montana but also the national Plant Something program and could be used by all 21 states currently participating in the program. Posters of the ads were also printed to give to the Montana retail nurseries to advertise the program and decorate their showroom space.

VIDEOS - Seven videos were created to add to the Plant Something Montana website. The content was created by the MNLA Education Chairman and the filming was done by Coffee Boy Productions. These videos are all posted on the website at www.plantsomethingmontana.org.

MEMBERSHIP BROCHURE - An updated membership brochure was printed including the Plant Something logo and website information. This addition to the brochure advertises the importance MNLA places on the program and directs potential members to the website.

Benefits to other Commodities:
This project solely benefitted nursery specialty crops.

Significant Contributors:
Montana State University-Bozeman (MSU) - MSU has been and continues to be a strong supporter of the Certified Plant Professional program. Three professors from MSU have also worked to write updates to the current study manual.

Montana Department of Agriculture - The Department supports the promotion to increase nursery stock sales as well as the Certified Plant Professional education program. The Department has been very helpful to answer questions throughout the life of the grant.

Goals and Outcomes Achieved
Activities Completed:
Goal #1 – Provide Montana nurseries with materials for marketing Montana-grown nursery stock to consumers. 15 foot blade banner flags were distributed to the 50 participating retail nurseries in letter was included with each kit delivered to the participating retail nurseries.

Goal #3 – Increase the number of Certified Plant Professionals in Montana. The target was to add 10 new certified Plant Professionals each year of the grant. There were a total of 38 test applicants from 2015 – 2017 and 17 successfully passed both the written and plant identification exams to become Certified Plant Professionals.

Goal #4 – Create a Resource Area with timely tips for Gardeners. A website was created for Plant Something in Montana – www.plantsomethingmontana.org. This site includes Our Mission,
Resources, Search Local, and Guides. In the Guides section are the informational videos created with funds from the grant for timely tips for Gardeners. Videos were created on Tree Planting, Pollinator Gardens, Cooking with Your Garden, Urban Gardening, Raised Bed Gardening and Container Gardening. An information video was also created during the 2017 Montana Green Expo on the Certified Plant Professional Program. The Search Local section offers the opportunity to search Montana retail nurseries and greenhouses and landscape companies by company name or by city. Plant Something information was posted periodically on Facebook. A Pinterest account was not created.

Goal #5 – Increase Consumer Awareness. The goal to Increase Consumer Awareness by printing 6000 copies of a buyer’s guide was not achieved. Instead we added a “Search Local” feature to the www.plantsomethingmontana.org website. A consumer can search by name or city in Montana to find MNLA member retail nurseries and landscape companies. In today’s market it is much more desirable for many to be able to search a site on the internet than to carry a paper copy of a directory with them. Dollars saved on this project were transferred to the video project.

Plant Something informational brochures were also printed to give to the participating retail nurseries to hand out to their customers. The brochure includes the mission of the program and the website address.

**Long Term Outcomes:**

None to report

**Major successful outcomes in quantifiable terms:**

- 50 MNLA member retail nurseries in Montana benefitted from the use of Plant Something promotional materials. The goal of the project was to increase sales by 8%. The cumulative total of gross sales increase from October 2014 – September 30, 2017 was 11%
- 17 individuals successfully passed the Certified Plant Professional exam over the life of the grant.
- 100 revised Certified Plant Professional Manuals Printed
- Montana consumers and the MNLA retail nursery members and landscape members continue to benefit from the creation of the www.plantsomethingmontana.org website.
- 7 promotional gardening videos were made for the new website.
- 4 new advertisements were created for the benefit of MNLA and the 21 other states involved in the Plant Something program. These ads are currently used in the MNLA Leaflet newsletter, Membership Directory, and Expo Brochure.

- Rocky Mountain Gardening magazine supported the program with an ad each quarter highlighting a Certified Plant Professional for a total of 12 ads over the life of the grant.
**Beneficiaries**

**Description:**

* 50 MNLA member retail nurseries in Montana
* MNLA members who wish to become Certified Plant Professionals.
* Montana consumers who visit the [www.plantsomethingmontana.org](http://www.plantsomethingmontana.org) website.

**Number of Beneficiaries:**

* 50 MNLA member retail nurseries in Montana. The potential economic impact of increased sales volume averaged 11% over the life of the grant. The goal was an 8% increase.
* 22 Nursery & Landscape State Associations across the United States enrolled in the Plant Something program with the addition of four new professionally designed advertisements.
* 17 individuals who successfully passed the Certified Plant Professional exam.

**Lessons Learned**

**Insights:**

Success follows if the Work Plan is well thought out and executed. It was important to maintain a budget spreadsheet to see at a glance how the project was progressing and sustain the expense categories.

**Unexpected Outcomes:**

No unexpected outcomes or results were noted.

**Outcomes Not Achieved:**

The goal to Increase Consumer Awareness by printing 6000 copies of a buyer's guide was not achieved. Instead we added a "Search Local" feature to the [www.plantsomethingmontana.org](http://www.plantsomethingmontana.org) website. A consumer can search by name or city in Montana to find MNLA member retail nurseries and landscape companies. In today's market it is much more desirable for many to be able to search a site on the internet than to carry a paper copy of a directory with them. Dollars saved on this project were transferred to the video project.

**Contact**

Jyl Story
Executive Director
Montana Nursery & Landscape Association
P.O. Box 215
Park City, MT 59063-0215
406.755.3079
[ed@plantingmontana.com](mailto:ed@plantingmontana.com)
Developing value-added products to increase profit margins for specialty crop farmers

Final Report Accepted December 2016

Project Summary
Montana farmers face a variety of issues in the marketing environment – e.g., competition, food trends, short growing season, economic uncertainties, legal certifications, etc. – which impact their profit margins. Currently, many Montana specialty crop producers sell their products as low-priced commodities, with associated low profits. Our goal is to find opportunities to convert some of these raw materials into value-added products, resulting in higher profits for the growers, and economic growth for the state of Montana.

We provided farmers with startup ideas for scalable, innovative, value-added products which will enable them to differentiate themselves and compete more effectively in a crowded marketplace. This idea is timely because there is currently high consumer demand for local food products, and for sustainably sourced whole foods. People and institutions are willing to pay a premium for food they know has been grown locally, that is organic, that is part of a sustainable food system, and that supports producers and communities.

Project Approach
The Farm to Market course was offered Fall 2015 as part of Montana State University’s DSEL (the Design Sandbox for Engaged Learning) initiative which supports cross-disciplinary teaching and learning for undergraduates. Farm to Market was developed and taught by three professors, Meta Newhouse (Graphic Design), Graham Austin (Marketing) and Janet Gamble (Nutrition) for students in each of those three disciplines. This course asked students to meet with three different local farm partners and use the Design Thinking process to define specific problems they could solve that would utilize the three disciplines of marketing, graphic design and nutrition.

As professors, we encouraged our students to specifically look at food waste but also the farmers’ unique situations and develop value-added consumer products that could help farmers boost profitability. In teams of three (one representative from each discipline), students worked to develop empathy for both their chosen farm/farmer, and for their potential customers; defined a problem to solve; ideated around that problem; prototyped both recipe and packaging ideas; tested those ideas with focus groups and iterated upon their ideas based on that feedback. At the end of the course students presented their ideas using both an oral presentation and curated videos and had to defend their decisions in a Q&A format. All food producers were in attendance.

Producer presentations and farm tours
During farm tours, all faculty and students were intensively oriented to each of the three farms we worked with. Our farmer partners first discussed their history, current status, challenges, and hopes for the future with the group, then walked us around their operations, explaining the operation in detail. Students were required to prepare beforehand by finding more general information related to the type of farm they were visiting.

After teams were assigned to individual farms for the final project, they went back for additional on-site meetings with their farmer partners. They continued to ask questions as they surfaced, to look deeper into what the farmers were capable of producing, and to collaboratively work through ideas during the design process. They also consulted via email and phone.

At the end of the term, the farmer partners came to the public presentation of the prototypes that the students had created.

**Public presentation of prototypes**

On December 7, 2015, the students in the class gave a public presentation of the prototypes and marketing plans they had developed with their farmer partners. In addition to the farmer partners and their guests, the class’s faculty and students invited MSU administrators, colleagues, MT Dept. of Agriculture personnel, other students, friends, and family members.

The presentation was held on the MSU campus, we estimate there were about 80 people in attendance – 60 guests in addition to the 21 people from the class. Guests included MSU President Waded Cruzado; deans and faculty from the colleges of business, arts and architecture, and agriculture; as well as staff involved in university communications; and a few people representing venture firms.

Each group produced a short (2-3 minute) professional-quality video that explains their process and final product. After showing the videos, groups then presented their prototypes and marketing plans, taking questions and comments from the audience at the end of each presentation. Each group’s total presentation time was approximately 20 minutes.

Videos of each project, which can be shared with ALL Montana specialty crop farmers, will be posted on a public Facebook page.

We are committed to posting 5 of these videos on the DSEL FB page. One video was corrupted and the student is unable to save a file that can play outside of their own computer.

**Goals and Outcomes Achieved**

**Student Project Examples:**

Rocky Creek farm produces abundant apples and pumpkins, and a considerable waste stream. “Forbidden Fruit” bars used apple cider mash as their primary ingredient, while “Patch” snacks were made from pumpkin seeds and were also positioned as a healthier substitute for croutons. These are both products with potential for apple and pumpkin growers.
It’s hard to make potatoes into marketable products that utilize the processing machines available at Bausch Potatoes. Both “Honest Potatoes” and “Nyo-Kee” allowed for home cooks to create delicious, sophisticated meals while limiting preparation time and effort. These products are both feasible for potato growers and require minimal additional equipment.

The issue for Cloud Nine farm is that the farmer grows a wide variety of organic vegetables during a very short growing season. “Savory Spice” was a value-added product that would allow farmers to reduce the time pressure to sell fresh produce, while simultaneously increasing profitability. "Cloud Nine Soup" was another value-added product that would also allow this producer to be profitable outside of the growing season. These products are practical for any organizations selling produce with a limited shelf life.

At the time of this writing (December 2016), none of the prototypes developed in fall 2015 have been taken to market yet. In hindsight, it was unrealistic to expect a food provider/farmer partner to take a new product to market, have sales figures and report those figures in the time frame suggested. So, we have no quantitative data yet for sales figures of value added products.

At the time of this writing, none of the student groups or the farmer partners have further participated in entrepreneurial incubation/scaling programs the ideas created during fall 2015.

Conclusions: The course delivered 6 unique, market-viable products that could be picked up by any food provider that grows the pertinent fruits/vegetables.

Recommendations: Work on ways to promote these products and share them with a wider audience.

**Beneficiaries**

Specialty crop producers who viewed the developed products and attendees to presentations and are interested in expanding to value added production.

The primary objective of this program is to increase producers’ profits by developing crop-specific value-added goods to sell to individual consumers/markets/restaurants/institutions. Waste reduction is a secondary objective; students and farmers collaboratively explore the potential profitability of utilizing producers’ waste materials as raw materials/ingredients for new value-added products. The products and techniques developed potentially benefit any of the 325 Montana vegetable farms counted in the 2012 census of agriculture.

**As of December 2016, there have been no financial beneficiaries of this project, since none of the ideas from the first year have been implemented.**

**Lessons Learned**

Most of our first round of partners were not as entrepreneurially minded as we expected. We fully appreciate their partnership, but they were fairly "set in their ways" and were not seriously interested in taking anything but raw product to market.

Future plans include:
1. Working with 5 farmer partners instead of 3. We had 6 partners, but one lost their lease and could no longer participate.
2. Also, vetting those partners to make sure they fully understand that our hopes are that they would consider exploring creating a value-added food product based on the course-provided research.
3. Encouraging the student teams to have more meetings with their farmer partners throughout the semester to create a stronger, emotional bond between the working groups, thus facilitating greater understanding between all of the stakeholders
4. Requiring student teams to meet with MSU’s Blackstone Launchpad 3x during the course of the semester – in order to cement their understanding of what it takes to create a viable product that has true market potential
5. Rewriting some of the assignment’s requirements so student teams and farmer partners have a better chance at applying for competitive grant funding and competition funding in the future (this could provide startup funds for the farmer/providers to get these value added product ideas “off the ground”

Contact
Meta Newhouse
Associate Professor Graphic Design
Montana State University
meta.newhouse@montana.edu
406-994-2201