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Reinvigorating the Sprout Industry

Project Summary:

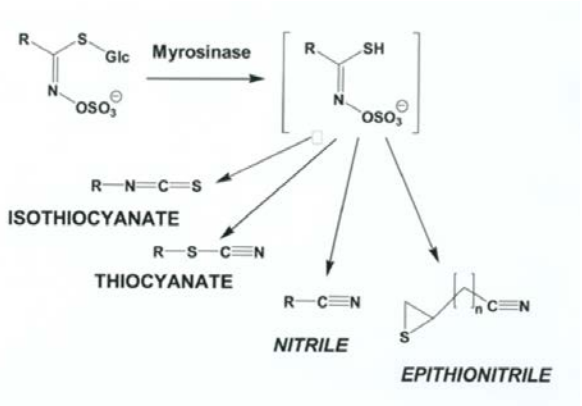
Research has clearly shown that sprouts, which encompass the first stages of plant growth and development, have desirable contents of vitamins, minerals, enzymes, amino acids and essential fatty acids. Sprouts are easily assimilated by the human body and could play a significant role in balanced nutrition. Unfortunately, sprouts have regularly been associated with food-borne outbreaks of *E. coli* in Europe, Japan and the United States. Subsequently, the US FDA has intensified regulation of this market and the consumer has lost confidence in sprout products. However, we suggest that there is still an opportunity and need for alternative fresh produce that are safer for the human consumer yet nutritious and simple to produce throughout the entire year.

Microgreens. Microgreens are similar to sprouts. *Microgreens* are immature seeded plants, produced by planting the seeds of vegetables and herbs into shallow soil and harvesting them after only the first two leaves are fully developed. In botanical terms, the first two leaves are the cotyledons (or the embryonic leaves) of the plant. Subsequent leaves are the first true leaves. Similar to sprouts, microgreens have higher nutritional value than seeds. The germination process from dry seeds to growing plants involves many metabolic activities. As the seeds germinate and the seedling emerge and develop, the content of protein and the balance of essential amino acids may be increased (Chavin et al. 1980) Thus, the content of quality protein and vitamins may be increased in these young growing plants relative to seed or to mature plants. For example, recent research has shown that in general, microgreens contain considerably higher concentrations of vitamins and carotenoids than their mature plant counterparts (Xiao et al. 2012). Increases in lysine and tryptophan content have been reported in sprouted corn, wheat, barley, triticicale, rye and oats relative to seed (Chavin et al 1989). Because microgreens are not produced under the same high humidity conditions as sprouts, they are less likely to harbor E. coli and production/sales are less regulated. That said, sanitation (clean hands, clean container, clean seed) is still imperative for production of clean edible product.

Camelina. *Camelina sativa*, an ancient European oil crop, is rich in omega-3 fatty acid (linolenic acid, C18:3) and Vitamin E (γ-tocopherol), a powerful anti-oxidant that stabilizes the oil. Both omega-3 fatty acid and tocopherol are desirable human nutrients.

Glucosinolates. Camelina also contains a group of compounds called glucosinolates. Like most plants in the Brassicaceae family (broccoli, horseradish, mustard, etc.), camelina has a natural defense mechanism to minimize insect feeding or pathogen attack. These plants produce chemicals called glucosinolates (Mithen et al. 2000; van Doorn et al. 1998). The glucosinolates are a large group of sulphur-containing compounds which occur in all economically important varieties of Brassica vegetable. Glucosinolates are responsible for the peculiar pungent flavor and bitterness of some of these vegetables, especially mustard and horseradish (van Doorn et al. 1998; Fenwick et al. 1983). When a plant containing glucosinolate is damaged (insect feeding, pathogen invasion, mechanical wounding), the plant releases the enzyme 'myrosinase' (thioglucoside glycohydrolase EC 3:2:3:1). This enzyme degrades the glucosinolate into a variety of breakdown products (isothiocyanates thiocyanates, nitriles, glucose and sulphate (Hopkins et al 2009; van Doorn et al. 1998). These breakdown products tend to be bitter which deters further insect feeding. Some of these breakdown products are toxic to plant pathogenic fungi (Manici et al. 1997).

The nutritional value of glucosinolates in both human foods and animal feeds is most dependent up the concentration of glucosinolate. Human beings are sensitive to the pungency and strong flavors of glucosinolate breakdown products. At high concentrations glucosinolate breakdown products exert toxic and anti-nutritional effects in higher animals (Mithen et al. 2000). Thyroid metabolism is the most intensely studied. The goitrogenicity of glucosinolates to domestic livestock limits the inclusion of brassica feedstuffs in commercial feeds. There are other toxicities associated with consumption of large amounts of glucosinolate. Resultantly, inclusion of camelina in beef and poultry diets is limited to 10% by the US FDA.



On the other hand, a number of studies have clearly demonstrated that moderate consumption of cruciferous vegetables is associated with a decreased risk for many cancers (lung, pancreas, bladder, prostate, thyroid, skin, stomach, and colon) (Keck and Finley 2004). This anticarcinogenic activity provides a strong motive for the manipulation of glucosinolate levels in vegetables for human consumption and development of new foods that contain moderate levels of glucosinolate. We postulated that the glucosinolate content of camelina sprouts would be in the range of collard greens and mustard green (Table 1).

Table 1. Glucosinolate Content of Cruciferous Vegetables (These are relative values. They are taken from different publications using different techniques and different equipment)

	~ µMol/100 g fresh wt		
Broccoli	188	Carlson et al. 1987)	
Broccoli Microgreens			
Brussels Sprout	466	Carlson et al. 1987)	
Cauliflower	95	Carlson et al. 1987)	
Collard Greens	439	Carlson et al. 1987)	
Mustard Greens	1191	Carlson et al. 1987)	
Rapeseed meal	4000	Boujard et al. 2000	
Canola meal	500	Boujard et al. 2000	
Camelina meal	2400	Aziza et al. 2009	
Camelina sprouts	??	??	

Anne Runkel, an undergraduate student research assistant, conducted a study I 2009, *"Environmentally caused chemical constituent and nutritional variation in the oilseed crop Camelina sativa",* and concluded that glucosinolate and omega-3 contents of camelina are highly affected by temperature fluctuation during plant growth. Sprouts grown at a day/night temperature range of 35 C to 15 C had significantly lower levels of glucosinolate than sprouts produced at a constant 15 C temperature. She also reported variation in the glucosinolate content of seed from different camelina lines. Significant differences in the glucosinolate content were also observed in sprouts from the different lines (Fig. 1). Thus, we can ultimately affect the glucosinolate content by the growing conditions and by choice of camelina variety.

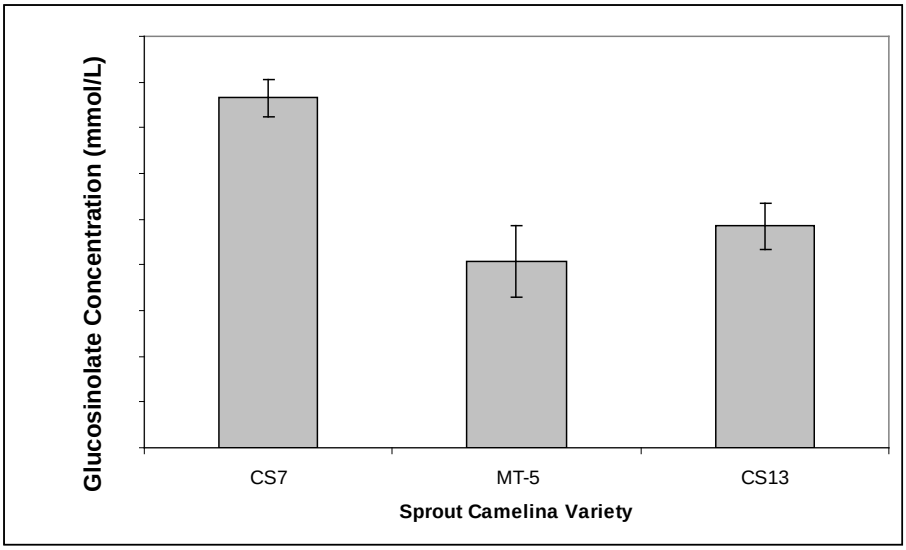


Figure 1: Sprout total glucosinolate concentrations of three varieties of Camelina grown at a day-to-night temperature range of 25°C to 10°C. Source "Environmental caused chemical constituent and nutritional variation on the oilseed crop Camelina sativa" by Anne Runkel.

Similar results were reported for omega-3 fatty acid composition. Different camelina varieties have slightly different fatty acid profiles. The omega-3 fatty acid content of sprouts produced at a day/night temperature range of 32 C to 25 C had lower levels of omega-3 fatty acid than sprouts produced at a constant 15 C day/night temperature (Fig 2). Again, we can control the content of this important nutrient simply by varying production temperatures.

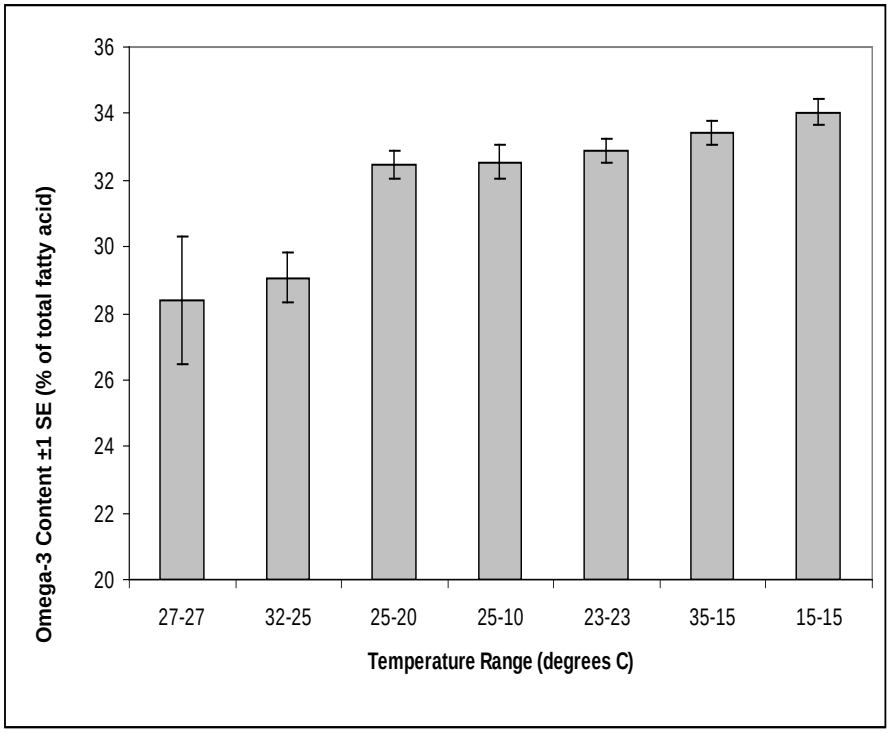


Figure 2: Sprout omega-3 concentrations of three varieties of Camelina at varying temperatures. Sprouts were grown at day/night temperature ranges of 35-15°C, 25-20°C, 25-10°C, and 32-25°C. Sprouts were also grown at steady temperatures of 15°C, 23°C and 27°C. Source "Environmental caused chemical constituent and nutritional variation on the oilseed crop Camelina sativa" by Anne Runkel.

Project Approach:

Research - Camelina Microgreens.

The quality of our micro-greens was determined by different organoleptic and sensorial tests. Intrinsic factors such as variety and growth conditions are related to the physical, chemical and microbiological parameters of the plant and will affect the sensory characteristics of the greens. The sensory characteristics of the greens (appearance, taste, and flavor) determine the acceptability and quality perceptions of consumers. We also conducted proximal analysis of our microgreens to determine the nutritive value.

Agronomy

Study #1: Effect of Growth Condition (Soil vs. Hydroponic) on Camelina Microgreens

Experimental Design. 3 different varieties of Camelina sativa ((Cs7, Cs13, and MT5) and one variety of Chia were planted to evaluate the germination and development of the greens in either soil or in water (hydroponic conditions). Growth characteristics were noted daily.

1. **Soil**: Rectangular pots were filled with Sunshine mix and seeds were sprinkled on top. The pots were watered and covered with either plastic film or a plastic lid to conserve humidity. The plants were watered as needed.
2. **Water**: The hydroponic system consisted of a terra cotta saucer in a glass petri dish. Water was placed into the glass petri dish. The camelina seed was sprinkled into the terra cotta saucer. Overtime, the water diffused through the terra cotta saucer. In this system, the camelina seed gets enough water to germinate but not enough water for the gum layer to form around the outside of the seed (This system was more or less modeled after Chia Pets). The system was wrapped with plastic film to conserve humidity. Additional water was added to the petri dish as needed.

Results. The daily growth observations are described in Table 1. Cs7 was the fastest growing line. On day 7, MT5 was the most desirable microgreen with stronger stems than either Cs7 or Cs13. Cs7 and Cs13 showed some signs of collapse on day 7. The germination of Chia was delayed relative to the germination of Camelina sativa but still produced healthy microgreens. Camelina sativa did better in soil than in the terra cotta dishes. The terra cotta dishes absorbed too much water. This condition is optimal for production of sprouts but not optimal for production of microgreens. The best condition to produce healthy and fully grown microgreens (2nd stage) was in pots containing 1-2 inches of soil. Deeper soil was not beneficial.

Study #2: Microgreen Production in soil lined with tissue paper.

Dave Sands had done some previous work with camelina for sprout production. He screened our entire camelina collection and selected several varieties for further development. These selections included Cs7, Cs13, 62 and 10-3-6. At this point we had a surplus of 62 and 10-3-6 seed and minimal amounts of Cs 7 and Cs 13. This study was done with C. sativa lines 62 and 10-3-6.

Experimental design. In the previous study, we determined that camelina microgreens were more suited to production in soil rather than water. In this study, we evaluated the effect of covering soil with a tissue paper and placing the seed on top of the paper towel. The rationale was that the tissue paper would facilitate harvest of the microgreen and would conserve soil humidity. Specifically, the paper would eliminate dirt from the final microgreen product.

Results. Camelina seed placed on top of tissue germinated less homogenous and slower than seed place on soil (Fig. 2). The tissue treatment reduced the germination of the seeds. The seedling roots were not strong enough to go through the tissue into the more nutrient rich soil.

Figure 2. The picture on the right shows camelina germination on tissue paper placed over soil compared with seed germination (left) directly in soil. Seed germination was much faster and more uniform in seed sowed directly into

Study #3: Microgreen Production in pots covered with tissue paper.
Experimental Design. We also evaluated the effect of covering the seeded pots with tissue paper. Again, this strategy was to conserve humidity in the pots. The seed was placed directly onto soil in black deli containers. The planted seed was covered with a sheet of tissue paper.

Results. Camelina seed covered with tissue paper actually germinated and grew better than non-covered seed (Fig. 3). However, the plant tissue adhered to the tissue paper making harvest impossible.

Study #4: Microgreen Production from camelina seed adhered to screen
Experimental Design. Camelina seeds were misted with a solution of carboxy methyl cellulose (CMC). Coating with CMC makes products sticky. The CMC treated seed was placed on plastic or polyester screen that was cut to fit the deli container. Each individual seed was approximately ¼" from the next seed. The screen would allow to have a near constant seed distribution at the surface of the soil and should facilitate harvest. The holes in the screen were smaller than the camelina seed. They did allow direct contact between the suspended seed and the soil. The deli containers were covered for 3-4 days with the deli lid. After the seed germinated the lid was placed under the deli tray as a water reservoir.

Results. This was by far the most effective way to grow camelina microgreens. The plants were robust and it was easy to separate the plant tissue from the soil (Fig 4). We simply removed the

screen from the container and directly washed the plant tissue. The green tissue was harvested from the screen by cutting leaving the root tissue behind. The same deli container/soil could be used again by simply placing another seed-embedded screen on the soil

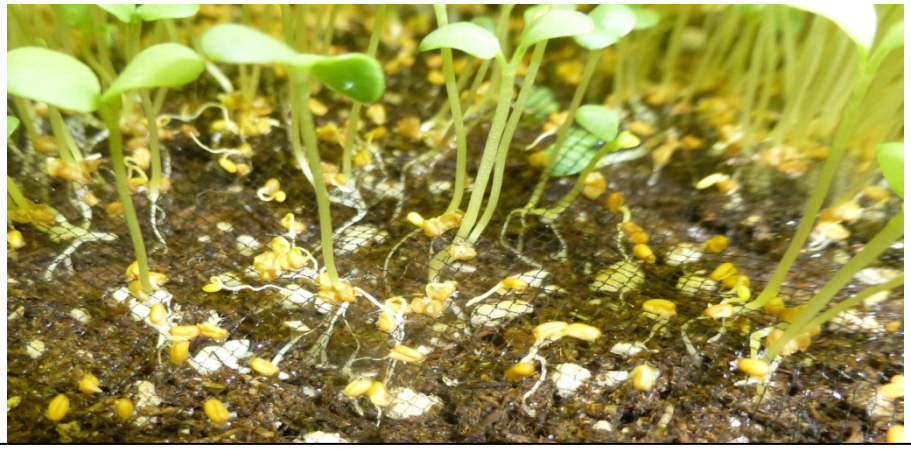


Figure 3: Microgreen production on fine polyester screen (similar to tull). The system enabled us to effectively produce and isolate robust, clean microgreens.

The production experiments enabled us to design camelina microgreen production kits. The kits consisted of a deli container plus lid and 3-5 screens embedded with camelina seed. Germination instructions were included with each kit along with a request for feedback. This is a very simple production scheme. Place the seed-embedded screen on the soil, water, and cover. After 2-3 days, uncover the seedlings and the sprouts will be ready by day 7.

The microgreens were shown and distributed in Local farmers markets (Gallatin Valley Farmer's Market and Bogart Park Farmers Market). The consumers voluntarily tasted a sample of camelina microgreens and were given a short introduction to the "Camelina oil crop". If they liked the microgreens, they were given a sample kit. The consumers were pleased with the simplicity of the kits and enjoyed the microgreens. At the first farmers Market (Bogart Park Famers Market), we collected phone numbers or other contact information from each kit recipient. After a week, we attempted to contact the recipients for a short survey. This proved to be very difficult as often people were not home. Few responded to verbal messages regarding the product. For the Gallatin Valley Farmers Market, we collected an email address from each participant. In addition, the kits included the short survey and participants could choose to contact us. Again, the feedback was minimal.

Figure 4: Gallatin Valley Fairground Farmer's Market, MSU extension stand. Camelina Microgreens exposition and survey.

Sensory Analysis

Sensory Panel Training
Objective: Train a sensory panel for descriptive analysis of camelina sprouts.
Experimental Designs. A single variety of camelina microgreens were produced under two different environmental conditions and were utilized for panel training.

- A → Variety 62 Greenhouse (GH)
- B → Variety 62 Growth Chamber at 60F

A sample of each microgreen was placed into a plastic cup pre-coded with random combinations of 3 numbers. A coin flip was used to determine which sample would be considered the control sample. For simplicity, we will assume that A was the control sample. The judges (12) tasted the control sample (A). They then individually tasted sample A and sample B. They were asked to determine which sample was most similar to the control sample (A). Panelists were also asked to define differences between samples A and B. Once the test was concluded, the data was analyzed using excel (Table 2).

Table 3: Correct and false identification of training samples.			
Judge	Correct	False	% correct judges
2	1	1	50%
17	1	1	50%
18	1	1	50%
19	2	0	100%
20	1	1	50%
21	0	2	0%
23	1	1	50%
24	1	1	50%
25	2	0	100%
26	0	2	0%
28	2	0	100%
29	2	0	100%
Total	14	10	58%

After a Binominal distribution analysis (Table 5), the 14 correct judgments would give 95% confidence in the results from the sensory panel.

Table 3: Binomial distribution. Minimum of right judgments to probe differences. It is adaptation of the Tables on E.B. Roessler, G.A Baker y M.A. Amerine. Food research 21, 117 - 121 (1956)				
Number of judgments (judge * # set)	**Probability level**			**Number of right judgments**
	0.05	**0.01**	**0.001**	
24	17	19	20	**14**

Sensory Analysis of Camelina microgreens. The camelina sensory evalution was done by the trained panel of testers. Microgreens from 4 different varieties of camelina were evaluated. Each variety of camelina was produced under different environmental conditions. (Data in senso1.2.xlsb)
Experimental Design. Four varieties of Camelina were grown in three different environmental conditions (Table 4 describes the varieties and the growth conditions). The development of the microgreens was observed every other day. Once the microgreens were mature (around 7-9 days), each treatment was harvested by cutting the greens close to the soil with a pair of sterile scissors. The microgreens were washed with abundant water and excess of water was removed using a paper towel.

Taste test preparation: Each variety of microgreen was distributed randomly in labeled 2 oz. plastic cup. Each panelist tasted each treatment (variety x growth condition).
The judges ranked the samples on a descriptive scale from 0 to 13. This scale took into account odor, color, taste, texture and overall appearance. The results were used to select variety and further define optimum growth parameters.

Table 4: Codes for camelina microgreen samples describing variety and growth conditions.

Camelina Variety	62	86	150	105	Growth condition
Code	A	D	G	J	Chamber – constant 60º F
	B	E	H	M	Green house – ambient T
	C	F	I	N	Chamber – constant 70º F

The results from the sensory analysis were evaluated using a multi-way ANOVA analysis (STATGRAPHIC centurion XVI.I). This analysis enabled us to compare the different varieties and the different growth conditions (Table 5). The analysis was based upon the panelist rankings of each treatment.

Table 5. Total Quality Score for each Treatment (variety x growth condition)

Condition	Camelina Variety	Growth condition	Total quality
A	62	Chamber 60º	43.69
B	62	Green house	37.04
C	62	Chamber 70º	35.98
D	86	Chamber 60º	43.09
E	86	Green house	37.24
F	86	Chamber 70º	35.46
G	150	Chamber 60º	38.75
H	150	Green house	36.55
I	150	Chamber 70º	37.08
J	105	Chamber 60º	34.06
M	105	Green house	37.23
N	105	Chamber 70º	41.08

Conclusions:

- Camelina variety 62: No significant differences were found in the average quality score for each growth condition. There were significant differences in ratings for color and texture but not for odor and taste of microgreens.
- Camelina variety 86: There was no significant difference in the average quality rating of camelina variety 86 grown under different temperature conditions. Specific ratings of odor, taste and texture were not significantly different. The color of the greens was significantly different with 95% confidence.
- Camelina variety 150: Panelists disagreed in the taste evaluation of this variety. There were significant differences in the judge's ratings. The averages are in line with the other varieties and do not reflect the spread of ratings. All the other parameters (odor, color and texture) were not affected by the environmental growth conditions.
- Camelina variety 105: The panelist ratings for this variety showed significant differences. However, one judge absolutely disliked the 105 microgreens. If we exclude this rating, only the color of the greens was significantly affected by the environmental growth condition.

Total Quality: this value was obtained adding the average score for each quality parameter into a single rating (table 3). Camelina variety 62 microgreens that were produced at a constant temperature of 60 had the highest rating (Treatment A). Camelina variety 86 microgreens were a close second. With exception of Camelina variety 105, the best environmental condition for the growth of microgreens is a constant temperature of or temperatures of 60®Fahrenheit.

With exception of the odor score, Camelina microgreen sensory qualities are strongly affected by the growth conditions. Color is most impacted by production temperature.

Glucosinolate Analysis

Objective: Glucosinolate content affects the taste and bitterness of different crucifers. The objective of this study was to determine if we could detect differences between camelina varieties and correlate these differences with sensory quality.

Experimental Design. The varieties of Camelina sativa evaluated in this study were selected based on the germination experiments and the sensory evaluation. Following Runkel's procedure, the amount of glucosinolate in a sample was determined using a simple and indirect assay. Glucosinolate was measured by measuring the amount of glucose released after the plant defense system was activated by mashing the plant tissue. When the plant was injured, it releases the enzyme myrosinase. Myrosinase interacts with glucosinolates resulting in production of defense molecules (i.e. nitriles, isothiocyanates or cyanates) plus a molecule of glucose. If you quantify the amount of glucose, you quantify the amount of glucosinolate. The results are presented in Table 6. Camelina variety 62 had the lowest concentration of glucose. Thus, it had the lowest content of glucosinolate. Camelina variety 62 was also the preferred microgreen variety.

We also evaluated the stems, the leaves and the whole microgreen for glucosinolate content. We determined that the glucosinolates were more concentrated in leaf tissue than stem tissue.

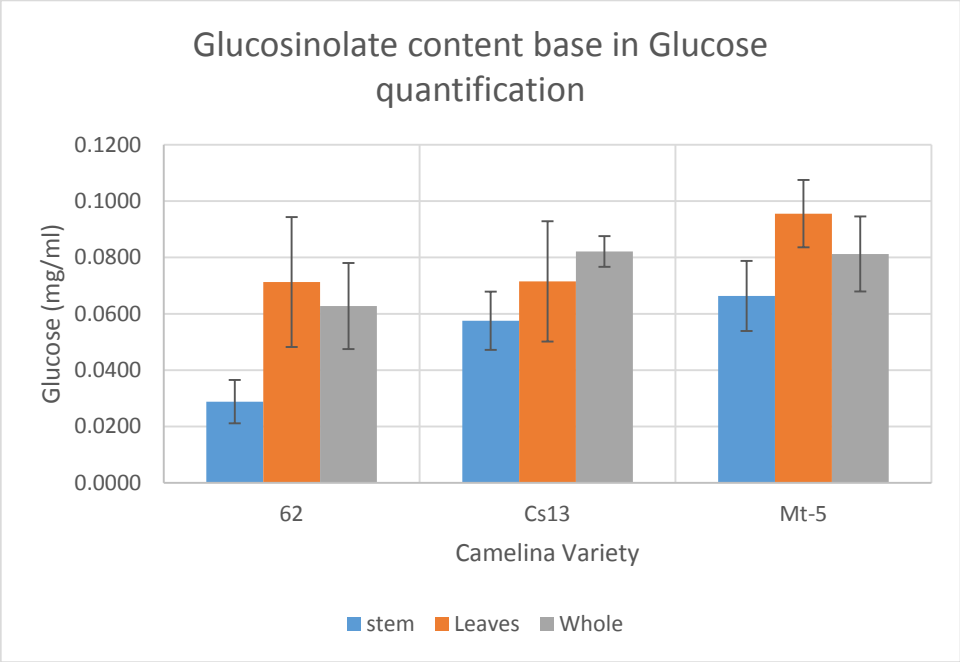


Figure 5: Indirect quantification of Glucosinolate by the level of glucose released from vegetable tissue.

Three years of research has resulted in a marketable product: Camelina sativa Microgreens. A cultivar was chosen after numerous tests on flavor, growth rate and appearance. The microgreens can be grown by a homeowner without worry of bacterial contamination, a problem that has plagued the sprout industry. The innovation is the microgreen launch pad that has seeds embedded in a plastic screen. The pad placed on moistened potting mix in a pie plate, is watered and placed in a window. In 7-9 days the consumer can harvest delicious microgreens ready for use in salads pizza topping or in any garnish. The camelina microgreens have a unique nutritional characteristic; they deliver fresh omega-3 oils to the consumer. We foresee great marketing potential for these camelina microgreens launch pads, packaged in lots of 12 or 24 pads. We successfully beta tested them for consumer desirability at several venues, including a farmer's market and a winter fair.

Goals and Outcomes Achieved:

The goals and outcomes changed slightly during the course of the project. The sprout industry underwent some devastating downturns brought on by the adverse publicity, lawsuits and loss of market sales of sprouts due to bacterial contamination of sprouts.

1. Accordingly, we designed a "grow your own at home" system for cultivation of microgreens. This involved embedding camelina seed in the top of a screen. The screen placed on top of potting mix by the home grower, is designed to be marketed in packs of 12 or more. The manufacturer only touches the seed never the vegetable product.
2. The technology was tested for consumer acceptance and the results were favorable as reported above. The venue was farmers markets and also students from MSU biotechnology classes. There was real consumer interest reported back after the 2 week interval necessary for sprouts to be grown at home, harvested and tasted, as reported above.
3. We developed a close relationship with a seedsman as mentioned in our proposal. They (MTGFP, Belgrade, MT) are able and committed to provide all the seed necessary for even the most optimistic microgreen market projections.
4. A new cultivar of camelina was selected and tested specifically for this microgreen kit. Flavor was very favorable and germination was very high and rapid with this new cultivar. This new cultivar can be protected by Plant Variety Protection (PVP) (estimated cost is $500.00.) PVP can provide affordable protection for a small or growing business, for example Wheat Montana's Bronze Chief (hard red spring wheat).
5. At present, one major vegetable producer distributer in Ohio is testing our microgreen kit to determine if it will fit with their distribution network that includes the entire East Coast.

Beneficiaries:

- More than 100 Montana ag producers

Commercial development of a personal system for microgreen production is still ongoing. We are in communication with distributors and have demonstrated our system. They are evaluating the system from a production/distribution standpoint. They may choose to commercialize the entire system or parts of the system.

We have also worked with local producers who market through Farmer's market. Several are working to adapt our system for a variety of different microgreens.

In either case, we suggest that the microgreen variety should be grown by 1-2 farmers in MT. The seed will be distributed by the aforementioned microgreen distributors. It is very imperative to PVP the variety.

The number of sprout cultivars released to seedsmen was zero.

However the number of microgreen cultivars released under license to Montana Gluten Free Processors was three; CS-7, CS-13 and C-62 (the latest). MSU has enough seed available to stay one season ahead of possible orders. They have yet to record sales however, a big distributor of fresh table vegetables in the Eastern US market wants to include these camelina microgreen kits in their distribution system. The approach would be for manufacturing here of the microgreen screens with seeds embedded. They anticipate doing the distribution and marketing. We are doubtful if a patent would be valuable but Plant Variety Protection (USDA) would protect the seed source. The University did not want us to sell the experimental embedded screens, so they were given away gratis at farmers markets in exchange for a report of their consumer use and value. It is from this system that we got very encouraging reports.

The freeze-dried sprout powder project never materialized because we moved from sprouts to microgreens.

We presented the camelina green project in a booth at the MSU Ag Days where more than one hundred ag producers visited, and about half asked pertinent questions relative to their specialty.

Their big focus was the availability of the germplasm (the microgreen cultivars) and we referred them to our primary licensed seedsman (Montana Gluten Free Processors). The interest was broad, with poultry producers and restaurant owners being interested in the omega-3 oil, the low glucosinolate level, and the high gamma-tocopherol (antioxidant) content. The most common approach that interested producers use is to call our laboratory directly.

In summary, we think that there is sufficient scientific back up here and enough commercial interest to initiate a viable industry in Camelina microgreen "launch pads" and the first real interest is on the East Coast market.

Lessons Learned:

The sprout industry basically collapsed about one year into this project, because of microbial contamination leading to severe illness (E. coli and Salmonella) in the customers.

It is very difficult to produce and distribute sprouts that can meet the hygiene requirements of food safety concerns. There are a number of points in production, packaging and transportation where contamination can occur. Sprouts are generally produced under very high humidity (i.e. Mason jars). High humidity will encourage rapid growth of number of undesirable bacteria. In contrast, microgreens are germinated under high humidity but grown under lower humidity. Sprouts and microgreens are commercially packaged in containers (plastic bags or containers) to facilitate transportation from the producing plant to the consumer, display in a grocery store cooler, and then storage in cooler or refrigerator. The goal of the containers is to keep the product fresh. Such containers may actually encourage bacterial growth.

Thus we changed our focus from commercial production and distribution of sprouts to consumer production of microgreens. The only hands that touch your food are your own hands.

The sanitation protocol for fresh market greens has been a real problem with the industry. Chlorine based (hypochlorite) treatments do not really hold up long enough for shipping requirements, limiting distribution. For this reason, we developed a dry screen embedded with pre checked Camelina seeds with a food grade adhesive. What this does is protect the homeowner from other people's bacteria by allowing the production to be at home. In essence, this is the safest way for a consumer to avoid E. coli and Salmonella etc. contamination. Camelina microgreens can be produced in a home, in a sunlit window.

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Nutritional value of locally grown vegetables: Determining management effects and marketing potential

Project Summary:

Small-scale vegetable production represents a rapidly growing and vibrant component of many local economies. Though the semi-arid environment of Montana seems an unlikely location for vegetable production, the local food movement has increased in this region by over 11,000 acres of vegetable production between 2002 and 2007 (USDA 2007a). Despite the rapid growth of the local vegetable industry and the farming community's need for evidence-based guidance, there is a dearth of research-based information to guide farmers in evaluating the best management practices for vegetable production in this state.

Many of the nutrients important to human health that we derive from vegetables are antioxidants in the forms of phenols, flavonoids and carotenoids. These compounds are secondary metabolites in the plant, aiding in UV protection, herbivory defense, wound healing, soil signaling, and fruit an flower pigments (Dey and Harborne 2002). Plant adaptation to climate, soil conditions and stress influence the levels of secondary metabolites produced. Several studies in other parts of the United States have found higher antioxidant levels in crops under organic management compared to conventionally grown crops (Mitchell et al. 2007, Toor et al. 2006, Howard et al. 2002).
A possible mechanism for this increase in antioxidant production may stem from carbon and nitrogen dynamics in organic systems, compared with conventional systems. Because organic farming relies on organic matter inputs for fertility management, different amounts of carbon in the various soil carbon pools and their effects on nutrient cycling and plant growth may also be

responsible for plant secondary metabolite production. However, the intensive tillage common in vegetable production can rapidly deplete soil carbon pools by aerating soil and increasing microbial metabolism (Overstreet and DeJong-Huges 2009). Both mineral and organic fertilizers are widely used in vegetable production and have very different effects on soil carbon pools. Our work investigates the effects of different methods of soil fertility management on soil fertility through time, crop production and crop nutritional value in intensive mixed- vegetable production systems.

The goals of this research were to: 1) identify the fate of organic and inorganic fertility inputs (green manure, straw and nitrogen fertilizer) with differing carbon to nitrogen ratios, typical in vegetable production in Montana; 2) determine the effects of different soil organic matter content on vegetable crop yields and antioxidant concentrations; and 3) determine the impact of enhanced nutritional value marketing on the sales of locally grown vegetables.

Project Approach:

We studied the effects of different fertility management practices on soil characteristics, vegetable crop yields and vegetable antioxidant concentrations for three growing seasons. Our study design consisted of a randomized split-plot design with four replicates of four fertility treatments - hay mulch, straw mulch, urea fertilizer and an untreated control - and four vegetable crops - spinach, broccoli, corn and tomatoes. Organic matter inputs (hay and straw mulches) were applied once in the fall of 2010 and tilled in in the spring of 2011. Straw mulch was applied at a rate of 5.5 kg/m2 and hay mulch was applied at a rate of 9kg/m2, following recommendations from local organic vegetable farmers. The mulches had differing C/N value (t-test p-value = 0.048), with a mean C/N of 41.6 in the straw mulch and 26.5 in the hay mulch. Urea fertilizer (46-0-0) was side-dressed each spring about 10 days after germination or transplanting, following MontGuide recommendations for vegetable production.

Sampling occurred at the harvest of each crop, between August and October of 2011, 2012, and 2013. Three plants per plot were sampled for tissue nutrient analysis and soil samples were obtained from the root zone of each sampled plant. Total yield per plot was also measured. Soil samples were used in a the following analyses: nitrate, total N, percent organic matter, phosphorus, potassium, cation exchange capacity, pH, water-extractable organic matter, microbial biomass, and potentially mineralizable nitrogen and carbon. Tissue samples were used for nitrogen analysis and two antioxidant assays, oxygen radical absorbance capacity (ORAC) and Folin-Ciocalteu analysis of total phenols. Samples obtained in the fall of 2013 are currently undergoing lab analysis.

Project oversight and contributions by project partners has progressed according to the plan laid out in our proposal. All field and laboratory work has been performed by PhD student, Karin Neff. Mid-season and post-season reports have been shared with project Co-PIs and other appropriate MSU faculty. Because additional graduate stipend was secured from other sources, we reallocated a portion of the personnel budget to hire three undergraduate students to assist with field and laboratory work and be trained in agricultural research methods as well as general best management practices for market garden vegetable production. Undergraduate research was presented at Montana State University in March 2012.

Results:

Yield and Plant Biomass: There were differences between spinach crop response to soil treatments in 2011 and 2012 (ANOVA, $F_{3,12} = 38.23$, $p < 0.0001$ and ANOVA, $F_{3,12} = 4.46$, $p = 0.025$, respectively). In 2011, hay plots had the highest yields with 0.88 kg/m2 and straw plots had the lowest with 0.09 kg/m2 . Nitrogen fertilizer and control plots were intermediate with 0.49 kg/m2 and 0.67 kg/m2, respectively. In 2012, both mulch treatments (0.80 kg/ m2 in hay and 0.84 kg/ m2 in straw) were greater than the control (0.137 kg/m2) and nitrogen-fertilizer was intermediate with 0.23 kg/m2 (Figure1). Yield data were not collected in all years for broccoli, tomato and corn due to pest pressure and inclement weather. Analysis of non-spinach crop data will be completed by December 2013.

Crop Antioxidants: Initial antioxidant analysis is inconclusive with no differences between treatments (Figure 2). Additional analysis is currently underway to confirm these results. At this point it appears that cropping system management is only one factor that affects vegetable antioxidant concentrations. Due to these results, few recommendations can be made to farmers regarding how soil management affects crop nutritional quality. Soil Microbial Activity: In 2011, the addition of mulches increased soil carbon respiration significantly compared to the two non-

mulched treatments (ANOVA, $F_{3,60} = 32.99$, $p < 0.0001$, Figure 3). Soil respiration in 2011 was 669.3 kg-C/ha in straw and 530.2 kg-C/ha in hay treatments, compared with 202.1 kg-C/ha in control treatments and 156.9 kg-C/ha in nitrogen fertilizer treatments. Respiration data from 2012 is currently undergoing statistical analysis and data from soils collected in 2013 are still undergoing lab analysis. All final analysis will be completed in December 2013. Microbial biomass differed between treatments in 2011 (ANOVA $F_{3,60} = 3.839$, $p = 0.014$). Straw mulch treatments had 2.5 mg microbial-C/g-soil compared with 2.4 mg microbial-C/g-soil in hay treatments, 2.5 mg microbial-C/g-soil in control treatments and 2.3 mg microbial-C/g-soil in nitrogen fertilizer treatments. Treatment differences were also seen in 2012 (ANOVA $F_{3,46} = 7.983$, $p = 0.0002$). Straw mulch treatments had 17.0 mg microbial-C/g-soil and hay treatments had 24.0 mg, compared with 10.1 mg in control treatments and 14.5 mg in nitrogen fertilizer treatments. Data from 2013 soils has been collected and is currently undergoing statistical analysis.

Soil Nitrogen Availability: In the spring of 2011, after the mulches had been tilled in but before crops were planted or nitrogen fertilizer was applied, nitrate-N differed between treatments (ANOVA $F_{3,12} = 15.03$, $p <0.001$). Nitrate-N was significantly higher in the hay treatments (25.5 kg-N/ha) compared with all other treatments (4.2 kg-N/ha in straw, 11.2 kg-N/ha in control and 10.9 kg-N/ha in nitrogen fertilizer plots). At spinach harvest in 2011, Nitrate-N still differed between treatments (ANOVA $F_{3,44} = 4.9$, $p = 0.005$). Hay treatments remained the highest with 61.5 kg-N/ha. Nitrogen fertilizer treatments followed with 40.9 kg- N/ha. Control treatments had 22.7 kg-N/ha and straw treatments had 32 kg-N/ha. In the spring and fall of 2012 nitrate-N still differed between treatments (ANOVA $F_{3,12}=3.827$, $p =0.039$ and ANOVA $F_{3,44}= 9.52$, $p < 0.0001$, respectively). In the spring, hay treatments had 55.7 kg-N/ha, control treatments had 30.0 kg-N/ha, nitrogen fertilizer treatments had 25.2 kg-N/ha and straw treatments had 24.7 kg-N/ha. At spinach harvest in 2012 both mulch treatments had higher available nitrate than the non-mulched treatments, with 30.1 kg-N/ha in hay, 32.8 kg-N/ha in straw and 22.5 kg-N/ha and 23.0 kg- N/ha in control and nitrogen fertilizer, respectively. Potentially mineralizable nitrogen was significantly different between treatments in 2011 (ANOVA, $F_{3,60} = 15.05$, $p < 0.0001$, Figure 3). Hay treatments had 1609.7 kg-N/ha of mineralized nitrogen, while straw treatments had 632.3 kg, control treatments had 566.1 kg and nitrogen fertilizer treatments had 779.9 kg. Potentially mineralizable nitrogen data from 2012 is currently undergoing statistical analysis and soils collected in 2013 are still undergoing lab analysis. Soil Organic Matter: Though percent soil organic matter is generally considered to be a stable variable and difficult to change in the short term, we did see changes in the first two years of our experiment. Data from samples taken in 2013 are still being analyzed. Percent soil organic matter differed between treatments in the spring of 2011, after mulches were tilled into the soil (ANOVA, $F_{3,12} = 11.15$, $p = 0.0009$). Organic matter ranged from 5% in straw and 4.5% in hay plots to 3.9% in the control and nitrogen fertilizer plots. By the fall of 2012, organic matter still differed between plots (ANOVA, $F_{3, 44} = 18.48$, $p < 0.0001$). Both mulch treatments differed from both non-mulched treatments, with 4% in straw plots, 3.9% in hay plots, 3.7% in control plots and 3.5% in nitrogen fertilizer plots. Water-extractable organic matter also differed between treatments (ANOVA, $F_{3, 59} = 8.9$, $p < 0.0001$) and was highest in the mulched treatments in 2011. Straw treatments had 168.7 kg-C/ha, hay treatments had 134.2 kg-C/ha, control treatments had 91.2 kg-C/ha and nitrogen fertilizer treatments had 74.7 kg-C/ha. Samples from 2012 and 2013 are currently being analyzed and data analyses will becompleted in December 2013.

The work performed under this grant contributed to the Ph.D. work of Karin Neff. Additional activities and ongoing work are to complete her doctoral dissertation and are funded by alternate means. All funds from this grant were obligated by 9/30/13 and expended by 12/31/13.

In order to expand the relevancy of this research, additional soil and spinach tissue sampling occurred in the summer of 2013 on five established market-garden farms around the Gallatin Valley, providing preliminary data for continuation of this project. Participating farms include: Gallatin Valley Botanical, Gallatin Grown, Three Hearts Farm, Three Fiddles Farm, and Amalthea Farm. Sampling protocol followed the above method in spinach rows the day before spinach was harvested for market. Soils have been analyzed for nitrate, total N, percent organic matter, phosphorus, potassium, cation exchange capacity and pH. Soil samples are currently under analysis for water-extractable organic matter, potentially mineralizable carbon and nitrogen and microbial biomass. Spinach tissue samples have been analyzed for nitrogen content and will undergo antioxidant analysis in December 2013. Results will be included in the final outreach products.

Educational materials: In addition to the soil and crop analysis, we also had an outreach component that was initially designed to address the potential to increase vegetable marketing as a result of enhanced nutrient concentrations. Due to the inconclusive results from our antioxidant analysis, **we will not be able to collaborate with state programs such as Montana Made** to label and promote vegetables with high antioxidant and nutritional value. Instead, recommendations will be made to state growers regarding mulch additions, crop yields and best management practices for vegetable production, and to researchers concerning future research that may assist in determining the mechanisms and practices that lead to highly nutritive crops. These materials are currently in preparation.

Results were shared through four farm tours on site in June of 2011, 2012 and 2013, approximately 30-45 growers attended each tour. Results from the first two years were also shared in 2012 at the Ecological Society of America (ESA) annual meeting in August (50 attendees) and at two state meetings, the Alternative Energy Resource Organization (AERO) annual meeting in October (100 attendees) and the Montana Organic Association (MOA) meeting in November (200 attendees), and at the Montana State University LRES Research Colloquium in April 2013 (35 attendees). Final data will be shared with producers and the Montana State University community in March 2014 at the MSU Local
Foods Fair (200-400 attendees expected).

Our **marketing strategy** was to share with producers the final results and recommendations as follows:

- **Publications**: the Montana Organic Association newsletter, Montana State University extension publications, and peer-reviewed manuscripts, currently in progress.
- **Presentations**: ESA annual meeting, AERO meeting, MOA meeting, MSU LRES Research Colloquium, MSU Local Foods Fair.

Lessons Learned:

Inclement weather and pest pressures in all years prevented the maturity of tomatoes, corn and broccoli in all three years. Our original rationale for using multiple crops was in anticipation of this situation. We will have a full data set for spinach and partial data sets for the remaining crops. All data will be analyzed by February 2014. This research will result in three peer-reviewed publications, including one on plant- available nitrogen management when using organic inputs with differing C/N, currently in progress. Other publications will discuss vegetable antioxidant content when grown with different fertility management inputs and organic matter decomposition in intensively managed mixed-vegetable farms and will be completed by summer of 2014.

Beneficiaries:

This project benefited members of the Montana State University community and state-wide vegetable producers. Specifically, students in the MSU Sustainable Food and Bioenergy Systems curriculum were exposed to and participated in on-farm research (approximately 100 students over 4 years). Also, the on- farm research plots developed in this project will be maintained and used by other faculty for future projects. Gallatin Valley vegetable farmers collaborated with this project and participated in farm tours (approximately 15 growers each year). All have expressed interest in the final results. State-wide growers have also expressed interest in the results from this project (approximately 80 producers).

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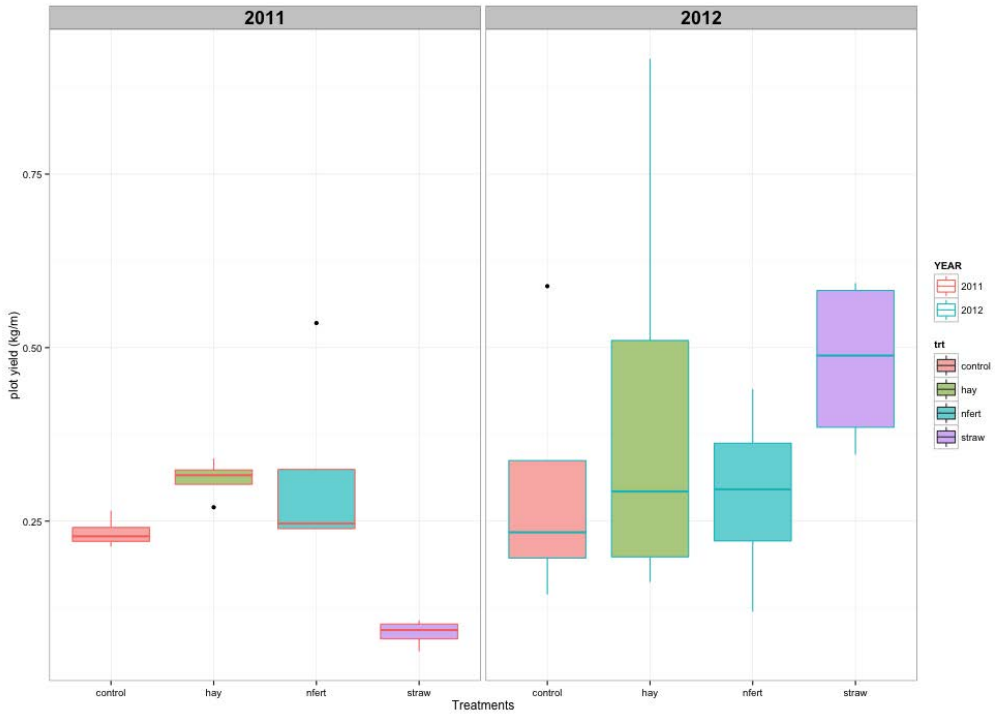

Figure 1. Spinach yield in each treatment in 2011 and 2012.

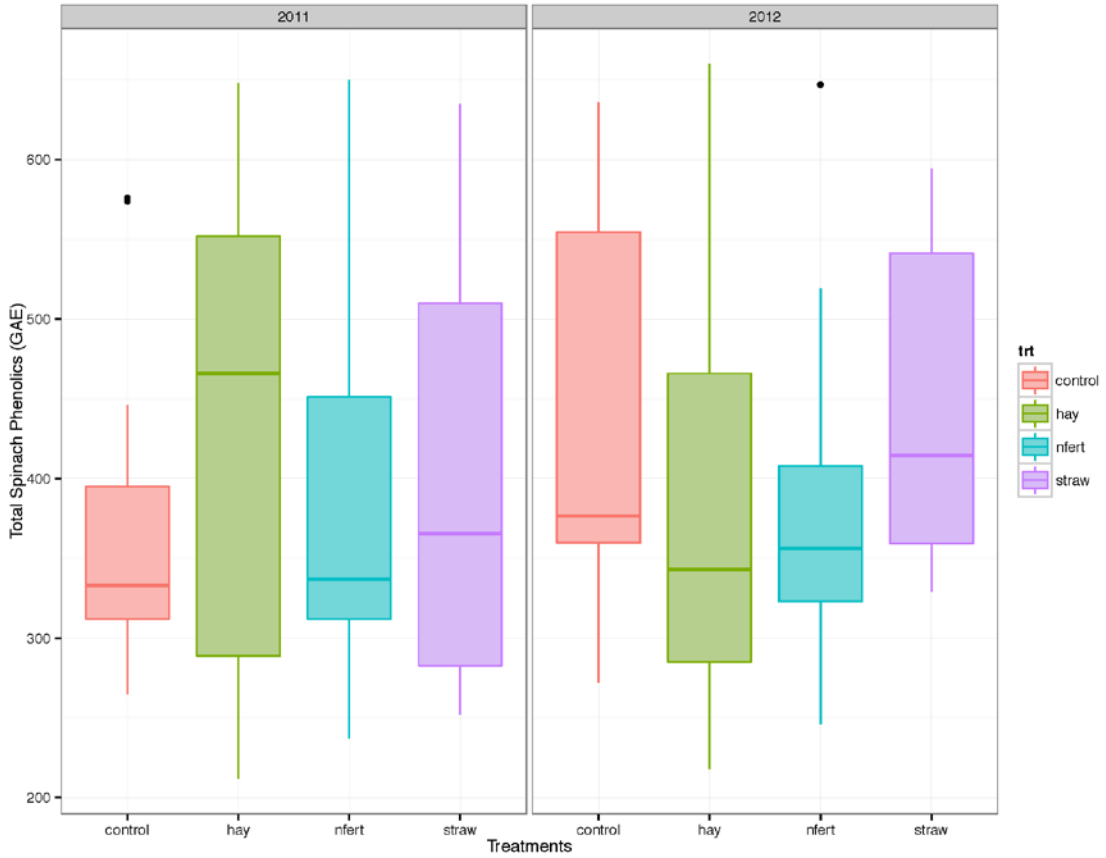

Figure 2. Total spinach phenolics in each treatment from 2011 and 2012.

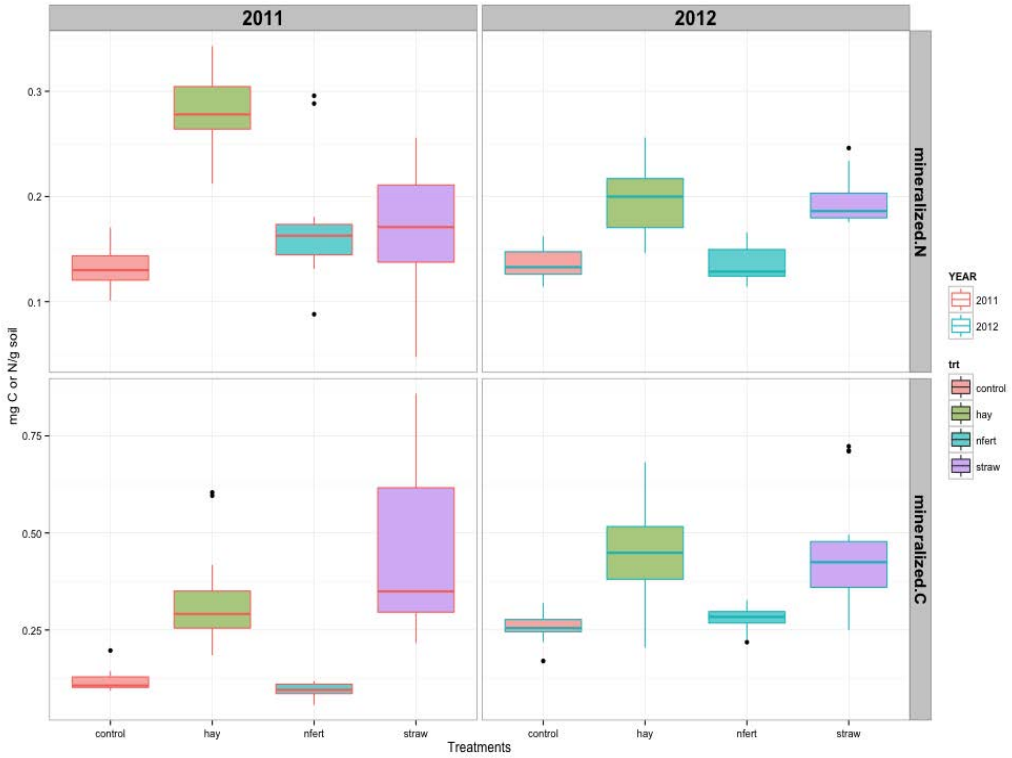

Figure 3. Mineralized nitrogen (top) and carbon (bottom) in 2011 and 2012 in each treatment.

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Seed Potato Disease Prevention Research

Project Summary:

Real-time PCR is the new standard for diagnostics of plant diseases in terms of high specificity and sensitivity. In order to stay at the forefront of diagnostic capabilities for potato diseases, it was imperative to adopt real-time PCR. This project enabled us to proof-test protocols for three important potato viruses in our lab. In addition, it was important for us to demonstrate how the real-time PCR diagnostic compared to conventional PCR and ELISA, two techniques which were already employed in our lab on a routine basis. We compared the sensitivity of all three methods and showed that with real-time PCR, we could detect all of the viruses at much lower titers than with conventional PCR or ELISA. Since the inception of this project, we have obtained our own instrument and have been using real-time PCR to detect both viral, and more recently, bacterial pathogens. This year alone, we have processed over 700 samples for detection of bacterial ring rot. These tests were demanded by the industry, and our ability to respond quickly with performance of the testing has been extremely beneficial to our growers. A second part of our project addressed the improvement of micro-tuber production. It costs approximately $1.00 to produce one micro-tuber in-vitro which makes early generation potato production extremely expensive. Through this project, we showed that larger tubers could be produced in the growth chamber in soilless media for approximately $.42/tuber, and that this technology could be employed by growers themselves. The third part of our project was to upgrade our database to establish seed lot numbers and trace back capabilities. This is something that was specifically requested by our customers in commercial potato producing areas. Our new data base generates seed lot numbers and also provides traceability from year to year through the potato generations.

This project had three distinct objectives that addressed current needs of the Montana Seed Potato Certification program. The first objective was to adopt real-time PCR for the testing of potato pathogens. Through previous funding by the Montana SCBGP, we demonstrated the application of conventional PCR to detect three potato viruses, and quantified the sensitivity of that assay compared to ELISA, which is used routinely. Real-time PCR is theoretically 100X more sensitive than conventional PCR, and is the most sensitive diagnostic tool. Through the use of an instrument in the Plant Science and Plant Pathology Department, we successfully adopted the real-time PCR protocols for PVA, PVX and PVY, and used the methodology to quantify varietal difference in potatoes to PVA. The second objective was to develop a more economical method of micro/mini-tuber production, and improve the size profile and quality. Our current in-vitro method of production is $0.65/microtuber with an average weight >0.5g, and requires greenhouse culture prior to transplanting in the field. This cost of production is passed on to the growers, and is a significant component of the total costs of the growers nuclear generation crop. The third objective was to develop a seed lot identification system that will assist buyers of Montana seed potatoes with compliance of “Good Agricultural Practices”. A data base was developed that assists in trace-back of all generations of seed potatoes to the specific farmer and field.

Project Approach:

The first objective involves the incorporation of real-time PCR for detection and quantification of plant viruses. The first step to achieving this objective was to obtain primers for PVA, PVX and PVY, and using published techniques, demonstrate that they can be used routinely in our lab with repeatable results. This has been accomplished, and we have the capability to extract leaf, tuber or sprout samples, and obtain a result within 1 day. This is a similar time-frame to what we had with ELISA, but RT-PCR is 1000 times more sensitive that ELISA, and it is more powerful in terms of providing a specific identification of the pathogen.

One issue for seed certification is obtaining rapid results for virus testing if leaf testing results are not available from ELISA from the winter test. In most cases, virus titers are low in tubers and ELISA is not sensitive enough to detect virus in highly diluted samples. For the sub-objective “Perform dilution experiments with infected tissue and healthy tissue testing the detection thresholds for real-time PCR compared to ELISA and conventional PCR”, we chose to use tuber tissue because it was important to determine how many samples we could combine and still reliably detect the virus. We performed tuber core dilutions with potatoes infected with PVA, PVX and PVY which were diluted with healthy tubers. From this information, we were able to demonstrate that for PVA, a maximum dilution of 1:2 was required to detect the virus while Conventional PCR and RT-PCR detected the virus at dilutions of 1:32. For PVX, detection at 1:10 with ELISA was intermittent and PVY with ELISA using a dilution factor of 1:10 yielded positive results. Dilutions of 1:100 and higher

were negative using ELISA. RT-PCR detected both PVX and PVY at dilutions as high as 1:400. These results indicate standard practices of combining 10 tuber-core samples and analysis using RT-PCR will yield very reliable results. This data validates the use of tuber core sampling for PVA, PVX and PVY in the absence of good grow-out information.

The second step was a time-series sampling of plants inoculated with PVA. Plants were inoculated with PVA infected sap then the leaf acropetal to the inoculated leaf was sampled 1, 2 and 3 weeks after inoculation. After 1 week, 0 of the leaves tested positive for PVA by ELISA and 40% of the leaves were positive using RT-PCR. At two weeks, 8.5% were positive using ELISA and 34% were positive using RT-PCR. At three weeks, 62% were positive using ELISA and 100% were positive using RT-PCR. These results indicate that for PVA, RT-PCR detects infections 1 week earlier than ELISA, and that RT-PCR detects almost 40% more infection than ELISA 3 weeks after inoculation. This data has very significant implications. Montana currently tests 100% of nuclear and Generation 1 potatoes for PVA using ELISA. This implies that we may be missing ~40% of infected plants (false negatives).

To determine the relative virus titers of Potato Virus A (PVA) in different varieties of potato, and the relative sensitivity of the ELISA and real-time PCR methods, 10 plants each of 10 different potato varieties were inoculated with PVA by rubbing sap from an infected plant on a lower leaf of 1-month-old plants. After 1 week, the leaf acropetal to the inoculated leaf was sampled and extracted for analysis by real-time PCR and ELISA. Presence of virus was determined using both 30 and 35 PCR cycles. 1 week after inoculation, no samples had detectable virus using ELISA across all varieties, 15 plants were positive for PVA using the 30 cycle threshold and 50 plants were positive for PVA using the 35 cycle threshold. At week 4, ELISA detected similar amounts of virus to real-time PCR, demonstrating that it is still a very viable technique for detecting virus in plants that have had sufficient time to build up virus titer. The real-time technique is much more sensitive and better for detecting early infections. One interesting observation is that at 35 cycles, there were significantly more positive plants detected across all varieties at 1 week verses 4 weeks. This may indicate that while the PVA virus is initially able to infect the plant tissue, varieties that are more resistant tend to eliminate the virus over time. This has significant implications for PVA management in the field. At 30 cycles, this was not demonstrated, but for varieties such as Amisk and Umatilla which have demonstrated resistance to PVA in previous trials, the PVA was detectable at week 1 using real-time PCR and not at week 4. This may indicate that these varieties actually suppress the replication of the virus within the plant.
In a previous project funded by the Specialty Crops Block Grant program, we demonstrated the rate of detection and relative sensitivity of ELISA and conventional PCR for detecting PVA and PVY in leaf, sprout and tuber core tissue. We have built upon data gathered in the project “Developing PCR protocols for high-throughput testing for potato viruses, and evaluation of varietal resistance to PVA” (SCBG Contract # 1050298, Grant # 12-25-B-0934). In the report for that project, we demonstrated that conventional PCR detected a higher percentage of infections in tuber cores and sprouts for both PVA and PVY when compared to ELISA. For leaf tissue, ELISA gave similar results. Since we still had all of the extracted tissue from this experiment, we chose to assay them using RT-PCR. The initial assays were conducted on samples collected from 214 tubers from a seed lot known to be infected with high levels of both PVY and PVA. Since these samples were on hand and we already had the data on ELISA and conventional PCR, we chose do RT-PCR on these samples rather than establishing new plants in the greenhouse. In the new analysis using RT-PCR, we demonstrated that RT-PCR detected a higher percentage of infections in both tuber core and sprout tissue than ELISA and conventional PCR, and that for PVA, RT-PCR detected over twice as high a percentage of infection as for the other two methods.

At this point, we have accomplished the goal of demonstrating how the relative resistance and susceptibility of different varieties can be measured using detection by real-time PCR, and how it is much more sensitive than ELISA.

A second objective of this proposal was to optimize microtuber production to increase size and reduce costs. A growth chamber experiment was conducted based on research performed at University of Wisconsin where minitubers were grown from stem cuttings in the growth chamber in vermiculite with plant hormones applied as a foliar spray. We compared this method to growing mini-tubers in soil-less media (Sunshine mix) with and without added hormones. There were significant differences between treatments. The sunshine mix treatment with hormones produced 49 g of minitubers and the sunshine mix without hormones produced 35 g of minitubers. Vermiculite with hormones produced 35 g compared to 15 g of minitubers without the hormones. These results indicate that the peat-based potting soil Sunshine mix along with hormones produces the highest weight of mini-tubers
Another experiment was conducted comparing two different hormone treatments and 4 different planting configurations. The planting configurations were 48 plants in square plugs, 48 plants in an open flat, 72 plants in square plugs, and 72 plants in an open flat. Each set of treatments was arranged in a split plot with half of the receiving liquid rooting hormone and the other half receiving hormex powder. All flats were standard black plastic bedding plant trays 11 X 21.37 x 2.44. There were four replications per treatment. Plants were grown in a growth chamber under artificial lighting. Day Temperature was set at 22 degrees for 18 hours with lights on; night temperature was 20 degrees with no lights. After 65 days three replications of each treatment were harvested and the number of microtubers and weight were compared. The last replication of each treatment was left for 100 days before harvesting.

Overall, the Hormex powder provided a better yield than than the liquid rooting hormone. The number of tubers produced in open flats was and in square plugs was similar. The average weight per tuber was higher in the 48 plant flats than in the 72 plant flats, and also was optimized in open flats versus square plugs. While more tubers can be harvested with a higher planting density, tuber size is compromised.
Development of these new mini tuber production methods may present a lower cost method for producing disease-free mini tubers by the MSU Potato Lab. We currently produce "micro" tubers in *in vitro* tissue culture. It currently cost ~$1.00 to produce 1 microtuber. Using data from the previous experiment presented, we estimate that using the stem-cutting method in the growth chamber, similar micro/mini tubers could be produced for ~$0.42. In addition, all of the methodology will be passed on to growers who may adopt these methods for growing their own mini tubers for their farm.

An experiment testing 7 different fertility regimes was conducted in the greenhouse. It was originally proposed to conduct all experiments in the growth chamber, but after talking with farmers, we concluded that they would benefit they were more likely to produce potato minitubers in a greenhouse than a growth chamber. The experiment compared growing stem cuttings in Sunshine mix alone to the soilless mix supplemented with Miracle Grow Slow-release, Nutrical (liquid calcium), Miracle Grow Slow-releasee + Nutrical, Miracle Grow + Calcium – slow release, and Peters 20-20-20 soluble fertilizer applied weekly, and Peters 20-20-20 soluble fertilizer plus Nutrical applied weekly. 16 potato stem cuts were planted in 20" x 14" square containers. There were 4 replications of each treatment. The best overall fertilizer was Miracle Grow Slow release + Calcium with an average tuber weight of 16.08g verses 11.93 grams for sunshine mix alone. The next best treatment was weekly fertilization with 20-20-20 Peters soluble fertilizer. The total weight of tubers/flat was also highest for the Miracle Grow + Calcium slow-release fertilizer. All treatments increased the number of harvestable tubers per flat compared to the Sunshine Mix alone. The second best treatment was 20-20-20- Peters soluble fertilizer. The addition of the soluble calcium Nutrical to the 20-20-20 seemed to inhibit tuber weight but the numbers of tuber harvested was still relatively high. Due to the decreased labor inputs of using a single application of slow-release fertilizer at planting, we will recommend that our growers use Miracle Grow + Calcium Slow Release fertilizer.

Another experiment that was proposed in the original proposal was testing different light and temperature regimes in the growth chamber. Due to the switch in emphasis from growth chamber to greenhouse experiments, we conducted an experiment aimed at increasing the number of tubers that could be produced per square foot in the greenhouse. We had done a small demonstration experiment where we planted stem cuttings in 2"x8" deep cells which could be split apart. In these tubes, we showed that we could harvest up to 8 tubers per tube, and that the tubes could be separated and the largest tubers harvested. The tubes could then be put back together for the small tubers to continue to grow, and even new tubers allowed to form. While this was a novel idea, it was not seen as practical by the growers. We then designed an experiment where 2'x8' nursery solid nursery tubes were compare to growing in standard flats. We demonstrated that you could produce 60 minitubers per ft2 in the tubes verses 26 tubers/ft2 in the flats. Tuber size was reduced in the tubes and averaged 2.9 verses 4.22 g for the flats.

A third objective of this project was to update the seed potato certification database. We have entered data into our new database for 2009 through summer of 2013. This database enables lab personnel to "trace-back" the source identity of seed lots that were used to grow each year's crop. This is very important for identifying problems which may arise from specific seed sources, and also for insuring food safety. The new database also generates seed lot numbers which are used to identify each specific seed lot which enable growers to comply with good agriculture practices (GAP). The new database is used to generate reports including summer and winter laboratory testing results, acreage reports, registered fields, North American Plant Health Certificates, and winter visual inspection readings. Forms are printed for field inspections and grower addresses. Results can be exported to an Excel worksheet. In addition to these functions, a new tag program has been developed to print the certification tags which accompany all lots of seed which have passed shipping point inspection by the MT Department of Agriculture. The tag program we were previously using relied on computer software and hardware that are no longer supported, so it was imperative to replace this program.

Goals and Outcomes Achieved:

For objective 1, we have been able to determine the detection thresholds for ELISA, conventional and real-time PCR for PVX, PVY, and PVA for both leaves and tuber cores. This has been especially important for the tuber cores because it has enabled us to develop a protocol for testing tubers in a postharvest, and established that we can bulk samples of 10 tuber cores together. For PVA we quantified the infection incidence in different varieties that had been inoculated with the virus. This data showed that some varieties are much more susceptible to PVA and this has been backed up with field observation. We have been able to recommend to growers which varieties are best to plant around their seed plots to reduce the likelihood of introducing PVA. Since the inception of this grant, we have also adopted real-time PCR protocols for numerous viral, bacterial and fungal pathogens. To date, at least 35 growers have requested real-time PCR testing for either viral or bacterial pathogens.

For objective 2, we demonstrated that Hormex rooting powder was superior to a liquid hormone treatment for producing minitubers in the growth chamber, and that planting in open flats yielded larger tubers than planting in individual cells. While increasing plant numbers yielded a higher number of tubers, the size was very small and not significantly larger than what we can produce *in vitro* . Because of the smaller tuber size, we decided to perform the fertility experiment in the greenhouse which produced much larger tubers. We demonstrated that Miracle Grow Slow release with Calcium produced the best yield. This is a significant finding that will be passed onto minituber growers who are currently using periodic fertilization with soluble fertilizers.

For objective 3, the development of the new database gives our program the first-ever opportunity to track seed lot data back over multiple years and establish seed lot numbers. Our previous database only documented certification data 1 year at a time and did not track seed lot numbers. This has assisted us in evaluating certification applications because if a seed lot that is being used as a seed source does not show up in the previous data base it shows a red flag which tells us that we need to contact that grower to determine whether or not they are planting a seed lot that is eligible for recertification. Our staff retroactively entered data back to 2009 so that at this point, every seedlot that is currently in our certification system can be traced back to the nuclear generation.

Lessons Learned:

Performing the multitude of assays with PVX, PVA and PVY established confidence in our laboratory staff in the real-time PCR technique. It has enabled us to perform these assays on a routine basis and with a very quick turn-around time. We determined that while growing minitubers in the growth chamber may be informative from a research perspective, growing in a greenhouse is what is demanded by the growers, and that practical research efforts should be directed there. The database was originally to be constructed by a database specialist with the MSU College of Agriculture. He worked with us to develop the original framework for the database but then retired. We hired a computer science student on a part time basis to construct the database and it functions quite well, but there are some small glitches. All of these have work arounds, but a database is never truly finished and requires updates and maintenance. It is difficult for our laboratory supervisor to find the time to optimize all of the functions, and also difficult to find anyone that can come in from outside to perform tune-ups. This is a problem that is difficult to fix, because the College of Agriculture no longer supports a database position. It may have been better to contract with someone who could have worked with the database on long term basis.

Beneficiaries:

All seed potato growers will benefit from our enhanced diagnostic capability which has already resulted in a reduced amount of time to deliver a diagnosis. To date, 35 of our growers (70% of all Montana growers) have requested real-time PCR testing for pathogen screening. All of the tissue culture stock that the lab maintains is tested yearly for 8 different pathogens. Since adoption of this technique, we have been able to do much more testing “in house” which has reduced the costs of our tissue culture program and results in lower costs to all growers. Adoption of real-time PCR has allowed us to develop a reliable assay to detect viruses in tubers which can substitute for winter grow out results. Before PCR, if we had to do virus assays on tubers, the tubers had to be sprouted first which usually took about 3 weeks before the sprouts could be sampled an analyzed with ELISA. If a grower is exporting to Canada, they may need the results in less than a week. Real-time PCR is also being used for the detection of bacterial ring rot, a new test that is being required to fulfill commercial contracts. Farmers growing minitubers will be able to increase their yields by using slow release fertilizer with calcium rather than soluble periodic feedings. Small farmers with smaller greenhouse facilities will benefit from a method to increase the number of tubers that are produced per ft^2 of greenhouse space. To date, 1 grower has used our information to set up a growth-chamber like mini-tuber growing system. Part of the original impetus to develop a new database was to designated our seedlots by number. This is to allow for our buyers to document the origin of specific seedlots to comply with Good Agricultural Practices. Our certification program benefits from the ability of the database to trace seedlots back to the nuclear generation, and also confirm whether a seedlot which is being used for planting was properly documented in previous years. The results of this project have been presented to all growers at each annual growers meeting, and the fee schedule for PCR testing was outlined in the Potato Lab newsletter.

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Sweet Cherry Variety Trials on Flathead Lake

Project Summary:

The Flathead cherry industry produces over 4 million lbs. of cherries per year with a previous value of over $3.5 million. The research project proposed in 2009 will increase the cherry growers competitiveness through variety selection of larger and firmer cherries. This is the first step in establishing Montana based processing of Flathead cherries in order to meet the demand for more locally grown products and make the cherry industry more profitable. Cherry growers are currently receiving only 40-60 cents per pound from Washington State food processors. With new varieties and Montana processing, growers can expect to double their income.

Cherry trees take approximately five years to reach maturity and full production. In 2009, Washington State processors did not accept 80% of the Flathead cherries and there was no alternative production facility. Many growers did not receive compensation for their produce in 2009. This situation continued through 2012.

Flathead Cherry growers have received at least $1.00 per pound in the past. This price is expected to be a conservative estimate for new varieties of cherries that can compete with Washington cherries and be processed in Montana. The push by citizens for local foods in schools, grocery stores, farmers markets and institutions is an additional benefit to the Flathead cherry industry.

The Flathead Cherry Growers, partnering with Flathead County Extension, sought funds to perform variety trials around Flathead Lake that would identify those cherries best adapted to Montana conditions. Winter hardiness, pest and disease resistance, production techniques and production rates are being compared. New varieties have been developed in British Columbia and Washington State. These trees needed to be grown and tested on Montana producer's fields. In 2012, the Monson Food Company, refused the Montana Lambert cherry. After this harvest, many growers cut down their trees and began ordering replacements. The initial data was timely for these cherry producers.

Montana does not have a horticulture specialist with knowledge of cherries. This project required the hiring of a temporary research assistant to complete the work in the trials and a research consultant from Washington State University. Without these individuals the research would not proceed. Plots had to be designed, planting supervised, trees monitored during the growing season and data collected. This project filled the need for sweet cherry research in Montana for the Flathead Cherry Industry.

The Montana Department of Agriculture Growth through Agriculture Program provided the intial funding for the trees and planting materials. The Speciality Crop Block Grant was needed to hire the research scientist for Washington and the research assistant to tend the plots.

Project Approach:

Work Plan:

Six, previously untested in Montana, varieties of cherry trees were planted on six orchards around Flathead Lake in May 2010. A total of 264 trees were planted in replicated trials and an additional 44 trees planted in an organic orchard in 2011. Orchards were identified that exhibited a difference in elevation and climate conditions. The varieties were selected by an advisory group consisting of organic and conventional cherry growers from the area. These varieties were approved and the plots designed by consultant, Dr. Matt Whiting from Washington State University. Each plot was replicated and trees planted in the same order with the same pollinator trees.

Patricia McGlynn, Montana State University Extension Agent, acted as PI and project manager. Dr. McGlynn conducted budget oversight, completed reports, scheduled meetings, set agendas, organized research time line and ordered materials. This work began fall of 2009 and will continue through August 2014. Dr. McGlynn interviewed potential project hosts and conducted field inspections.

Matthew Whiting, Washington State Associate Scientist & Professor, Extension Specialist E-3, served as scientific advisor. Dr. Whiting made the final decision on variety selection and production techniques. He also determined planting design and defined planting specifications. Dr. Whiting visited each site twice a year and met with orchard owners to discuss best management practices.

Flathead Lake cherry growers initiated the call for research. They supported the project by suggesting variety selections, maintaining the research trials, donating labor and acreage for plots, conducting tours and field days and evaluating the trials. These growers began planning fall of 2009 and will continue caring for the trees through August 2014.

A research assistant collected data on the trees and helped with analysis. This person assisted with PI duties. The assistant was hired on a part time basis May 2010. The assistant worked through the 6 month growing season. Data collected was bloom time, vigor, and winter survivability. In 2013, the first fruit was evident but due to an early frost many of the trees did not provide a full harvest. Production rates will be examined in July 2014.

Cherry trees were ordered in 2009 and plots were established May 2010. An additional organic plot was added to the study in 2011. Data was collected and recorded on a weekly basis throughout the growing season. Data will continue to be analyzed for five years total. The assistant and the consultant, Dr. Whiting, were hired from 2010 to 2013.

The variety trials will be the initial phase of a strategy to promote and bolster the cherry industry. Concurrently, efforts are being made by the farmers to establish new distribution channels and improve marketing. Value-added products are being investigated and institutional collaborations are being established for the production of canned cherries to schools and prisons. It was imperative that test varieties of cherries were planted on producer's fields in Montana to begin the process of making the industry sustainable.

Goals and Outcomes Achieved:

The purpose of the project was to establish research trials that test six new varieties of sweet cherries on Flathead Lake in order to identify at least one variety to replace the Lambert traditionally grown.

This will help the cherry growers manage their risk when choosing and transitioning to new varieties of trees. There was no research being conducted in Montana to support the cherry industry. This research increases the grower's chances for success by testing under Montana conditions. The new varieties being tested were developed in British Columbia, Washington and New York. Processing facilities are demanding larger fruit and later varieties. Through this research, growers can identify and then plant the varieties that are the most hardy, provide increased production and have the attributes desired by the public.

Continued profitability of the cherry growers is paramount to sustaining the industry. The cherry industry in turn supports the local communities around the lake. Flathead Valley tourism amounts to over $140 million annually. Tourists are attracted to the area because of the natural beauty created by the orchards and pristine water quality. Flathead Lake hotels and restaurants depend on the tourists. Over 200 jobs are directly related to the cherry industry.

This research will enable the Flathead Lake Cherry growers to make the most educated decisions on new varieties that subsequently lead to securing new markets. New markets hold the potential to increase profits by securing a position at the processing facilities. Larger and larger fruit is required to stay competitive. A later variety opens a window of opportunity to markets that cannot be filled by other states. New varieties allow some growers to open their farm stands earlier and leave them open longer for local fresh fruit purchases. This is the most lucrative alternative for growers.

The trees being tested will be visible to other growers and will eliminate the need to travel to Washington or Oregon to see new varieties in production. Annual reports were distributed and field days conducted with tours of the plots for all Flathead Lake cherry growers.

1. The first goal of the project is to establish research variety trials on Flathead Lake. The measureable outcome would be the actual planting of the trees, data collection, and documentation of results.
2. The second goal is to help cherry growers manage their risk when selecting new cherry varieties. The objective is to increase profitability. The second measureable outcome would be the identification of cherry varieties that excel under Montana conditions and publication of the information.

At this time only approximately 10 growers have started transitioning their orchards to new varieties. Many growers are waiting until the research trees produce a full harvest in their fifth year. The growers that have reported planting new varieties are Beighle, Swanberg, St. Sauver, Johnson, Hurst, Herring, ReDiesel, and Rogers. There could be more. The market keeps fluctuating. Washington State did not accept the Lamberts in 2011 and in 2012 but did take them in 2013 due to a crop failure in the west.

Both outcomes have been achieved. The Santina cherry has been identified as an early cherry, large and firm and great tasting. Santina is the cherry selected by a number of cherry growers that have road side stands. This cherry allows stands to open earlier and extend their season.

Based on these findings, my recommendations to the Montana cherry industry are as follows: Attika is a variety that is proving to be a real winner. The only challenge that this cherry suffered was not pollinating in cold weather. The tree is extremely vigorous and has large, tasty fruit. It appears to be resistant to splitting and stays on the tree a long time. The Regina preferred pollinating in cold weather which is more like its native Germany. At this time, since the weather is so unpredictable in Montana, the research shows that planting this variety in combination with others would be beneficial. Glory, is late maturing and shows great promise. Glory has large fruit and one of the favorites for taste. With another year's growth, this tree should produce heavily and more data can be collected. Pinedale Ruby has proven to be another late, large, great tasting cherry. The Ruby is as vigorous and productive as the Attika so far.

Out of the six varieties tested, four show extreme promise under Montana conditions. Some growers began planting the new varieties in spring 2013. Time will tell which ones of the four cherries ship and pack the best. We did not have as good of a crop to compare in 2013 as we had expected due to the frost at blossom time. The growers will be doing more fine tuning on their ranking in July 2014.

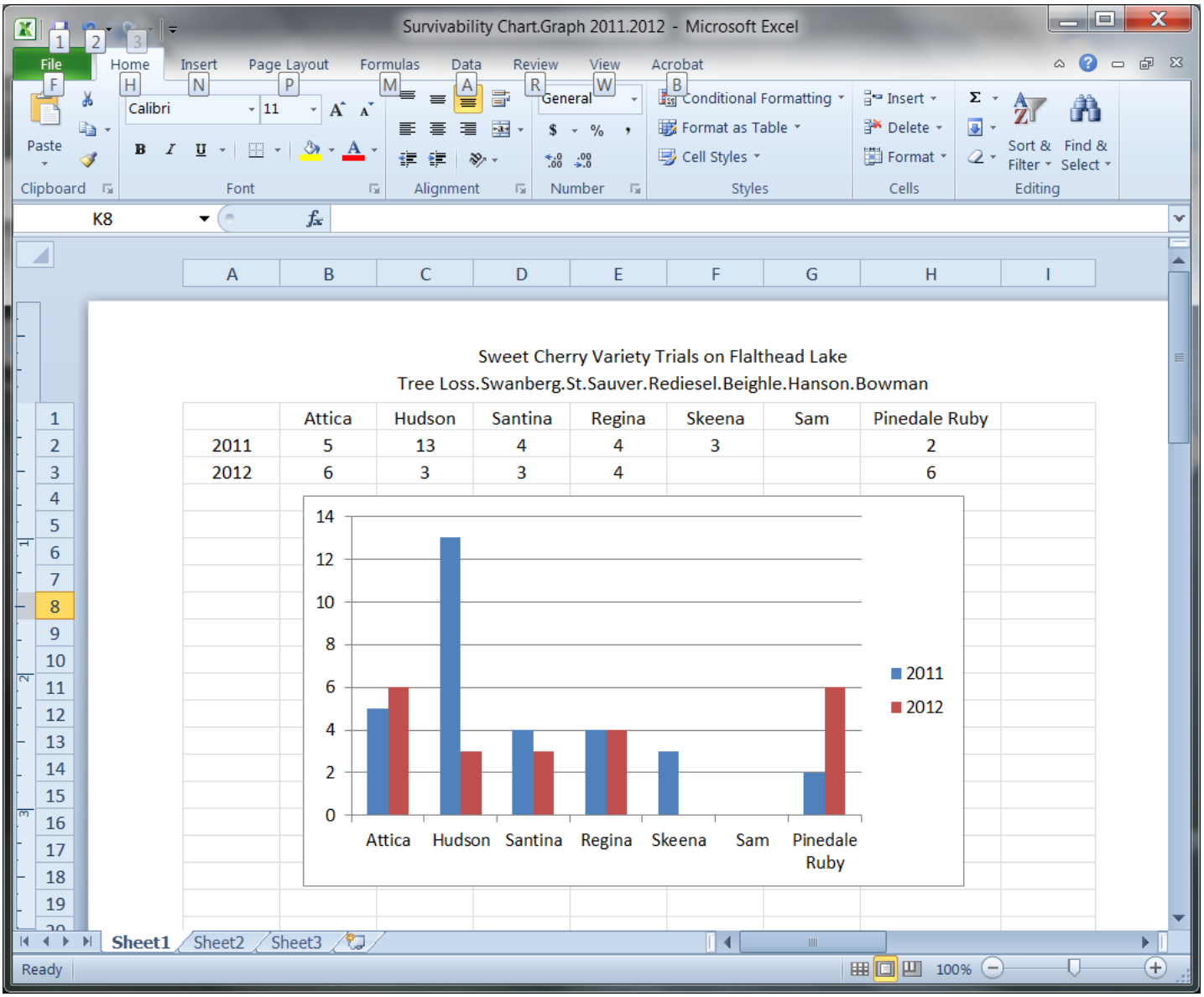
Annual reports were distributed at the annual grower meeting in 2012 and in 2013. Roughly 70 growers attend these meetings each year. The reports were distributed at the field days. In 2012, 27 growers attended the field days and in 2013, there were 64. I also provided the annual reports to the local library for a featured exhibit on the Flathead cherry industry. I mailed reports to local legislators to demonstrate what was happening with the industry. The grower group was not willing to share their mailing list so I uploaded a copy of the annual reports onto the Flathead Lake cherry co-op website so it is available in digital format to all growers. Co-op board members each received a few dozen annual reports to distribute to members. The pest management employee, Chris Beason, took the annual report with him and passed them out to people who may not have received them at general meetings.

Growers were able to dialogue with experts from Oregon and Washington State while learning new production methods.

Sample data

2012 Cherry Tree Distribution/Survivability

Grower	Attika	Hudson	Santina	**Regina**	Skeena	**Sam**	SR500	Glory(Goodwin)
Swanberg	1 dead							
St. Sauver	2 dead	1 dead	1 ½ dead					2 new
Rediesel		1 dead	2 dead				2 dead	5 new
Hanson	3 dead	1 dead		4 dead			4 dead	
Beighle								2 new
Rogers								
Bowman								
Other:								
Herring								5 new
Lawrence								1 new



Lessons Learned:

There is a great deal of variability when research is performed on host sited versus in an experiment station. The plots were challenged with a number of issues. One producer lost his irrigation for a summer and many of his trees did not survive. An especially deep snow enabled deer to climb over fences and eat the trees in two of the plots. The first spring we learned that a fungus disease had entered many of the young trees through the dormant pruning process. Our consultant suggested in the future pruning during flowering which is not normal timing. This appears to be a problem in Montana due to the wet spring season. One grower did not understand the importance of replication in all research plots and planted his trees out of order and not according to the design.

In spite of these setbacks, growing the trees under normal grower's conditions proved invaluable. The soils were different around the lake; fertilizer applications varied; pruning varied. Growers had their own favorites by the end of the trial. The growers felt ownership and really took the initiative to inform their peers about the progress.

As the facilitator, a huge impact that I observed was that cherry growers were getting together at field days and talking with one another. Co-op members, independents, organic and conventional growers were meeting for the first time to talk about the research. There was no other avenue for this to happen. Growers visited each other's orchards and began to dialogue about purchasing and marketing together. This was an extra benefit. This group took a trip together to tour the research at Washington State University. The camaraderie that was built will last way into the future.

The cherry grower's co-op learned new ways of making decisions and finding consensus within the group. A few of the board members were research hosts. These members used the research to spring board new ideas to the group.

Beneficiaries:

Montana cherry growers: Montana cherry growers needed research on new cherry varieties in order to decide on transition strategies for their current orchards. Planting new varieties of cherries was the first step in making the cherry industry profitable once more. Identification of new varieties may be the key component of greatly increasing the price of cherries and keeping Montana competitive in the cherry industry. Processing in Montana, improved distribution channels and developing value-added products, will all be addressed in the next phase. Sales of new cherries may bring Montana sales up past $5 million once new plantings have matured. There are about 150 cherry growers and I feel they have all benefitted in one way or another from this research. There have been 34 newspaper, radio and television broadcasts about the cherry research. All of the growers I have spoken with say that the general public is much more aware of the industry due to the research. Sales are up at the roadside stands due to increased visibility and awareness. The growers have also benefitted from learning the scientific method of comparing varieties and creating new partnerships. The dynamics of the co-op board has shifted in large part from new relationships forming over the research meetings. There are eight new orchards starting on Finley Point due to new interest in the industry. Growers are just now beginning to plant new varieties and adoption will take some time. After all, the old Lamberts have been there over 100 years.

Montana residents: Montana cherry growers will continue to hire seasonal help. There are currently over 130 orchards on the lake and depend on hired labor for harvest. Development pressure will be decreased and the attraction of Flathead Lake by tourists will be maintained. The communities around the lake depend on tourists for their livelihood.

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Dry Pea and Bean Cultivar Research and Selection

Project Summary:

Although Montana is considered as the largest dry pea producer in the USA, variety development and agronomic research are inadequate, especially for Chickpea and marrowfat pea. Due to *Ascochyta* blight disease chickpea production acres remain low in Montana, even though the chickpeas have higher market prices.

The PI at the Central Agricultural Research Center (CARC), Montana State University (MSU) worked with breeders from Pacific Northwest, Canada, and Europe to evaluate chickpea and marrowfat pea varieties and breeding lines for potential adaptation to Montana environment and produce good yield and quality. Three commercial marrowfat pea varieties were evaluated for their yields and seed sizes in Montana. Several breeding lines were also selected and tested. Marrowfat pea yields are related to seed size; bigger seed sized varieties generally have lower yields, and marrowfat pea yields are lower than common dry peas under dryland production.

For chickpeas, several commercial varieties were planted and evaluated at multiple locations in Montana. The newly developed CDC Frontier, CDC Orion, and CDC Alma showed good disease resistance and good stable yields. Therefore, these varieties are recommended to Montana producers to grow. Several advanced breeding lines from USDA-ARS Pullman breeding program also showed competitive yields and disease resistance compared to CDC Frontier. These lines will be further tested and released to market for farmers to grow. Several breeding lines selected from the segregating populations showed promising, and these lines will be further tested at multiple locations in Montana for adaptability, disease resistance, yield potential and quality.

Project Approach:

Plant breeding and cultivar development takes many years before a suitable cultivar is developed and accepted by producers. To expedite the selection process, we adopted two approaches: 1) screening existing commercial varieties and testing those varieties at multiple locations in Montana; 2) developing breeding lines from selected single plants and testing these lines for yield potential and quality in Montana.

1. Marrowfat Peas

There commercial marrowfat pea varieties, Supra, Guido, and Big Daddy, and several advanced breeding lines were planted at Moccasin to test their adaptability and yield potential in 2011, 2012, and 2013.

In addition, a nursery of marrowfat pea segregating breeding populations was planted in 2009 at Moccasin, MT. Single plants were selected and seeds were threshed. The seeds were planted in single rows in 2010, and breeding lines were selected. Those selected breeding lines were tested in 2011, 2012, and 2013, and further selections were conducted.

2. Chickpeas

Several existing commercial chickpea varieties were planted and evaluated at multiple locations in Montana under dryland and irrigation conditions for their adaptability, yield potential, and disease resistance in 2011, 2012, and 2013.

In addition, a chickpea nursery of segregating breeding populations was planted at Moccasin in the spring 2009, and individual plants that demonstrate good agronomic characteristic and seed quality were selected from the segregating breeding populations. The breeding material included in those nurseries was specifically selected to address the problems of Montana. Specifically, chickpea breeding populations for inclusion in the nursery included those with genes for resistance to the prevailing pathotypes of *Ascochyta rabiei* that cause *Ascochyta* blight, large seed size and high yields. Those selected individual plants were threshed separately in the laboratory by hand. Seeds collected from each plant were planted in a single row trial using a single row planter in spring 2010. Plants from each single row were harvested and threshed by hand. Seeds from those single rows were examined and screened for quality and potential end users. The selected lines were further planted and evaluated in 2012 and 2013.

Crop tours and field days were organized at several of the testing sites to give producers a visual comparison of cultivar performances in 2011, 2012, and 2013. Montana Pulse Day was organized by Northern Pulse Growers and Montana Department of Agriculture once a year in 2009, 2010, 2011, 2012, and 2013. More than 200 people attended the event each year and the PI presented the research results from this project at these events.

Goals and Outcomes Achieved:

The ultimate goal of this project is to select and develop suitable cultivars of marrowfat pea and chickpea that adapted well to Montana's climate and soil conditions with disease resistance, high yield, and good quality.

Results of Marrowfat pea line selection and testing:

Data in Table 1 showed that the selected breeding lines did not show yield advantage over the commercial varieties. Marrowfat pea yields ranged from 673 to 954 lbs/a in 2011, and from 930 to 1038 lbs/a in 2012. There is a trend that bigger seed sized varieties had lower seed yields (Table 1). Marrowfat pea yields are generally lower than common dry peas under dryland production. Therefore, marrowfat peas must receive higher price premium to compensate the lower yield compared to common dry peas. It is not clear if the marrowfat peas show yield advantage over common dry peas under irrigation. This research team will conduct a study under irrigation in 2013 when seeds are available.

At this moment, the economic advantage of growing marrowfat peas is not clear compared to yellow or green dry peas. Furthermore, due to the big seed size, marrowfat peas are susceptible to harvest damage by a harvest machines. Therefore, we recommend two varieties Guido and Supra for farmers to grow, but net economic returns needs to be accessed.

Due to the big seed size, marrowfat peas are susceptible to harvest damage by a harvest combine. The seed coat of the marrowfat peas were damaged when we were harvesting 2012 plots, which resulted in low germinations in 2013, therefore, the yield data in 2013 were discarded. We saved the seed for the study under irrigation in 2014.

During the project period, we have selected five marrowfat lines (PS0877MT663, PS0877MT621, PS0877MT625, PS0877MT624, and PS0877MT833). In addition, we tested three commercial varieties (Big Daddy, Guido, Supra) and three advanced breeding lines (PS99101364, PS99101365, and PS02100740) at Moccasin, MT in 2011, 2012, and 2013. The yields and seed sizes are presented in Table 1. During the research center field days in 2011, 2012, and 2013, the PI

gave presentations to about 120 producers each year about marrowfat pea production technologies, yield potential, and cautions.

Table 1. Marrow fat pea yield, test weight, and seed weight at Moccasin, MT in 2011 and 2012.

	2011		2012	
Variety	**Yield (lb/a)**	**Seed wt (g/100seeds)**	**Yield (lb/a)**	**Seed wt (g/100seeds)**
PS02100740	954	32.4	1029	28.36
PS99101365	686	34.2	841	25.84
PS99101364	673	34.2	930	27.18
Supra	806	34.9	1038	30.20
Guido	679	37.6	955	40.14
Big Daddy	705	36.3	947	30.84

Results of Chickpea line selection and testing:
Commercial chickpea varieties CDC Frontier, Dwelley, Dylan, Myles, Sawyer, Sierra, CDC Alma, and CDC Orion were tested at multiple locations in 2011, 2012, and 2013 (Table 2).

Table 2. Commercial varieties were tested at multiple locations in Montana in 2011, 2012, and 2013.

Year and Variety	Locations and Yield (lb/a)					
	Bozeman (dryland)	**Conrad (dryland)**	**Corvallis (irrigated)**	**Huntley (irrigated)**	**Moccasin (dryland)**	**Richland (dryland)**
2011						
CDC Frontier		3422			824	1606
Dwelley		2474			817	467
Dylan		2872			1047	574
Myles		2749			996	1096
Sawyer		2906			1062	1328
Sierra		2739			990	710
2012						
CDC Alma						
CDC Frontier	875	2103	1971	2745	605	2488
CDC Orion	852	2090	---	3167	1619	1907
Dwelley	---	---	1189	2052	570	58
Myles	994	1626	1693	2668	964	1588
Sawyer	777	1493	1308	2544	786	782
Sierra	450	1311	1477	1935	657	180
2013						
CDC Frontier	1594	1936		2605	1420	2951
Myles	1233	1757		3225	1392	2584
CDC Orion	1574	1846		1521	1806	2930
CDC Alma	1396	1610		1467	1533	2704

Results showed that the newly developed varieties, such as CDC Frontier and CDC Orion, had better disease resistance and stable yields. The yield variations at Richland site was due to *Ascochyta* blight (Fig. 1). CDC Frontier and CDC Orion were identified as adaptable varieties with relatively good disease resistance and higher yields. Therefore, these two varieties were recommended to growers to grow in Montana.
CDC Frontier and CDC Orion were identified as adaptable varieties with relatively good disease resistance and higher yields. Therefore, these two varieties were recommended to growers to grow in Montana.

Fig. 1. A picture of chickpea testing plots at Richland, MT showing disease susceptible and resistant varieties.

In addition, several advanced breeding lines from USDA-ARS Pullman were tested at three locations in Montana (Table 3). Some of the advanced breeding lines showed equivalent or better yields and disease resistance compared to top commercial varieties (Table 3).

Breeding lines developed from single plants selected from segregating populations also showed promising (Table 4). Among the 24 selected breeding lines, nine top lines had yields equivalent to CDC Orion, CDC Alma, and CDC Frontier. These lines will be planted in replicated trials at multiple locations in Montana in 2014 to test their adaptability, disease resistance, and yield potential.

The information of suitable chickpea varieties and production techniques gained from this project were shared with producers at 1) CARC Field Day in 2011, 2012, and 2013 (120 attendees each year); 2) Richland Crop Tour in 2011, 2012, and 2013 (60 farmers each year); 3) WARC Field Day in 2012 (about 60 attendees); 4) Organic Growers Meeting in 2013 (about 30 organic growers attended); and 5) Montana Pulse Day in 2011, 2012, and 2013 (about 200 attendees each year). Most noteworthy is that several organic producers adopted the information and had a successful chickpea crop in 2013.

In summary, we have made good progress in this marrowfat pea and chickpea cultivar selection and testing project. Some breeding lines show higher yield potential compared to check varieties in the trials. A few advanced chickpea breeding lines showed good disease resistance and higher yields. With the large production area in Montana, a small yield increase and good disease resistance in new varieties can make a big difference to the industry.

Table 3. Advanced breeding lines were evaluated at three locations in Montana in 2011, 2012, and 2013.

Year/breeding line	**Location/yield (lb/a)**		
2011	**Corvallis (irrigated)**	**Moccasin (dryland)**	**Richland (dryland)**
CA0390B007C		964	1241
CA04900421C		1029	1593
CA04900843C		1105	987
CA0690B0250C		994	755
CA0690B0409C		1045	1082
IS-14		919	687

2012			
CA0469C025C	1963	905	2589
CA04900421C	1870	1223	910
CA0690B0427C	1746	659	759
CA0790B0042C	1801	981	201
2013			
BGC08009M		2084	3358
BGC090023		1812	2619
BGC08008M		1810	2339
CA0890B0427C		1807	1063
BGC090016		1719	2019
CA0790B0549C		1700	287
CA0790B0042C		1600	506
CA0790B0547C		1551	1617

Beneficiaries:

As of 2013, dry pea acres in Montana have reached 380,000 acres, producing 722,000,000 lbs dry peas. Montana surpassed North Dakota becoming the #1 producer of dry pea in USA. Although this expansion of the production area is mainly resulted from good economic returns and rotation benefits of dry peas, the multi-location variety trials have provided visual demonstration of dry pea performance to farmers in different climate and soil zones of Montana.

Chickpea planting acres have increased from 9,000 acres in 2011 to 23,000 acres in 2012, but back to 13,900 acres in 2013. The chickpea acres decrease in 2013 was likely due to the large increase of dry pea production area; dry pea acres increased from 293,000 acres in 2012 to 380,000 acres in 2013. The decrease of chickpea acres in 2013 may also indicate that farmers are cautious in planting chickpeas due to the risk of disease infestation.

Marrowfat pea production acre is minimal in Montana. As demonstrated in this project, marrowfat pea yield is lower than common dry pea in dry land. In order to have farmer to grow marrowfat peas, the market premium must offset the yield reduction compared to common dry peas.

Field days organized at each of MSU research centers, and the Montana Pulse Days organized by Northern Pulse Growers and Montana Department of Agriculture each year have provided more comprehensive information to producers on pea and chickpea variety performance, production technology, and economical returns. As mentioned above, the PI of this project not only has given presentations to field days at three testing sites (CARC, WARC, and Richland farmers land) where 60-120 people attended each year, but also presented the project results to Montana Pulse Day once a year, where more than 200 people attended the conference each year. The attendees include pulse crop producers, Montana Pulse Crop Advisory Committee members, Northern Pulse Growers Association executive committee members, USA Dry Pea and Lentil Council officials, and pulse crop processers and buyers from USA and the world. The information generated from this project, as well as from the USA Dry Pea and Lentil Council (USDPL) and Northern Pulse Growers Association (NPGA) funded projects, was presented at above events. Because part of the USDPL and NPGA grants were used as matching fund for this project, we presented information from both this SCBG and USADPL and NPGA funded project. A 45-page annual report was published each year and distributed to 500 producers and industrial personnel (not include many electronic copies delivered by email and website downloading).

All these activities have helped Montana farmers to understand and adopt these specialty crops. The expansion of pea and chickpea planting areas from northeastern Montana to central and north central Montana may reflect a portion of the beneficiaries of this research project. Because of the expansion of production areas, several pea and chickpea buyers have set up buying and processing facilities at several locations in Montana.

Table 4. Yields of breeding lines developed from single plants selected from segregating populations at Moccasin, MT in 2013.

Variety/line	Yield (lb/a)		Variety/line	Yield (lb/a)
CDC Orion	1806		CA0879MT251	1357
CA0879MT394	1766		CA0879MT481	1296
CA0879MT445	1754		CA0879MT484	1285
CA0879MT291	1622		CA0879MT291	1282
CA0879MT254	1618		CA0879MT043	1246
CA0879MT292	1599		CA0879MT074	1196
CA0879MT443	1574		CA0879MT111	1192
CA0879MT394	1568		CA0879MT252	1189
CDC Alma	1533		CA0879MT044	1091
CA0879MT075	1523		CA0879MT391	1079
CA0879MT485	1459		CA0879MT393	1065
CDC Frontier	1420		CA0879MT071	1047
Myles	1392		CA0879MT392	501
CA0879MT072	1389		CA0879MT482	411

Lessons Learned:

Chickpea is most susceptible to *Ascochyta* blight. Several chickpea cultivars performed well at central Montana were severely damaged by the disease at northeastern Montana. Cultivar development for *Ascochyta* resistance will be a multi-year effort. We are happy to see better disease resistance and stable yields of several newly developed commercial varieties and advanced breeding lines in this project. The integrated pest management (IPM) strategies (including disease resistant cultivars, fungicide applications, and cultural practices) will be needed for chickpea production.

Environment specific cultivar selection had to start from single plant selection, and the seed increase takes several years. Due to the limited amount seed available, multi-location testing for the breeding lines selected in Montana will occur in 2014.

Herbicide management and record keeping is very important for pea and chickpea production. In 2012, the chickpea breeding line evaluation trial at Moccasin was damaged by residual herbicide in soil, but we collected seeds from survival plants for 2013 trial.

Due to the big seed size, marrowfat pea seed coat can be easily damaged by harvest machine, which will affect quality as seed or marketing commodity. Therefore, combine must be set appropriately before harvesting marrowfat peas.

Additional Information:

The funding from this Specialty Crop Block Grant was used to support the planting, selection, harvesting, and sample processing of marrowfat pea and chickpea plant population and single row nurseries. Additional funding was received from Montana Agricultural Experiment Station and USA Dry Pea and Lentil Council as matching fund to support multi-location pea and chickpea variety trials across Montana. The PI's salary is paid by Montana State University.

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Export Assistance & Development for Specialty Crops

Project Summary:

The Montana Department of Agriculture issues over 500 specialty crop federal phytosanitary certificates annually through an agreement with USDA-APHIS-PPQ. The largest user of this service is located over 100 miles from the nearest inspection office. The current funding model for the issuance of federal phytosanitary certificates for some Montana specialty crops (e.g. small lots of nursery seed) does not cover the cost associated with providing the service. The grant funds were utilized to continue offering phytosanitary certification for Montana specialty crops while alternative funding methods are being explored. Without these grant funds Montana specialty crop producer access to these service and world markets would have been limited by the current program budget. The Department used funds to provide phytosanitary export certification services to specialty crop producers in Montana and, in doing so, kept producer costs at a minimum by offsetting expenditures incurred by the Department for providing the service. Grant funds were successful in assisting in the issuance of over 1,000 specialty crop phytosanitary certificates from January 1, 2011 to December 31, 2013 to twenty-three businesses. Certificates were issued for the following Montana specialty crops: plant material, tree and plant seeds, potato tubers, cherries, and mint plants.

Foreign markets require documentation that agricultural products meet phytosanitary requirements. Without phytosantiary certificates, products cannot be exported.

The program generates between $35,000 and $37,000 a year in revenue through fees for phytosanitary certification. Fees are the sole source of state funding for phytosanitary certification. Fees represent approximately 21% of the funding needed to pay the costs associated with providing the service. All state funds generated through fees were used to pay expenditures of phytosanitary certification services. The federal grant funds were used to supplement the state funds in meeting expenditures not covered by the state funds.

Project Approach:

The Montana Department of Agriculture employs nine field inspectors at remote location throughout the State to provide timely phytosanitary inspection services. All of these inspectors have annual operating expenses that cannot be easily recovered by fee-for-service programs. Grant funds were used to support the operating costs of the inspection and certification costs of over 1,000 specialty crop phytosanitary certificates issued from January 1, 2011 to December 31, 2013. Only after having been awarded the grant, did we realize that we could not utilize grant funds to cover personnel costs because it is considered supplanting, i.e., we intended to pay existing staff salary and benefits. The funding was utilized by itemizing inspection and other operating costs per each individual specialty crop phytosanitary certificate over the 3 year funding period. Single certificate costs were only charge for specialty crops and annual operating costs (e.g. windshield replacements, tire replacements, car washes, oil changes, etc.) were charged proportionally based on specialty crops as a percentage of total certificates issued by an individual inspector.

Goals and Outcome Achieved:

The grant has supported the issuance and international export of Montana specialty crops. Over 1,000 specialty crop phytosanitary certificates were issued by Department inspectors between January 1, 2011 and December 31, 2013.

The grant supported the issuance of 2,036 different specialty crop type shipments. Under the current fee structure, specialty crop producers paid certificate fees totaling approximately $150,155 (1,527 non-commercial certificates x $23= $35,121 plus 509 commercial certificates x $50= $25,450, plus $44 per inspection= $89,584) during the three year grant period. If the Department had raised fees as proposed ($105 for non-commercial and $180 for commercial), the same producers would have paid $251,955, a savings to Montana specialty crop producers of $101,800.

Lessons Learned:

A financial review of the program has been completed and the Department is proceeding with raising export certification fees to allow the program to function within its fee-for-service structure.

Beneficiaries:

Twenty-three Montana specialty crop businesses received phyosanitary certificates supported by this grant. These businesses included fruit tree nursery stock exporters, specialty seed dealers, seed potato producers, cherry producers, and mint plant producers.

As an example, Glacier Fresh Cherries was issued 243 federal phytosanitary certificates during the funding period for the international exportation of fresh cherries. This service cost the business approximately $22,842 between 2011 and 2013. In the absence of federal support the Department would have raised fees in 2011 and this company would have paid approximately $38,880, a savings of $16,038.

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Montana Grown Specialty Crop Nutrition and Promotion Campaign in Montana Schools

Project Summary:

Lake County Community Development Food and Ag Center and the Mission Mountain Food Enterprise Processing Facility (The Center) are divisions of Lake County Community Development Corporation (LCCDC). The Center provides expertise in food business development and incubation to individual enterprises, cooperatives, and specialty crop producers. This project will build the capacity of The Center to meet the growing opportunity of a Farm to Institution market for specialty crops through a Buy Fresh Buy Local campaign to Montana institutions. Through efficient processing, a focused market campaign and education program our center proposes there will be a direct increase in the usage of local specialty crops, which will bring an increased revenue stream to specialty crop producers.

The center's request for $49,868 from the USDA Specialty Crop Block Grant Program supported this unique farm to institution project modeled after the University of Minnesota Farm to School toolkit for food service that aligns with the USDA's Food Nutrition Services HealthierUS Challenge's goal to raise a healthier generation of kids.[1] This project directly served specialty crop producers in western Montana by increasing awareness of the nutritional value of their crops and increased their sales through value added processing for the institutional marketplace.

Project Approach:

The Mission Mountain Food Enterprise Center (MMFEC) launched a Farm to Institution Program in 2010 with the focus of increasing the usage of value added specialty crops to local school districts and other Montana institutions. The project approach was collaborative in that our core partner, Western Montana Growers Cooperative (WMGC) who has 39 specialty crop producers as member owners and they were the source of the raw product that was value added in MMFEC's food processing facility. Since that time the center has increased sales of specialty crops to Farm to School from WMGC producers by 97%. The cooperative sales started with three school districts in 2010-2011 totally $1,417.00 and grew to eight school districts in October 2012-September 2013 with a total annual sales of $50,445.00. Overall total sales from Oct 2010 to Sept 2013 for the cooperative were $73,268.00 which directly supported the specialty crop producer-members of the cooperative. Our center, in collaboration with the Montana Food Corp Vista Program, worked extensively with local schools and universities to establish markets for the value added products. The Food Corp program grew out of Montana to become the National Food Corp Service Member Program and our center hosted a service

[1] University of Minnesota. Farm to School: Minnesota toolkit for food service. Retrieved from http://www.mn-farmtoschool.umn.edu/default.htm

member in 2011, 2012 and is continuing the program in 2013. We established relationships and developed sales with eleven schools in Montana which far exceeded our estimate that six schools would purchase locally produced and processed specialty crops through this program. During the time period of October 1, 2010 to September 30, 2013 the center processed 94,106 pounds of specialty crops[2] which again far exceeded our projected 57,000 pounds by year two. The center has created 3.0 FTE to meet the demand of the increase in food production and has retained 2.0 FTE. The new staff has undergone food safety training such ServeSafe, HACCP and Process Control School. Through a previous Specialty Crop Grant the center developed and adopted a full Food Safety Program and has trained staff to insure they uphold all of the recordkeeping, staff training and food safety procedures outlined in the plan.

The lentil patty recipe was fully developed, produced and tested in seven school districts. There was a mixed review from students. While speaking with many individuals, it became apparent that the students who enjoyed the lentil burger truly loved it and asked for seconds. Those who disliked it usually stated that they liked beef better and would rather stick with that. Many students simply refused to try it. The students offered name suggestions such as:

- Montana Veggie Burger
- The Killer
- Lentil bug
- Montana burger
- Flaming hot hamburger
- Valley Veggie Burger
- Big Sky Burger
- Montana Moose Burger

[2] Specialty Crops processed- carrots, apples, cucumbers, cherries, melon, watermelon, tomatoes, butternut squash, pumpkin, beets, mixed root vegetables, zucchini, cabbage, potatoes, onions, peas, broccoli

Goals and Outcomes Achieved:

Goals- Year 1	Benchmark	Target	Outcomes Achieved	monitoring/data collection used
Goal 1- Increase the capacity of The Center's processing facility to meet the quantity, form, quality, price, and food safety demands of farm to institution markets in order to increase the consumption of Montana grown specialty crops.	Currently there is limited capacity to meet these demands with only prototypes of 3 products developed for the institutional marketplace amounting to 5,000 lbs of specialty crops purchased.	The Center purchases approximately 27,000 lbs of specialty crops for farm to institution products resulting in approximately $21,000 in additional revenue for western MT producers - 1 new FTE created at the centers food processing facility and 2 FTE Retained	1) During the time period of 10/1/2011 to 9/30/ 2012 the center processed 17,339 pounds of specialty crops[3] 2) Total sales of WMGC from Oct 2011 to Sept 2012 for the cooperative were $21,406 3) The center created 1.5FTE and retained 2 FTE	1) LCCDC Quick books accounting system tracks all F2S sales and processing poundage and revenue. 2) WMGC Quickbooks accounting system F2S sales annual reports 3) LCCDC Payroll reporting
Goal 2- Increase child and adult nutritional knowledge of Montana grown Specialty Crops in institutional food service establishments	Currently there is no educational forum on the nutritional benefits of Locally grown (MT) specialty crops that local food service establishments can access.	A Buy Fresh Buy Local Farm to Institution market campaign developed and Website and promotional materials assembled	Thirteen promotional and educational posters on specialty crops have been designed- They can be viewed on the MMFEC website- www.mmfec.org	n/a
Goals- Year 2	Benchmark	Target	Outcomes Achieved	monitoring/data collection used

[3] Specialty Crops processed- carrots, apples, cucumbers, cherries, melon, watermelon, tomatoes, butternut squash, pumpkin, beets, mixed root vegetables, zucchini, cabbage, potatoes, onions, peas, broccoli

Goal 1- Increase the capacity of The Center's processing facility to meet the quantity, form, quality, price, and food safety demands of farm to institution markets in order to increase the consumption of Montana grown specialty crops.	There is increased capacity from Year 1 activities to meet farm to institution demands with only prototypes of 3 products developed for the institutional marketplace amounting to 5,000 lbs of specialty crops purchased.	-The Center purchases approximately 30,000 lbs of specialty crops for farm to institution products resulting in approximately $23,000 in additional revenue for western MT producers -1 new FTE position created at The Center's food processing facility -3,000 lentil burgers processed at The Center and test marketed to 6 local school districts during Harvest lunch week – approximately 3,000 students eat a western MT specialty crop each day of the week	During the time period of 10/1/2012 to 9/30/ 2013 the center processed 76,767 pounds of specialty crops 2) Total sales of WMGC from Oct 2012 to Sept 2013 for the cooperative were $50,445.00. 3) The center created an additional 1.5 FTE and retained 2 FTE 4) The lentil burger was developed and 2000# of lentil burgers were sold to local schools 5) 5 local schools have institutionalized local specialty crops in their weekly Fresh Snack programs and lunch programs	1) LCCDC Quick books accounting system tracks all F2S sales and processing poundage and revenue. 2) WMGC Quickbooks accounting system F2S sales annual reports 3) LCCDC Payroll reporting their revenue 4) LCCDC Quickbooks accounting system 5) Food Corp Service Member quarterly reports.

Goal 2- Increase child and adult nutritional knowledge of Montana grown Specialty Crops in institutional food service establishments	Currently there is no educational forum on the nutritional benefits of Locally grown (MT) specialty crops that local food service establishments can access. A website does not exist that schools can access to gain information on how they can purchase locally produced specialty crops and the nutritional value they will bring to school menu planning.	-An Buy Fresh Buy Local Farm to Institution market campaign is underway and with an increased awareness of the nutritional value of local specialty crops -Website launched -- 13 specialty crops highlighted complete with nutrition facts, promotion materials, and links to where to purchase Montana grown specialty crops	1) Eleven schools display the promotional posters. 2) The Food Corp Service member conducted 112 educational events and had 2191 interactions with students to increase awareness of the nutritional value of local specialty crops. 3) The MMFEC website (www.mmfec.org) has a Farm to Institution link that highlights the promotional posters and educational resources and links to purchase Montana grown specialty crops. The website is has an average of 461 hits daily.	1) Food Corp Service Member quarterly reports. 2) Food Corp Service Member quarterly reports.

In 2012 the centers sold approximately 2000# of lentil burgers but have experienced a drop off in 2013 due to lack of student enthusiasm. The product is under evaluation and a new product, lentil/beef crumble is under development.

In our report 12/2011 we indicated 17,339 pounds of specialty crops were processed for Farm to School from 10/2010-12/2011. In 12/2012 we reported 24,795 pounds of specialty crops were processed from 1/2011-12/2012. In our final report we reported that 76,767 pounds of specialty crops were processed for Farm to School from 10/1/2012- 9/30/2013. The program far exceeded the 27,000 pound projection and we have not experienced a decrease since the project started.

The program developed thirteen Farm to School Posters that are posted on MMFEC website (www.mmfec.org) The Farm to School Posters have been distributed to 11 schools and they are used in the Food Corp Service Member education plans. The Montana Office of Public Instruction Team Nutrition Program has requested publishing rights to the posters to use in their educational program. The Food Corp Service Member has conducted 112 individual lessons or events that are held in the classroom and highlight the nutritional facts of locally produced specialty crops. Her lesson plans are posted on the MMFEC website (www.mmfec.org) to share with teachers and other organizations interested in promoting local specialty crops. The service member also has documented 2191 interactions with students on a less formal basis that focuses on the nutritional value of specialty crops. Because of the program five schools have institutionalized local specialty crops in their weekly Fresh Snack program and school lunch programs.

LCCDC, on the advice of our web designer, opened a Google Analytics Account September 30, 2013. Since that date the LCCDC website has had a total of 8133 page views with 1300 hitting the MMFEC site. The promotional and educational posters are part of the MMFEC site but there is not specific recording through this service for hits to that page. Our web designer has been contacted and to conduct specific page analysis we would need to contract them to conduct that specific service.

Mission Mountain Food Enterprise Center, because of the success of the Farm to Institution Program value added products and the impact of the promotional materials has experienced a positive cash flow in the processing facility. Our

center is the sole processor of all the F2S products and the substantial demand for the products has increased our processing revenue by 30%. This program has established a foundation of collaboration between local specialty crop growers' cooperative, local schools and our center that is projected to grow by 25% in the next year.

Lake County Community Development Corporation (LCCDC) processing facility is DBA "The Mission Mountain Food Enterprise Center". MMFEC is operated and accounted for as a separate entity and all the revenue generated by MMFEC is used strictly for the operations of MMFEC. For the time period of this project (October 1, 2010- 9/30/2013) MMFEC generated a gross income of $69,250.00 in farm to school processing which was accounted for in a specific fund to track the progress of Farm to School. The revenue was strictly used to support processing staff and operational costs of the processing period for the Farm to School program. The Western Montana Growers Cooperative paid MMFEC for the processing of their specialty crops and the local schools purchased processed products from the growers cooperative. The pounds of products processed have been reported in our annual reports. None of the gross revenue generated from Farm to School processing have been used in supporting LCCDC program work or staff nor are any of LCCDC federal funds used to support operations of the processing facility.

Beneficiaries:

The beneficiaries of the project are threefold. Firstly the Western Montana Growers Cooperative producer members have had new markets for their specialty crops through the development of a Farm to Institution Program. The gross F2S sales for the cooperative during the time period of the project have been $73,268.00. Because the producers who supplied the raw product are member/owners of the cooperative they receive 80% of the sale of their products. Most of the producers are small scale operations that truly receive a direct benefit that increases the sustainability of their farm operations. Secondly, the school districts have received tools and resources to educate their students on the benefit of locally produced specialty crops. Five schools have institutionalized the use of locally produced specialty crops into their weekly food programs. The students are the ultimate beneficiary in that they are learning about the nutritional value of the foods they eat and they are learning about the farms their food comes from. All of this is creating an environment that is beneficial to the local farmer, local school and students.

Specifically, 38 Western Montana Growers Cooperative producer members benefited from this project. In 2013 at the close of this project the cooperative reported a profit which was shared amongst its members through dividends.

Student participation data is as follows:

School Name	**School District**	**# Students**
K. William Harvey Elementary	Ronan	390
Pablo Elementary	Ronan	244
Cherry Valley Elementary	Polson	288
Linderman Elementary	Polson	367
Polson Middle School	Polson	528
Edgerton	Kalispell	569
Russel	Kalispell	299
Elrod	Kalispell	320
Cornelius Hedges	Kalispell	373
Lillian Peterson	Kalispell	387
Kalispell Middle School	Kalispell	1038
	Total	**4803**

Finally the Mission Mountain Food Enterprise Center has the benefit of operating a Farm to Institution Program that is creating new revenue for the processing facility. The center has experienced a 25% increase in revenue and this has enabled the center to hire 3 new FTE and retain 2 FTE. The center also, because of the increase in processing, was able to secure a grant from the Montana Department of Agriculture and Good Works Foundation to install a new freezer to meet the final product inventory management of the program. This freezer is designated for F2S and is utilized by the Western Montana Growers Cooperative to store frozen inventory.

Lessons Learned:

This project had many lessons learned and the most important one is the business model this project has developed that is now a model for many Food Hubs and F2S programs across the nation. The project first started with MMFEC purchasing raw material from WMGC to process into value added products for F2S. After the first quarter of processing it was determined that it is very difficult for a not for profit to cash flow the inventory cost of raw product from local producers and carry the highest risk of the project. Therefore WMGC and MMFEC sat down and discussed how the structure of the product and cash flow could be designed to address the issue of one party carrying all the risk but how both parties could share the risk. A MOU was designed with the WMGC being the owner, marketer and distributor of the product and MMFEC would provide the value added processing services. MMFEC and WMGC met with area schools and agreed to develop a plan of costing that would meet the cooperatives' pricing needs, the schools' pricing needs and MMFEC processing costs. The plan was implemented in 2011-2013 and all parties have had their needs addressed. All parties have agreed to enter into a Cooperative Agreement in December of 2013 to formalize their relationships and to continue to build upon a very successful program.

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