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Project Title

Selecting for and Improving Chickpea Adaptation to Western Nebraska

Project Summary

Chickpea (*Cicer arietinum* L.) production in Nebraska has fluctuated over the past decade (1,500 acres in 2000, to almost 10,000 acres in 2006), but consumption has been increasing over this time. Unfortunately, less than 300 acres were planted in 2007 and 2008, zero in 2009, and about 100 acres in 2010, due primarily to Ascochyta blight incidence.
Although chickpeas are reported to be susceptible to more than 50 pathogens, Ascochyta blight (*Ascochyta rabiei*), a seed-borne disease, is the most limiting disease found in the Nebraska Panhandle. The pathogen attacks all aerial portions of the plant, and causes economic losses, due to reduced yields as well as reduced quality (up to 80%). For a crop like chickpeas, quality may be more important than gross yields, as payments for small discolored seeds (result of pod and seed infection) are significantly lowered. Because of the small profit margins for chickpeas in Nebraska, growers have been reluctant to make multiple fungicide applications for blight control. Seed treatments have been shown to improve initial stands, but do not protect from blight later in the season. Unless new cultivars with adequate levels of resistance are identified and implemented by growers, chickpea production in Nebraska will likely cease. Therefore, the main goal of this project was to identify chickpea cultivars with Ascochyta and root rot resistance for western Nebraska.

Project Approach and Goals and Outcomes Achieved

Experiments were carried out from 2012 to 2014 to access yield losses due to Ascochyta blight and to identify varieties with resistance. Twenty lines including eight cultivars and 14 experimental lines selected in 2012 were evaluated at the Panhandle Research and Extension Center (PHREC-Mitchell, NE) under irrigated conditions. Ascochyta blight was controlled with one fungicide treatment (LEM 17 EC) at flowering stage. The treatments were arranged in a split plot design, where the fungicide treatment (protected vs. non-protected) was the main plot, and the chickpea lines were assigned as sub-plots. Each treatment was replicated 4 times. PHREC-Ca-Comp. #1 and PI 17256 were used as tolerant checks. Additionally, thirteen experimental lines (PHREC-*Ca*-Comp. #1, PI 17256, CA0469C020C, CA0469C025C, NE21-11-12, NE21-11-5, NE21-11-16, NE21-11-17, NE21-11-18, NE21-11-21- NE21-11-22, and NE21-11-23) were planted in strips on May 7, 2013, at Grant, NE, in Chad Briggs' farm.

Thirteen chickpea lines were planted in a grower's field near Grant, Nebraska. Two undergraduates and one high school student participated in planting the strip plot, and were trained to screen the chickpea trial.

Ascochyta blight incidence was low in 2012 due to the high temperatures. Under non-chemical control, Ascochyta blight incidence was 11% compared to 5% under chemical protection. Yield and 100-seed weight was reduced by 29.1% and 7.3% comparing chemical and non-chemical control. CDC Frontier, CA0469C020C, NE21-11-18, and CA0469C025C had the highest yields under the non-protected trials (2747, 2603, 2515, and 2368 lbs/acre,

respectively). The commercial checks performed by Dylan and Sarah had the lowest yields under the non-protected environment (911 and 1266 lbs/acre, respectively). Under the protected trial, CDC Frontier, PHREC-*Ca*-Comp. #1, NE21-11-18, CA0469C025C, and CA0469C020C had the highest yield (4235, 3457, 3455, 3420, and 3169 lbs/acre, respectively). Dylan had similar results under both non-protected and protected trials (911 and 1045 lbs/acre, respectively). CDC Frontier, PHREC-*Ca*-Comp. #1, NE21-11-15, NE21-11-21, NE21-11-22, and NE21-11-23 responded positively to the fungicide treatment. The experiment at Grant, NE planted by Chad Briggs was destroyed by hail by the end of September.

Twenty two chickpea cultivars (8) and lines (14) were evaluated in a replicated trial at Mitchell, Nebraska. Thirteen experimental lines were planted in grower fields. UNL Plant Pathology sprayed against Ascochyta blight and helped collect Ascochyta blight incidence. The UNL Dry Bean Breeding program planted, weeded, maintained the plots, harvested, and collected the information for evaluation. Below are the 2013 results.

Chickpea trial grown at Mitchell, Nebraska during 2013.

PEDIGREE	Yield	No. seeds/pound
	lbs/acre	#
SIERRA	1026	1154
DYLAN	664	958
MYLES	593	2796
SARAH	618	3359
SAWYER	1117	1266
CA0090B347C	1398	1328
CA0469C020C	1505	1232
CA0469C025C	1082	1281
PI 17256	1265	1859
PHREC-Ca-Comp.#1	1520	1505
CDC ALMA	1389	1351
CDC ORION	1855	1309
CDC FRONTIER	2069	1431
NE21-11-12	973	1380
NE21-11-15	1773	1265
NE21-11-16	1074	2572
NE21-11-17	1517	1300
NE21-11-18	1523	1535
NE21-11-21	1605	1229
NE21-11-22	1724	1120
NE21-11-23	1372	1298
HB 14	771	1164
GRAND MEAN	1292	1531
LSD 5 %	841	296

CV %	32.6	9.7

Data recorded was days to flowers, days to maturity, Ascochyta blight and root rot incidence and severity, yield, seed size, and extent of seed discoloration. Each plot consisted of 4 rows 25 feet long spaced 22 inches apart and harvested with a Wintersteiger plot combine. Quality parameters were assessed by individual samples in the lab.

In 2013, Ascochyta blight incidence was very low in 2013 due to the high temperatures. Since no difference was detected among the chemical treatment, yields were combined. CDC Frontier was the highest yielder followed by CDC-Orion, NE21-11-15, and NE21-11-22 with yields of 2069, 1855, 1773 and 1724 lbs/acre, respectively. Myles, Sarah, Dylan, and HB-14 had the lowest yields of 593, 618, 664, and 771 lbs/acre, respectively. Sarah, Miles, and NE21-11-16 were desi types. Dylan has the largest seed, kabuli type.

In 2014, Ascochyta blight incidence was low due to high temperatures. There was some rainfall at the end of September and the plots continued growing. e sprayed Round-up as desiccant. The chickpea plots were pulled by hand on November 7, 2014 and left the burlap bags in the greenhouse. UNL will process the data as soon as the samples are completely dried down.

From 2012 to 2013 experiments, CDC-Frontier had a good performance under both protected and non-protected trials. Several University of Nebraska lines, PHREC-*Ca*-Comp. #1, NE21-11-15, NE21-11-21, NE21-11-22, and NE21-11-23 responded positively to the fungicide treatment. These experimental lines have the potential to be released either as a germplasm or as cultivars.

The experiment was carried out from 2012 to 2014 to access yield losses due to Ascochyta blight and we were able to identify varieties with Ascochyta blight resistance.

From 2012 to 2014, CDC-Frontier had a good performance under protected and non-protected trials. Several University of Nebraska lines, PHREC-*Ca*-Comp. #1, NE21-11-15, NE21-11-21, NE21-11-22, and NE21-11-23 responded positively to the fungicide treatment. These experimental lines have the potential to be released either as a germplasm or as cultivars.

Six undergraduates and one high school student participated in planting of the exeriments and collecting data.

Beneficiaries

The chickpea trial results were reported during the Nebraska Dry Bean Growers Day on August 27, 2013. Approximately 80 growers attended the field day. In 2013, a report was published in the local newspaper (*StarHerald*) and the *Nebraska Bean Bag*.

The Principal Investigator disseminated the results of this project through grower-oriented newsletters/publications (*Nebraska Bean Bag)*, and web site postings

(http://www.ianrpubs.unl.edu/epublic/live/g1676/build/g1676.pdf). A poster entitled, "2013 Chickpea results and Cooking Time Experiments in Dry Beans" was on display at the Nebraska Dry Bean Growers Association meeting held January 14, 2014. Approximately 150 dry bean growers attended the meeting. On March 5, 2014, a project report will also be provided to the Stateline Dry Bean Growers during their annual meeting.

On December 17, 2013, results were disseminated during the annual New Alliance Bean and Grain annual meeting, and on January 8, 2014, results of chickpea trials will be disseminated during the Nebraska Dry Bean Growers Association Day. In addition, results will be published in the *Bean Bag*, and on the Panhandle Dry Bean web page at http://www.panhandle.unl.edu/drybeans.

About 1,300 dry bean growers were reached though the field days, *Star-Herald* local newspaper, *Nebraska BeanBag*, and http://cropwatch.unl.edu/varietytest/othercrops (2012 and 2013 garbanzo bean report and data). The successful development of new Ascochyta blight resistant cultivars will enhance the possibility of increasing production of chickpeas. Without this development, expansion of acreage will be minimal, due to previous problems experienced with this disease in western Nebraska.

Lessons Learned

Several potential sources of Ascochyta blight were identified. PHREC-Ca-Comp. #1 and PI 17256 were used as tolerant checks, and Ascochyta blight incidence was low from 2012 and 2014 due to high temperatures. The experiment at Grant, Nebraska, planted by Chad Briggs in 2012 was destroyed by hail by the end of September. In 2014, harvest was delayed due to a late maturity. Round-up was sprayed to desiccate the experiment.

The Western Nebraska bean growers are now planting green peas. There is a big demand for dryland green peas in the region.

The UNL Plant Pathology sprayed either Headline or LEM 17 EC against Ascochyta blight and helped collect Ascochyta blight incidence from 2012 to 2014. UNL Plant Pathology sprayed Round-up to dry down the plots in 2014. UNL Dry Bean Breeding program planted, weeded, maintained the plots, harvested, collected, analyzed, and published the information.

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Project Title

Irrigation and Nitrogen Management of Potato under Reduced Water Availability

Project Summary

Drought is a continual problem in western Nebraska and has promoted a decline in water availability for agriculture. The objective of this proposal was to determine a period during potato production in which the negative impact of limited irrigation would be least detrimental to market yield. For potato growers in the Southwest and the Panhandle of Nebraska, it simply means less water and greater risk to yield and market quality. Under limited irrigation, less water is applied than is required to meet the optimum requirement. As a result, the crop is stressed. The goal is to manage irrigation timing and nitrogen fertilization such that the resulting water stress has less of a negative impact on marketable potato yield. The effects of reduced irrigation or mild stress for extended periods has not been studied previously. This project is the last year of a four-year study and provides verification data under unusually high temperature and under drought conditions.

Project Approach

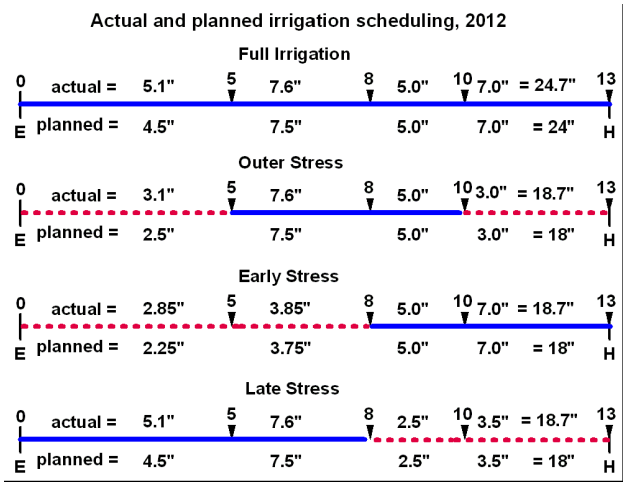
Potato cultivar Atlantic was exposed to reduced irrigation during three periods (first weeks after 0emergence, first five weeks plus last four weeks, and last six weeks); see Figure 1. Irrigation during these periods will be reduced by half resulting in six inches less precipitation or 25% reduction from full irrigated plots (check). Controlled irrigation, adjusted for rain, was applied using a linear-move overhead (Lockwood) sprinkler irrigation system. Irrigation plots were divided into sub-plots based on nitrogen, as UAN, application which was applied at 90, 150 or 210 lb/a. Nitrogen application was pre-plant, plant emergence, and early post-emergence. Main plots were randomized and replicated four times. Major plots were 16 rows by 40 ft. Morphological readings on vine growth were taken at each irrigation period change; also soil moisture and nitrogen, and plant nitrogen were determined at these times. Upon harvest, tubers were sorted by size and weighed. Premium sized tubers were scored for external and internal defects. Tubers were prepared and fried to determine cooking characteristics. Size, defects and cooking quality determined market compatibility.

The 2012-season trial was conducted exactly according to the Work Plan as stated and all measurements were taken. All activities were completed. The outcomes described below are for the fourth and final season of the study. The accomplishments fulfilled the goals set for this project.

Significant results and accomplishments are listed below in the “Goals & Outcomes Achieved” so the conclusions and recommendations are summarized here. Yields were severely depressed when water was only partially applied during the onset of tuber growth (5-8 weeks after emergence, WAE). A water shortage during this period also caused a darkening of potato chips fried from these tubers and increased tuber infection by common scab. The tentative recommendation is that the worst period to deprive potato from full irrigation is during the onset of tuber growth, 5-8 WAE.

Irrigation - Due to a lack of rain in June, irrigation began on 22 June(2012) (Figure 1). Rainfall variation was compensated by adjusting irrigation. Irrigation went as planned.

Figure 1.



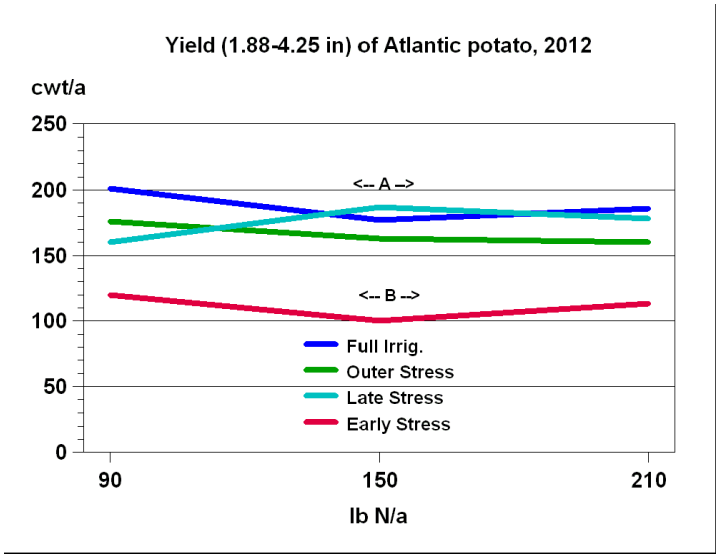
Goals and Outcomes Achieved

The following summarizes the results and conclusions following the format of "Expected Measurable Outcomes" in proposal.

1. "The most distinctive outcome from the study will be to identify a specific seasonal period in which limiting irrigation will not adversely affect market yield of potato."

actual accomplishment:
Yield was severely reduced by limiting water availability to potato plants for the first 8 WAE (July) in 2012 (Figure 2). Similar to 2011, withholding half the water during mid to late tuber growth (last five weeks, 8-13 WAE) showed no yield difference from fully irrigated plants. Increasing nitrogen application did not significantly improve yield although a trend was noticeable when water was limited early.

Figure 2. Yield



2. “Market yield will be measured at the end of the season by harvesting total yield and then recording tuber size distribution, external and internal defects, and cooking characteristics.”

actual accomplishments: Yield was determined based on tuber size distribution. Tubers were evaluated as to quality for frying. Chip color was negatively and significantly affected when water was reduced at any period (Figure 3). Infection by common scab, a defect that eliminates market value of tubers, was too low to detect differences (Figure 4). Several quality aspects, notably dry matter content and tuber shape were assessed and were not adversely affected by limiting water availability.

Figure 3. Chip Color

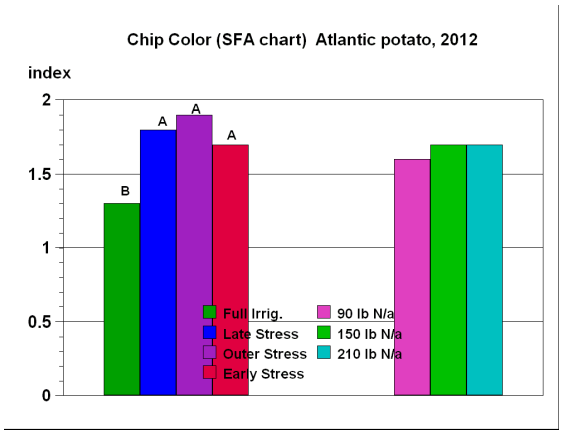
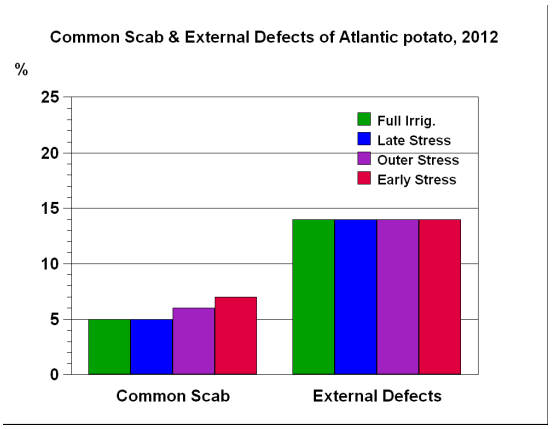


Figure 4. Common Scab and External Defects



3. “Additional clear and measurable outcomes will be the determination of water use and timing, soil water depletion, nitrogen requirement and interaction during water shortages, and soil nitrogen changes. Changes in soil water and nitrogen, and petiole (in plant) nitrogen will be tracked at the start and end of water limitation periods throughout the season.”

actual accomplishments: The following were already reported in the Annual Report and only summarized here. Fully irrigated plots contained 16-20% soil moisture or about 90% saturation during tuber bulking. Irrigation regiments directly affected soil moisture, and N uptake and utilization. The timing of tuberization and flowering were not affected by limiting irrigation. Canopies were very smaller, weighed less and had reduced leaf area when water was limited. The unusually high temperatures in June and July caused plants to grow less than normal and also resulted in a considerable reduction in yields.

4. Rainfall and evapotranspiration will be monitored weekly throughout the season.

actual accomplishments: See ‘Irrigation’ under “Project Approach” above.

5. An economic evaluation of the market yield price based on Frito-Lay contracts, agronomic inputs, and savings in irrigation and fertilization costs will be tabulated at the end of the project.

actual accomplishments: Yield and growth parameters were more adversely affected in 2012 due to the severe drought experienced that year. This fourth year was compared closely to the previous three years and the long-term economic outcome is being evaluated.

Beneficiaries

The results and findings of this study were disseminated to the target audiences. Although this study is completed, dissemination of information continues. The FY11 plan covered the last year of a four-year project. The target audiences are potato growers and scientists.

A list of presentations in the fourth year (2012-13) of the study, were to the :

1. Nebraska potato growers at various informal meetings - target audience = 20.

2. Central Great Plains Working Group in August 2013 in Colby, KS - target audience = 50, researchers, from U. Nebraska, Colorado State U, Kansas State U, U Wyoming, and USDA-ARS interested in limited irrigation in crops in the Great Plains region.

3. Potato Association of America (PAA) in July 2013 in Quebec City, BQ - target audience = 300, USA and Canadian potato growers, University, USDA-ARS and Ag-Canada researchers.

4. NCERA211 ("Potato Research and Extension Program") in Dec, 2012 in Chicago IL - target audience = 60, north-central region potato growers, potato scientists and USDA representatives.

5. Internet - target audience = 8,000, all potato growers, researchers and government representatives world-wide. The conclusions for the four-year study are being prepared for uploading onto the PI's website "Potato Education Guide" under "Potato Research" for international dissemination.

6. Scientific Community - target audience = 1,000, a manuscript for submission to the American Journal of Potato Research, the journal of The PAA, is being prepared for submission in 2014.

7. Growers - target audience = 1,000, a Univ. Nebraska Extension publication, *NebGuide*, is planned in 2014-15 on the cost of limited irrigation on potato and the recommendation for this study as to when to reduce irrigation to mitigate the negative effect of less water.

The quantitative data of most interest to the potato community, concern yield, tuber quality, and cooking characteristics as these were affected by periods of limited irrigation (Figures 2, 3 and 4). Plant and soil data are critical to understanding soil water and nitrogen interactions, and the health of potato vines to withstand climatic stress.

Lessons Learned

The fourth year's data verified most of the tentative conclusions of previous years but added the element of severe heat stress in June and July. When limiting water supply, it is least deleterious to withhold water toward the end of the season, from mid bulking (8 WAE) to harvest, and worst when withheld during early tuber growth, 5-8 WAE.

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Additional Information

None.

Project Title

Extending the Growing Season for Nebraska Specialty Crop Growers

Project Summary

Nebraska's fertile Typic Argiustolls soils that expand across Nebraska's 77,358 square miles play a large role in the state's agricultural success. It has enabled fruit and vegetable growers with the ability to respond to the rising consumer demand for locally grown produce in recent years. But despite the state's agricultural success, its growing season has its limitations. Growing days range as long as 165 days in the southeast to 120 days in the northwest with killing frosts ranging from October to April and September to May, respectively. Since Nebraska's humid continental and semi-arid climates do not provide fruit and vegetable growers with the luxury of multiple growing seasons within a single calendar year, growers are constantly exploring new avenues with which to extend their seasons to increase crop productivity. In an effort to address this need, this three-year project provided small, competitive grants, in the amounts of less than $5,000, to seven Nebraska specialty crop growers who were wanting to implement season extension practices. Project funds were used to help offset the costs of innovative, time-honored methods such as the construction and implementation of cold frames, plasticulture, biodegradable mulches, floating row covers, drip irrigation, low tunnels, and/or high tunnels. Other alternative extension practices, also fundable under this project but used more sparingly in recent times, include smudge pots, wind machines, windbreaks, heat sinks, and cloches. It's no secret that many of these practices, especially plastic mulches and high tunnels, are becoming extremely popular nationwide as more and more gardeners see them as essential, practical methods to extending the growing season and increasing crop productivity. These methods produce earlier crops in the spring and maintain consistent production well into the fall, thus increasing the income and profitability of local gardeners. As a requirement for this program, each grant sub-recipient was required to provide a written report and presentation of his/her completed season extension project to Nebraska produce growers so as to increase the knowledge base of all specialty crop producers and to encourage other growers to adopt the production methods to incorporate into their own operations.

NDA accessed its fruit and vegetable database, which at the time consisted of 511 Nebraska growers who were actively engaged in the production and selling of fresh fruits and vegetables. Announcements, eligibility requirements, and application instructions were sent to the growers encouraging them to apply. Each application returned to NDA was carefully reviewed. Those that failed to clearly state how their potential season extension practices would solely enhance specialty crops were denied consideration as a potential sub-recipient under this program. Once the sub-recipients were selected, they worked with a UNL professor to design, construct and/or implement their season extension practices.

Project Approach and Goals and Outcomes Achieved

This three-year project provided small, competitive grants, in the amounts of less than $5,000, to 5 Nebraska specialty crop growers who were wanting to implement season extension

practices. Initially, this project was designed to provide funding to seven grant sub-recipients. However, two relinquished the active direction of their projects in 2013 due to health reasons. Due to the project's scheduling and makeup, it was too late for NDA to select two other sub-recipients to receive the extra funding. Therefore, in an effort to make the most efficient use of the unutilized funds, NDA modified its project budget slightly to pay for other additional expenses associated with this project, which were initially going to be absorbed by NDA via matching funds. A total of $4,500 was added to the "Other" cost category to pay for farm tour announcements and/or mailing expenses and the remaining was added to pay for indirect charges.

Expected Measurable Outcome #1: Identify the number of eligible growers interested in implementing season extension practices.

The first goal of this project was to identify the number of eligible growers interested in implementing season extension practices. Although no concrete benchmark existed, the target was set that 60 growers, or 12% of Nebraska's produce grower population, would apply for grant funding during the course of this three-year project. The performance measures were determined based upon the number of applications NDA received from produce growers. This project's outcome was achieved.

Year 1

In October 2011, NDA developed a two-page application form and a one page instruction sheet describing the purpose of the project and how to apply. The application was written to capture applicant details, grower eligibility requirements, and desired season extension practices. The form also included two essay questions. The questions had a multifaceted approach.

1. The first question required growers to describe the practice they would like to implement and how it would benefit their operation and Nebraska's specialty crop industry. Growers were to describe how the practice would compliment their business plans and aid in achieving their long-range goals.

2. Secondly, they were to explain why they were applying and why they should be selected as a grant sub-recipient. They were to state the problems they face, interest, need, and how the practice(s) would alleviate their problems. They were to explain why their project was important and timely.

The application instructions clearly described the project's purpose and stated that small, competitive grants, in amounts of up to $4,600, would be provided to a limited number of Nebraska's specialty crop growers for the sole purpose of extending the growing season for specialty crops. Growers who wanted to be considered as a potential project applicant must have fully met the application's eligibility requirements and must have submitted a complete application form to NDA by November 30, 2011.

Following the development of the application form and instructions, NDA contacted a UNL professor of agronomy and horticulture who had extensive experience in the development, construction, and management of season extension projects. In October, 2011, the UNL professor accepted NDA's offer to assist with this three year project on a part-time, contractual basis

The Nebraska Department of Agriculture (NDA) accessed its fruit and vegetable database, which consisted of 511 Nebraska growers who were actively engaged in the production and selling of fresh fruits and vegetables. Announcements, eligibility requirements, and application instructions were sent to the growers in November 2011 encouraging them to apply. This information was also available for download on NDA's web site at www.nda.nebraska.gov and on the Nebraska Our Best to You web site at www.ourbesttoyou.nebraska.gov. Applications were to be postmarked or e-mailed to NDA on or before November 30, 2011. A total of 51 growers submitted an application to NDA.

Year 2

As a result of the first year's application process success, the steps performed in year 2 were nearly identical to that of year 1, with a few exceptions. It was discovered that in year 1 some of the application essay questions were too broad and were not fully answered by the applicants. Additionally, many applications lacked project research that supported their desired practices. Therefore, the application essay questions, which once again had a multifaceted approach, expanded from two to five.

1. The first question required growers to describe the practice they would like to implement.

2. Secondly, they were to state how their desired practice would benefit their operation and Nebraska's specialty crop industry.

3. Next, they were asked what research was performed to support their practice.

4. They were to describe how their practice would compliment their business plans and aid in achieving their long-range goals.

5. Lastly, they were to explain why they should be selected as a grant sub-recipient.

The application instructions clearly described the project's purpose and stated that small, competitive grants, in amounts of up to $4,600, would be provided, to a limited number of Nebraska's specialty crop growers, for the sole purpose of extending the growing season for specialty crops. Growers who wanted to be considered as a potential project applicant must have fully met the application's eligibility requirements and must have submitted a complete application form to NDA by November 30, 2012.

In October 2012, announcements, eligibility requirements, and application instructions were again sent to the growers in NDA's database who were actively engaged in the production and

selling of fresh fruits and vegetables. This information was available for download on NDA's web site at www.nda.nebraska.gov and on the Nebraska Our Best to You web site at www.ourbesttoyou.nebraska.gov. Applications were to be postmarked or e-mailed to NDA on or before November 30, 2012. A total of 37 growers submitted an application to NDA.

The applicant names between years 1 and 2 were crossed checked against one another, and it was discovered that, cumulatively, a total of 67 growers applied for grant funding during the course of this three-year project. This target was achieved.

Expected Measurable Outcome #2: Select seven growers who will receive grant funding to implement season extension practices.

The second goal was for NDA and the UNL professor to determine which applicants should be awarded grant funds to implement season extension practices on their individual farms. Generally, applicants who were currently practicing extension techniques received lower scores than those without season extension practices. A lower score could have been a potentially deciding factor as to why some were not selected as a grant sub-recipient. Sub-recipients were asked to implement a technique they had not practiced in previous years. The practice they wished to incorporate into their farming operation must have been clearly identified, and they were to select the most applicable, affordable practices they believe would most appropriately fit their current landscape, soil conditions, climate, topography, and production needs. No such benchmark existed due to lack of data. Growers selected to participate in this project were located in different areas of the state so as to represent the different topographical regions of Nebraska. The target was set that three farmers would be awarded grant funds in 2012 and four in 2013. The project's success was measured by the variety and types of season extension practices incorporated into the farming operations.

Year 1

A total of 51 applications were submitted. NDA and the UNL professor independently scored and ranked the proposals against the criteria listed on the Evaluation Criteria Score Sheet developed by NDA. The score sheet broke down the maximum number of points (100) for each part of the application, with 60% of the points spread out between the application's two essay questions.

Each application was carefully reviewed. Those that failed to clearly state how their potential season extension practice would solely enhance specialty crops were denied consideration as a potential sub-recipient under this program. Of the 51 NDA received, four were late and four were disqualified due to incomplete applications.

On January 18, 2012, NDA and the UNL professor sat down to discuss the project, compare applicant scores, and determine who the three grant sub-recipients would be for 2012. Tomato Acres, Savory Eats, and Hintz Produce received high scores from both reviewers and were selected as the three sub-recipients. On February 2, 2012, NDA sent a letter to all of the other growers who applied informing them that they were not selected as a 2012 sub-recipient, but encouraged them to reapply when the second round of applications were released in the

fall. Initial visits were made to Tomato Acres, Hintz Produce, and Savory Eats on February 21, February 28, and March 6, respectively. Follow-up visits were made to each of the three locations on August 27, October 5, and October 30.

Below are the names of the three sub-recipients, a description of their topographical regions, the season extension practices they decided to implement, and why they were selected as grant recipients.

Tomato Acres is a small family-owned business which began in 1990. It is located in Elm Creek, Nebraska, which is a small town located in south central Nebraska. Their primary crop is tomatoes, but they offer a wide variety of garden vegetables. The tomatoes are grown and vine ripened in the soil, many of which are in a greenhouse or high tunnel. Tomato Acres currently has four greenhouses and a large garden area spanning more than three acres. Produce is sold at the Haymarket Farmers' Market in Lincoln on Saturday mornings and at the Kearney Area Farmers' Market on Wednesday afternoons and Saturday mornings.

Topographically, this area of the state is located near the Platte River, which is Nebraska's most popular and longest river and a tributary of the Missouri River. The region is classified as a "valley," which consists of flat-lying land along a major stream. The materials of the valley are made of stream-deposited silt, clay, sand, and gravel.

Tomato Acres applied to utilize funds to erect a shade structure. One of the primary reasons Tomato Acres scored so well on their application is because this type of unit is innovative and not easily found in Nebraska's produce industry landscape. To NDA's knowledge, it is the first of its kind for a produce grower and appears to be an affordable unit that is easily adaptable to Nebraska's landscape, soil conditions, climate, topography, and production needs. This unit could easily be scaled to fit beginning, intermediate, or advanced growers. Tomato Aces is a veteran grower who made an excellent use of grant funds.

Savory Eats is a small diversified farm operation that has been in operation for approximately 2 years now. They are located near Brunswick, Nebraska, which is a small town located in northeast Nebraska. They raise a number of produce crops on 2.5 acres, including aronia berries, which is a relatively new crop that has gained a lot of attention over the past few years. Savory Eats currently sells produce at the Santee Farmers' Market, which is a market held in a Nebraska Indian Reservation that primarily consists of Native American vendors.

Topographically, Brunswick is located in an area of the state identified as the "plains" region. The plains consist of flat-lying land that lies above a valley. The materials of the plains are sandstone or stream-deposited silt, clay, sand, and gravel overlain by wind-deposited silt (loess).

Savory Eats applied for grant funds to build a high tunnel to enhance their raspberry crop. Savory Eats has over 250 raspberry plants that are capable of producing fruit well into the fall months. However, harvesting berries has been severely limited due to the early frosts they have experienced in the months of September. The early frosts have led to shorter growing seasons, lower yields, and loss of potential income. It was determined that the advantage of a

high tunnel would protect the plants from the frost. This would allow them to bear fruit into November thus enabling Savory Eats to demand a premium for their berries, especially during certain times of the year when this crop is not in season. There are a couple of reasons why Savory Eats scored so well on their application and why they were selected as a grant recipient.

1. Nebraska has a small and somewhat limited fruit industry. The number of Nebraska vegetable growers far outweigh fruit growers. Therefore, in an effort to find ways to promote the fruit industry, it was decided Savory Eats would be an excellent sub-recipient candidate. It was determined that a high tunnel would likely increase the number of growing days, avoiding killing frosts in September, and increase the market viability of raspberries and potentially other popular fruits grown in Nebraska. Funds were awarded to Savory Eats to purchase and construct a high tunnel for their raspberry plants. The high tunnel was built by October 2012, and the raspberry plants were transplanted into the high tunnel in 2013.

2. Savory Eats is a relatively new business and is considered a beginning grower operation. NDA supports agricultural operations of all shapes and sizes and utilizing grant funds to help beginning growers is just as important as helping intermediate, advanced, and/or experienced growers. High tunnels are an affordable unit that can be easily adaptable to Nebraska's landscape and production needs. They vary in size and can easily be scaled to fit beginning, intermediate, or advanced growers.

Hintz Produce is a small produce operation located near Hebron, Nebraska, which is a town located in southeast Nebraska. They have been in operation for 15 years and grow a wide variety of produce (primarily tomatoes) on approximately 4 acres of land. Their produce is sold at the Hebron Farmers' Market.

Topographically, Hebron is located in an area of the state that is considered as the "dissected plains" region. The land is hilly with moderate to steep slopes, sharp ridge crests, and remnant of the old, nearly level plain. The dissected plains are old plains eroded by water and wind.

Hintz Produce applied for grant funds to build a high tunnel in an effort to provide a more stable weather environment for their specialty crops, especially tomatoes. There are a couple of reasons why Hintz Produce received high marks on their application.

1. There is a large number of Nebraska produce growers located in southeast Nebraska. Although NDA has over 500 produce growers in their database, a large number of growers are located in the eastern and southeastern potion of Nebraska. If timed right, the farm tour could attract a large number of growers.

2. High tunnels are becoming increasingly popular in an effort to extend the growing season of produce and increase crop productivity.

The use of high tunnels in vegetable production is becoming increasingly popular among produce growers. This popularity, coupled with a large concentration of growers in southeastern Nebraska are some of the main reasons why this grower was awarded SCBGP grant funds.

Year 2

A total of 37 applications applied for funding. NDA and the UNL professor independently scored and ranked the proposals against the criteria listed on the Evaluation Criteria Score Sheet developed by NDA. The score sheet broke down the maximum number of points (100) for each part of the application, with 80% of the points spread out between the application's five essay questions.

Each application was carefully reviewed. Those that failed to clearly state how their potential season extension practice would solely enhance specialty crops were denied consideration as a potential sub-recipient under this program.

On January 14, 2013, NDA and the UNL professor sat down to discuss the applications, compared scores, and determined who the four grant sub-recipients would be for 2013. Pekarek's Produce, Field of Greens, Robinette Farms, and Harvest Meadows, received high scores from both reviewers and were selected as the four sub-recipients. Initial visits were made to each operation on January 28, January 29, February 5, and February 6, respectively. Follow-up visits were made to Pekarek's Produce on September 4, Robinette Farms on November 15 and Harvest Meadows on November 22. A visit to Field of Greens was not conducted since they withdrew from the program. Details regarding their wish to withdraw are explained below.

Below are the names of the four sub-recipients, a description of their topographical regions, the season extension practices they decided to implement, and why they were selected as grant recipients.

Pekarek's Produce is a family-owned and operated vegetable production operation that began in 2004. The produce is grown near Dwight, Nebraska, where they raise over 50 varieties of crops on approximately 13 acres. Their produce is sold at the Lincoln Haymarket and Seward Farmers' Markets. They also have a Community Supported Agriculture (CSA) operation.

Topographically, Dwight is located in an area of the state identified as the "plains" region. The plains consist of flat-lying land that lies above a valley. The materials of the plains are sandstone or stream-deposited silt, clay, sand, and gravel overlain by wind-deposited silt (loess).

Pekarek's Produce applied for grant funds to apply mulch on their cantaloupe crop. Mulches have been used commercially on vegetables since the early 1960s to help growers in extreme northern and high-altitude climates harvest heat-loving crops that were previously impossible to grow. The use of this technique is gaining popularity, especially with black plastic mulch

which is the most commonly used mulch. However, the comparison of black plastic versus black biodegrable versus black fabric versus no mulch has not been tested on Nebraska farms to evaluate their differences and if any technique extends the season, reaps higher yields, and increases produce quality. Therefore, based upon NDA's suggestion, Pekarek's agreed to give the various mulches a trial run in the 2013 and 2014 growing seasons.

Robinette Farms is a small scale family farm in Martell, Nebraska. They grow 5 acres of vegetables, have a 150 member CSA Program, and sell at the Old Cheney Road Farmers' Market and to a handful of local restaurants.

Topographically, Martell is located in an area of the state that is considered "rolling hills." This is hilly land with moderate to steep slopes and rounded ridge crests. In eastern Nebraska, the rolling hills are mostly glacial till that has been eroded and mantled by loess, while in northwestern Nebraska the hills were produce by the erosion of clay an clay-shale beds.

Robinette Farms applied to utilize funds to erect a shade structure, similar to the one built by Tomato Acres. This unit will be slightly different in both design and size. One of the primary reasons Robinette scored so well on their application is because this type of unit is innovative and still not easily found in Nebraska's produce industry landscape. To NDA's knowledge, it appears to be an affordable unit that is easily adaptable to Nebraska's landscape, soil conditions, climate, topography, and production needs. This unit could easily be scaled to fit beginning, intermediate, or advanced grower operations.

Harvest Meadows Farm was established in 2011 and is located 14 miles north of Sidney, Nebraska. The 12-acre farm is privately owned and operated. Sustainable farming practices are followed through conservation of natural resources, crop rotation, animal and green manures, and biological pest controls. They currently participate in two farmers' markets and have a roadside stand offering a large assortment of naturally grown fruits and vegetables.

Topographically, Sidney is located in the south central panhandle of Nebraska, and in an area of the state identified as the "plains" region. The plains consist of flat-lying land that lies above a valley. The materials of the plains are sandstone or stream-deposited silt, clay, sand, and gravel overlain by wind-deposited silt (loess). This area is also very close to a unique portion of the nation called the "sand hills." The sand hills consists of hilly land composed of low to high dunes of sand stabilized by a grass cover. The sand dunes mantle stream-deposited silt, sand, gravel, and sandstone.

Harvest Meadows Farm applied to utilize funds to erect two moveable high tunnels built on a rail system. One of the primary reasons Harvest Meadows Farm scored so well on their application is because moveable tunnels in Nebraska are not easily found in Nebraska's produce industry landscape. The tunnels appear to be affordable units that are easily adaptable to Nebraska's landscape, soil conditions, climate, topography, and production needs. Late season harvest and overwintered crops would be planted in late summer and early fall followed by early season planting starting in February or March. Moveable tunnels would allow for an increase in the weeks available to CSA members and wholesale markets. Additionally, it would provide warm weather products much earlier in the year and protection

when hardening off seedlings. It is believed moveable tunnels could be scaled to fit beginning, intermediate, or advanced growing operations.

Field of Greens was the fourth recipient selected to receive grant funds. They are located near Plattsmouth, Nebraska, which is in the far east central part of the state that, topographically, consists of rolling hills. Their idea was to build a two layered low tunnel system. The outer layer would consist of a clear plastic to protect crops from frost. Once the chance of frost was no longer possible, the top layer would be removed exposing the second layer, which was an insect-proof net. This inner layer would protect the plants from hail and insects and would trap in the bumble bees, which were needed for crop pollination.

A total of seven sub-recipients were selected to receive grant funding. However, in May 2013, Field of Greens decided to relinquish the active direction of their project and informed NDA that they could not fulfill the terms of their project due to health-related reasons. In April 2014, the Robinette Farms applicant was seriously injured in a vehicle crash causing paralysis. As a result, they too could not fulfill the terms of their project. Due to the project's scheduling and make-up, it was too late for NDA to select other sub-recipients. A letter from NDA was sent to the USDA on June 13, 2013, and April 3, 2014, informing them of both situations. Due to these unforeseen circumstances, only five sub-recipients received funding. Therefore, this goal was not achieved.

Expected Measurable Outcome #3: Increase the construction and implementation of time-honored methods that extend market seasons.

The third goal of this project was to provide the selected sub-recipients with resources and project funds to help offset the construction and implementation of their selected production methods. It was anticipated that the alternative extension methods implemented would primarily consist of cold frames, plasticultre, biodegradable mulches, floating row covers, low tunnels, drip irrigation, and high tunnels. Smudge pots, wind machines, windbreaks, heat sinks, cloches, and other methods would be acceptable upon prior approval from NDA. Sub-recipients worked with a UNL professor to design, construct, and/or implement their methods. By the time the projects were complete, it was anticipated that innovative, time-honored practices would be incorporated into five produce operations instead of seven as originally anticipated. The success of this goal was measured by surveying the sub-recipients to determine if their methods extended their crop availability. This outcome was achieved by all five sub-recipients.

Figure 1 - Shade Structure

Year 1

Tomato Acres erected a shade structure that consists of a metal pipe frame structure. A removable netted cloth is suspended over the seven foot high pipes allowing for a flat roof and side walls that are perpendicular to the ground (Figures 1 & 2). The cloth is tied down

Figure 2 - Shade Structure

by straps anchored to ground posts. The cloth is black, thus blocking out some of the sun's rays, but allows for adequate airflow. The advantage of a shade structure is multifaceted. It increases yield, lengthens the growing season for cool season crops (during the spring and fall months), protects crops from wind and hail, and allows produce to ripen near to perfection. It enables growers to charge premium prices because of produce quality and the limited number of cool season crops grown in Nebraska. The sunlight under the unit is diminished and is cooler than its surroundings and is an ideal environment when starting new plants. It provides enough light to maintain plant growth and production. Crops grown under the structure generally require less fertilizer and water. More importantly, the netting decreases the kinetic energy of rain drops hitting the soil thus decreasing water splash and the spread of disease. In terms of convenience, the shade netting can be easily installed and removed in a matter of minutes. The netting is gradually installed in sections at the onset of summer but then gradually removed at the onset of fall. Tomato Acres' particular unit is 90 feet long and 36 feet wide, but could easily be scaled to fit any beginning, intermediate, or advanced operation, regardless of size.

Savory Eats has two raspberry varieties. Some bear fruit in the spring and the others bear fruit in the fall. The growing days in this area of the state are relatively shorter than those in the southern areas with killing frosts that hit as early as September. This area is two climate zones colder than southeastern Nebraska. Savory Eats has been using a rather archaic method to extend the season of their fall raspberry varieties despite repeated days of freezing temperatures. Their practice involves watering the plants in the evenings, allowing the frigid night temperatures to freeze the water on the plants so they are covered in ice (Figure 3). During the day, the sun melts the ice, but the process is then repeated the following night. To some degree, this freezing/thawing method has protected the plants allowing them to bear fruit longer in the season, but it has been met with only marginal success. Their high tunnel was built so these fall fruit bearing raspberry crops can be transplanted under the high tunnel so this ancient freezing/thawing method can be disposed of.

Figure 3 - Frozen Raspberries

Figure 4 - High Tunnel

High tunnel bramble production offers the

opportunity to bridge the gaps in availability during late spring and late fall. Because tunnels offer a less expensive form of season extension than greenhouses, they appear to be an ideal production option when temperatures reach the freezing point. Furthermore, high tunnels allow less hardy floricane-fruiting raspberries to overwinter in climates where they would otherwise be killed. High tunnels allow raspberries to be produced where the growing season is too short to mature the crop. These technologies, coupled with the continued development of new varieties and field production techniques, bring the goal of all season bramble production closer to fruition.

Savory Eats' high tunnel is 30 feet wide and 60 feet long. It is a large hoop house covered with plastic, with side end walls to be opened to regulate temperature (Figure 4). It provides an intermediate level of environmental protection and control between field production and greenhouse production. The tunnel is not heated, but traps the heat from the sunlight's rays always keeping the tunnel warmer than the temperature outside the tunnel. Although this tunnel is not yet irrigated, an irrigation system can easily be installed and is necessary as the protective covering nature excludes rainfall. When the plants are transplanted under the tunnel in the spring of 2013, they will be placed relatively close in terms of spacing. It was decided that installing the tunnel over existing rows as an afterthought would be difficult, and the row spacing could not be changed. Additionally, it was thought that there could be a possibility that diseases and weeds for berries grown in tunnels could gain a foothold in the planting prior to covering the tunnel. This size of tunnel should allow for five rows, two feet wide, with a buffer strip between each row. The tunnel should be able to house up to 300 raspberry plants.

High tunnels used in raspberry production can greatly extend the market season, beginning in early spring (March) for some floricane-fruiting cultivars and extending through late fall (November). This extended season will assist Savory Eats and other growers in capturing a larger market share, especially in early and late season when raspberries command a premium price. High tunnel production will likely result in improved fruit quality and shelf life and a more consistent crop harvest. Raspberries may be kept up to a week in cold storage without significant deterioration. It will also ensure continuous fruit production when conditions for field harvest are unfavorable. Soil warming, wind, longer growing degree days, and rain protection are just some of the benefits of high tunnel production over field production. The need for disease, insect, and wildlife management, compared to field production, will also be reduced; this minimizes pesticide inputs. In addition, the high tunnel production will allow for diversification of farming operations, requiring less capital expenditure than greenhouse production, and for relatively low investment, often yields high returns.

Hintz Produce utilized grant funds to build a high tunnel in an effort to provide a more stable weather environment for their tomatoes. Such a unit protects the operation from Nebraska's extreme weather conditions and allows for a more controlled climate environment. The tunnel increases best management farming practices and decreases the presence of fungus, bacterial wilt, and blight.

High tunnels are a simple, relatively inexpensive, and effective way of protecting high-value crops from the effects of marginal low temperatures, wind, rain, insect and foliar diseases, pests, and wildlife damage. There are 1.9 million acres covered with high tunnels worldwide.

In the U.S. there are 4,400 acres, with 3,000 of those in California. While high tunnels have been increasing in northeastern states, they remain underutilized in Nebraska. There is ample opportunity for expanding high tunnel production, without saturating Nebraska markets. High tunnel growing offers season extension, yield and quality improvements, reduction in fertilizer leaching, reduction in costly pesticide and fungicide inputs, and quick payback on capital investment. They are an answer to many problems, if growers are willing to manage the technology. Daily raising and lowering of the plastic sides each morning and evening (sometimes more often) is required to control temperature and humidity.

Early crop production means capturing customers early in the season, keeping them season-long with companion field production, and long into the fall. This results in higher sales, at reliably higher prices, from higher marketable yields per unit area. Providing earlier, consistently available quality crops enables growers to successfully compete in several market outlets and adds to a larger customer base.

High tunnel costs and management are “scalable” meaning they offer equal “farm size neutral” benefits to small and large farms, rather than requiring a large farm economy of scale to realize benefits.

Once the sub-recipients were selected, they worked with the UNL professor for direct consultation. During the initial visits with growers, the professor discussed the specific nature of the season extension projects the growers selected. He shared his experience, expertise, and knowledge with the respective applicants and offered recommendations and suggestions that would assist the growers in their season extension project. Throughout the life of the project, he provided recommendations and suggestions to help the growers along. During the follow-up visits in the fall, he evaluated each structure and provided his overall thoughts along with suggestions and recommendations for the growers to consider that might improve the practice implemented or built. He also played an integral role in the farm tours serving as a valuable resource expert for attendees to turn to with their specific questions.

All three sub-recipients from Year 1 reported that their methods extended their crop availability, as stated in the farm tour videos found on the Nebraska Our Best to You YouTube Channel at http://www.youtube.com/channel/UCUfhUcNUldN4_hf6attsvww.

Year 2

Pekarek’s Produce chose to try three different kinds of mulches on their cantaloupe varieties to evaluate their effectiveness. The trials were also performed to make a comparison with cantaloupe grown on bare soil with no mulch (Control Group) against the produce grown on mulch. The mulch varieties used included black plastic, biodegradable, and fabric mulch. Mulch has several benefits. It allows for earlier crop production, suppresses weed growth, reduces soil and water loss, increases soil temperatures, and improves vegetable yield. For the mulches to be most effective, it is important that it be in contact with the soil to reduce any air pockets, which act as insulation that reduces heat transfer. Below are the specific characteristics of each of the three mulches Pekarek’s used in their trial.

1. Black plastic mulch is most commonly used. Soil temperatures under black plastic mulch during the day are generally 5 degrees higher at a depth of 2 inches and 3 degrees higher at a depth of 4 inches compared with bare soil. At the end of the season, the mulch must be removed from the field and disposed of.

2. Black fabric mulches are very durable and can last multiple growing seasons. They are generally porous in nature, which allows water, fertilizer, oxygen and other gases to enter and exit. This mulch must be removed at the end of harvest if drip tape is beneath the mulch. However, it can be laid down again the following year. Eventually, this mulch too must be removed and disposed of.

3. Biodegradable mulches are made with starches from plants such as corn, wheat, and potatoes. They are broken down by microbes. Biodegradable plastics on the market are more expensive than traditional plastics, but their price is countered by their true environmental cost. It was discovered that biodegradable mulch performed similar to the other two mulches. However, unlike the other two, it can be either removed or plowed into the ground after harvest.

Drip tape was first buried in the soil an inch or two prior to mulch installation. Once mulch had been laid down using the proper equipment, slits were cut or burned into the mulch to insert the cantaloupe seeds. Burning holes into the mulch prevents the mulch from fraying and unraveling.

A follow-up visit by NDA and the UNL professor was made on September 4, 2013, to assess the first year's results of the project. The entire yield results were extremely positive. Plants grown under the mulch performed much better than the Control Group. The grower experienced earlier crop production, less weeds, warmer soil temperatures, and better vegetable yields. One noticeable disadvantage was that many melons laying on the mulch

had some black mulch residue that should be wiped away for cosmetic purposes. These same trials were again performed in 2014 so that the grower was able to address the benefits, challenges, opportunities, and disadvantages to those who attended the farm tour on August 10, 2014.

Robinette Farms chose to erect a shade structure similar to that of Tomato Acres. Although they removed themselves as a grantee sub-recipient due to health reasons, they were able to build a portion of their shade unit. It currently consists of metal posts anchored to the ground down the center and around the perimeter of the baby green production area (15 posts total). If eventually completed, high tensile wire will be stretched between the posts and shade cloth will be installed across the wires and secured to the posts with wiggle wire. The cloth will cover ¼ acre, which will be used for the production of baby greens that typically cannot be grown during the hottest parts of Nebraska's growing season. Only half of the area will be covered so that the covered production area can be directly compared to the uncovered area. The advantage of a shade structure is multifaceted. The cloth will allow for adequate airflow. It is designed to reduce soil temperatures while allowing for greater natural ventilation overhead that is possible in a high tunnel. Additionally, a high shade cloth will allow for the use of currently installed overhead irrigation. It should also increase yield, lengthen the growing season for cool season crops, protect crops from wind and hail, and allow produce to ripen near to perfection. It will enable growers to charge premium prices because of produce quality and the limited number of cool season crops grown in Nebraska. The sunlight under the unit will be diminished and is cooler than its surroundings and is an ideal environment when starting new plants. It provides enough light to maintain plant growth and production. More importantly, the shade cloth decreases the kinetic energy of rain drops hitting the soil, thus decreasing water splash and the spread of disease. In terms of convenience, the shade cloth can be easily installed and removed in a matter of minutes.

A follow-up visit to Robinette Farms, with the UNL professor, was made in November 2013 to see what progress had been made. Although some of the shade materials were purchased in 2013, construction of the shade unit was severely delayed due to the sub-recipient's budget, time constraints, and health condition. Only the metal posts anchored around the perimeter of the land was complete; all of the ground posts were anchored by December 31st. The tensile wire and shade cloth may eventually be installed, but it was not within this grant's time period. The applicant does hope to complete the project someday and host a farm tour to demonstrate the benefits of his shade cloth.

Harvest Meadows Farm chose to build two moveable high tunnels with low tunnels within each structure. The tunnels have been built using two different types of rail systems. The first tunnel is on a wood rail, and the other is on a metal rail. The rails extend two or more times the lengths of the high tunnels, making multiple sites available for each tunnel. Moveable high tunnels allow for multiple cropping sequences.

A follow-up visit to Harvest Meadows Farm with the UNL professor was made on December 6, 2013, to see what progress had been made. The wood high tunnel is 14' x 48' on a 94' rail system. The tunnel is constructed of 1 3/8" top rail, 12' wide and 7' high at the center creating comfortable access for planting and cultivation of beds. End walls are made of wood to aid in

structural strength. Six millimeter film is used to cover the structures and the low tunnels are covered by a second layer of Agribon fabric as an added layer of insulation. The rail tunnel was built using these same specifications and dimensions. Two different kinds of rail systems proved to be especially beneficial during the farm tours to demonstrate the advantages and disadvantages of each system.

Late season harvest and overwintered crops are planted in late summer and early fall. The tunnels are moved over the newly planted crops no later than the end of October. The tunnels allow for early season planting in February or March, allowing the grower the ability to transplant tomatoes 30 – 45 days earlier than currently allowed. When summer arrives and the tomatoes have been transplanted, the houses are moved down the rails to provide summer-loving crops with tropical-like conditions protecting them from extreme weather conditions such as high winds, extreme heat, and low rainfall. At the end of the summer, the sequence is repeated. If so desired, the tunnels could also be used to protect summer crops from frost allowing for the plants to bear fruit longer.

Expected Measurable Outcome #4: Increase the number of Nebraska growers who will implement practices into their own operations by attending farm tours hosted by the seven sub-recipients.

The fourth goal of this project was for the sub-recipients to host farm tours to teach Nebraska specialty crop farmers how they implemented their season extension practices. The tours provided interested growers with firsthand knowledge as to how the season techniques were incorporated into the farming operations. Grower education addressed the challenges, obstacles, and opportunities the sub-recipients encountered and how they could have been circumvented. The benefits and results were provided to demonstrate the affordability and practicality of the shade structure and high tunnels. It was estimated that the presentations, over the course of this three-year project, taught over 100 growers how to incorporate season extension practices into small-scale specialty crop operations, thus lengthening and increasing the availability of fresh produce statewide. It was anticipated that 25 percent of the 100 growers attending the farm tours would utilize the season extension practices demonstrated on the farms. Written reports of each project were posted on the Nebraska Our Best to You web site to further promote and address project results. The success of this goal was measured by how many growers attended the farm tours. A total of 138 growers attended the farm tours. This goal and respective target was achieved.

Three farm tours were held in 2013 and two in 2014. The featured grower, UNL professor, and NDA representative were the presenters at each event. Meals were provided to all attendees at each tour and this expense was charged to the grant. The farm tours were located on farms in rural Nebraska where public facilities and restaurants were not accessible. Additionally,

there was insufficient time available to allow participants to find food on their own. Therefore, the food was used to maintain the continuity of the tours. In an effort to better publicize the results of this project, all five tours were recorded and posted to the Nebraska Our Best to You YouTube Channel at http://www.youtube.com/channel/UCUfhUcNUldN4_hf6attsvww. Written grower reports of each project can also be found on the Nebraska Our Best to You website at http://www.ourbesttoyou.nebraska.gov/. Below is brief summary of each tour.

Year 1

The **Tomato Acres Farm Tour** was held in Elm Creek, Nebraska, on June 9, 2013. NDA worked with Tomato Acres to publicize this event. Announcement of this tour made to the Nebraska delegation who attended the Great Plains Growers Conference in St. Joseph, Missouri, on January 11th, and to growers who attended the Lincoln Farmers' Market Meeting in Lincoln, Nebraska on February 9th. Approximately 30 and 70 people attended each event, respectively. In May, NDA sent out 167 postcards to specialty crop growers who lived near Elm Creek encouraging them to attend. Additional postcards were sent to Tomato Acres for additional publication in an effort to better canvas this area, and NDA sent individual announcements to non-profit organizations and University personnel who might have a potential interest in the tour. The announcement was also posted on the Nebraska Our Best to You website. Growers were asked to RSVP to NDA by May 31st. A total of 67 people made RSVP reservations, of which 29 attended.

Following the conclusion of the tour, the UNL professor sent out an electronic survey to the attendees to measure the success of this tour. The results were extremely positive. Although not all attendees completed the electronic survey, 100 percent of the survey respondents stated that they have a better understanding of how a shade unit can be used and it was valuable to conduct a farm visit to see this shade unit in use. The survey showed that 13 percent of the respondents are planning to develop a structure/system of their own and 75 percent are somewhat likely to build one, but are not sure when. Overall, 63 percent of the respondents found the tour to be very informative.

The **Hintz Produce Farm Tour** was held near Hebron, Nebraska, on July 19th. NDA worked with Hintz Produce to publicize this event. NDA sent 141 postcards to growers near the Hebron area encouraging them to attend. The postcards reached growers in 14 different counties. Additional postcards were sent to Hintz Produce for additional publication in an effort to better canvas this area, and NDA sent individual announcements to non-profit organizations and University personnel who might have a potential interest in the tour. The announcement

was also posted on the Nebraska Our Best to You website. Growers were asked to RSVP to NDA by June 30th. An e-mail reminder was sent on July 10th to growers who received the announcement, had an e-mail address, but had not yet made a reservation. Approximately 22 RSVPs were received, 20 of whom attended the tour.

The **Savory Eats Farm Tour** was held near Brunswick, Nebraska, on October 4th. NDA worked with Savory Eats to publicize this event. NDA sent approximately 246 postcards to growers surrounding the Brunswick area encouraging them to attend. Due to the small fruit industry in Nebraska, raspberry growers were included on this list. The postcards reached growers in 39 Nebraska counties. Additional postcards were sent to Savory Eats for additional publication in an effort to better canvas this area, and NDA sent individual announcements to non-profit organizations and University personnel who might have a potential interest in the tour. The announcement was posted on the Nebraska Our Best to You website. Growers were asked to RSVP to NDA by September 30th. An e-mail reminder was sent on September 17th to growers who received the announcement, had an e-mail address, but had not yet made a reservation. A total of 41 RSVPs were received prior to the event, and 31 attended the farm tour.

Year 2

The **Harvest Meadows Farm Tour** was held near Gurley, Nebraska, on June 6th. NDA worked with the grower to publicize this event. NDA sent approximately 151 postcards to growers in the panhandle encouraging them to attend. The postcards reached growers in 26 Nebraska counties. Additional

postcards were sent to Harvest Meadows Farm for additional advertisement in an effort to better canvas this area. NDA sent individual announcements to non-profit organizations and University personnel who might have a potential interest in the tour. The announcement was also posted on the Nebraska Our Best to You website. Growers were asked to RSVP to NDA by May 31st. The postcard was also sent via e-mail to 411 Nebraska produce growers and 58 farmers' market managers on May 16th. A total of 30 RSVPs were received prior to the event, and 29 attended the farm tour.

The **Pekarek's Produce Farm Tour** was held near Dwight , Nebraska, on August 10th. NDA worked with the grower to publicize this event. NDA sent 512 postcards to growers in 55 Nebraska counties. The announcement was posted on the Nebraska Our Best to You website, and the postcard was sent via e-mail to 438 growers on August 4th. Additional postcards were sent to the grower for additional promotion. Growers were asked to RSVP to NDA by August 8th. A total of 22 RSVPs were received prior to the event, and 29 attended.

Beneficiaries

Longer seasons result in larger annual incomes, customer retention, higher yields, and premium prices. Additionally, it can provide extended employment for skilled workers on produce farms who might otherwise be lost to other jobs at the end of the growing season. Approximately 138 Nebraska produce growers involved in the growing and selling of specialty crops were the beneficiaries of this project. Through use of a competitive application process, NDA selected growers to receive SCBGP funds. The sub-recipients were located in different areas of the state so as to represent the different topographical landscapes of Nebraska and to allow interested growers an opportunity to attend a farm tour that is in relative close proximity to where they live.

This project attracted a lot of attention. Each sub-recipient shared their project results with Nebraska produce growers through detailed public presentations and written reports. Grower education exposed existing and new specialty crop growers as to how the extension techniques were implemented. The challenges, opportunities, benefits, obstacles, and results were fully addressed by the sub-recipients. It is estimated that the presentations, over the course of this three-year project, would teach 100 growers how to incorporate season

extension practices into small-scale specialty crop operations, thus lengthening and increasing the availability of fresh produce statewide. More than 100 growers received this education; therefore, this target was achieved. Sub-recipients were required to host farm tours, which were open to the public. Written reports of each project are posted on the Nebraska Our Best to You web site and videos of the farm tour can be found on NDA's YoutTube Channel to further promote the results of this project.

NDA and the UNL professor worked with the growers to identify times that work best to host their farm tours. NDA assisted in heavily publicizing the farm tours in an effort to attract growers and representatives from public agencies and non-profit entities that have an interest and expertise in specialty crop food and agricultural systems. Grower education at the farm tours exposed the desired practices to existing and new specialty crop growers. The challenges, opportunities, benefits, obstacles, and results were fully addressed.

Lessons Learned

Initially, NDA intended to work with a UNL Extension Educator who had extensive knowledge, understanding, and experiencing in season extension practices. However, when the project first began in October 2011, the Extension Educator informed NDA that, due to his UNL position, he was being deployed to the Middle East to teach agronomic farming practices to Afghanistan farmers. His extended absence would delay this project for several months. Therefore, with the Extension Educator's assistance and recommendation, NDA identified a UNL professor of agronomy and horticulture in October 2011 who agreed to work with NDA on this project. This UNL professor was very well versed in season extension practices and had experience working with various farming practices and methods. The UNL professor proved to be an excellent candidate for this position and was a key part of this project's success.

Before NDA and the UNL professor selected the sub-recipients for this project, NDA had previously established strong working relationships with three of the five sub-recipients. Although these relationships did not weigh into the determination of who received grant funding, it did provide NDA with a strong understanding of their farming operations and their level of involvement and interest in Nebraska's produce industry. However, NDA did not have a previous working relationship with the other growers, including the two who turned down grant funding due to health reasons. After the initial visits with the growers, NDA and the UNL professor had some reservations about the interest the growers had in produce production. Although their applications were very well written, that was not necessarily reflective of their operation. In Year 1, we had already informed the growers that they were one of the lucky grant recipients so it was too late to make any retroactive decision to rescind the grants. When the 2013 recipients were selected, a visit to each operation was performed before grant awards were made. Operation size, desired season extension practice, and industry involvement was considered during the initial visits. NDA wanted to make sure the grants were awarded to growers who had a vested interest in the specialty crop industry. Thankfully, all five farm tours attracted large audiences, thus validating the growers as perfect project sub-recipients after all.

A total of seven sub-recipients were selected to receive grant funding. However, Field of Greens and Robinette Farms decided to relinquish the active direction of their projects and informed NDA that they could not fulfill the terms of their projects due to health-related circumstances. Due to the project's scheduling and make-up, it was too late for NDA to select alternate sub-recipients. Letters from NDA were sent to the USDA on June 13, 2013, and April 3, 2014, informing them of this change. Due to these unforeseen circumstances, only five sub-recipients received funding under this project.

The initial thought of this project was to help beginning and intermediate growers extend their season. It was believed that experienced growers would be secondary in nature. However, now that the project is complete, it is evident that this project benefited growers of all shapes and sizes.

The October 4, 2013, and June 6, 2014, farm tours were tested by Nebraska's inclement weather. Thunderstorm and tornado warnings were issued literally one hour before the start of both tours. Thankfully, by the time the tours were to start, the storms had passed through and moved far enough north that enabled for the tours to commence. A total of 31 growers attended the October 4th tour and 29 attended the June 6th tour. With the storms out of harm's way, the tours proved to be pleasant, informative, and successful. These tours, similar to the other two, were surprisingly very well attended.

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Additional Information

For more details regarding this project and the tours, please visit the Nebraska Our Best to You YouTube Channel at http://www.youtube.com/channel/UCUfhUcNUldN4_hf6attsvww. Written grower reports of each project can also be found on the Nebraska Our Best to You website at http://www.ourbesttoyou.nebraska.gov/. Below are photos of each farm tour.

Tomato Acres

Harvest Meadows

Savory Eats

Hintz Produce

Pekarek's Produce

Project Title

Improving Good Ag Practices for Nebraska's Farmers' Markets Vendors and Food Safety for the Public

Project Summary

In partnership with the steering committee for the Nebraska Farmers' Market Association, Old Cheney Road Farmers' Market (OCRFM) designed this project to increase food safety practices for farmers' market managers, vendors, and customers. Farmers' markets are great places for Nebraskans to find and buy specialty crops grown by local farmers. In the last decade, the number of Nebraska farmers' markets has doubled in size from 45 in 2000 to approximately 90 in 2010. This growth is not expected to slow down due to the increased interest in local foods.

Food safety of fresh fruits and vegetables and other specialty crops is a real issue facing markets and their vendors today. Safe, locally grown produce is as important to the producers as it is to the consumers. The purpose of providing Good Agricultural Practices (GAPs) training to market managers and produce vendors is to reduce the risks of microbial contamination of fruits and vegetables. The overarching aim is to help increase the safety or quality of local foods purchased at farmers' markets. A series of workshops and webinars were conducted for vendors and managers to learn about Good Agricultural Practices (GAPs) and how to implement food safety guidelines on the farm and at the market. Educational information for customers was made available at farmers' markets across Nebraska to increase the awareness of food safety, what to look for when buying produce and how to safely handle and store it once it has been purchased.

It is valuable to begin educating producers and consumers on the importance of food safety to prevent food borne illness in locally grown foods. This could be a significant benefit at local farmers' markets. GAPs training was offered to several produce vendors in 2011, but the USDA Rural Development grant funding for the trainings ended and there were many vendors and managers who did not receive training. SCBGP funds enabled the trainings to continue for an additional year, thus allowing more specialty crop producers to participate while still making it an affordable opportunity. UNL Extension assisted in providing the training to the producers.

Food safety is becoming increasingly important for local food producers. In January 2011, President Barack Obama signed the FDA Food Safety Modernization Act into law. This Act features the traceability of fresh produce grown in the United States, as well as great responsibility for food producers. The bill requires producers to evaluate hazards to their products, create measures to prevent contamination, and to develop written food safety plans.

The University of Nebraska-Lincoln Extension, the University of Nebraska Rural Initiative and the Nebraska Farmers' Market Association in partnership with the Old Cheney Road Farmers' Market (OCRFM) helped producers meet the requirements of the new legislation with this project.

Project Approach

The GAPs Training Team was put together in 2011 to provide the first trainings offered to fruit and vegetable growers in Nebraska. The initial guidance and funding support came from the University of Nebraska Rural Initiative, with program support from the Nebraska Department of Agriculture and the Nebraska Fruit and Vegetable Growers Association. A team of UNL Extension Educators taught the workshops in 2011 and in 2012. Curriculum and PowerPoint presentations were developed for the trainings. Together with OCRFM and the Nebraska Farmers' Market Association, the 2012 trainings were offered to a larger number of growers, market vendors and farmers' market managers. The workshops were vital to prepare Nebraska growers before the implementation of future federal regulations and assisting in the creating of farm food safety plans specific to their operations.

The 2012 GAPs trainings were offered as five, one-day trainings throughout the state in Scottsbluff, Ogallala, Kearney, Norfolk, and Omaha. A total of 105 producers, market vendors, market managers, UNL Extension, Master Gardeners, and representatives of the Nebraska Food Cooperative participated in the trainings. The topics covered helped producers enhance worker sanitation, harvesting, handling, packaging, storage and transportation standards of fresh produce from farm operations to markets, schools, restaurants, and retail stores. By completing a Farm Food Safety Plan, producers could differentiate themselves in the marketplace and appeal to many customers who perceive this training as an added benefit. All educational materials and costs of the workshop were provided by the University of Nebraska GAPs Training Team.

The dates, location, and number of people who attended each training is listed below.

1. January 25, 2012 at Panhandle Research and Extension Center, Scottsbluff, Nebraska. A total of 25 people attended (20 growers/producers and 5 UNL staff members representing UNL Extension Nebraska Rural Initiative).

2. January 26, 2012 at Valentino's Restaurant, Ogallala, Nebraska. A total of 17 people attended (10 growers/producers, 1 market manager, and 6 UNL staff members representing Extension and Nebraska Rural Initiative).

3. January 27, 2012 at Buffalo County Extension Office, Kearney, Nebraska. A total of 30 people attended (23 growers/producers, 1 market manager, and 6 UNL staff members representing Extension and Nebraska Rural Initiative).
4. February 8, 2012 at Lifelong Learning Center, Norfolk, Nebraska. A total of 11 people attended (5 growers/producers, 2 market managers, and 4 UNL staff members representing Extension and Nebraska Rural Initiative).

5. February 15, 2012 at Douglas/Sarpy Extension Office, Omaha, Nebraska. A total of 22 people attended (14 growers/producers, 4 market managers, and 4 UNL staff members representing Extension and Nebraska Rural Initiative).

Educational information for customers was made available at farmers' markets to help increase awareness of food safety and how to purchase, store, preserve, and prepare local

specialty crops safely. OCRFM, in partnership with the Nebraska Farmers' Market Association, put together and sent out the *2012 Farmers' Market Food Safety Success Toolkits* to 17 farmers' markets across the state. These Tool Kits included educational materials on food safety for market customers as well as ideas for planning events, community partners to consider, and press releases to help markets promote their activities and assist with outreach efforts. The tool kits were made available free of charge to participating farmers' markets.

Goals and Outcomes Achieved

The first goal of the project was to increase the number of farmers' market vendors in the state who have an integrated GAPs farm plan. The project built upon and supplemented the work accomplished thus far by targeting both growers and market managers who were not previously trained. The target was set to train 15 – 20 farmers and 5 – 10 market managers. This goal was achieved.

Participants were surveyed following each GAPs training to measure knowledge gained on issues pertaining to good agricultural practices. (n=64).

1. 87% increased knowledge about the need for farm food safety.
2. 80% increased knowledge about GAP field practices.
3. 66% increased knowledge about GAP transportation, traceability, and traceback practices.

Participants were also asked to provide feedback on what improvements could be made in the trainings, what they enjoyed the most, and important topics that were covered.

The second goal of the project was to increase specialty crops food safety knowledge among adults. To achieve this goal, food safety information discussing proper selection and storage of farmers' market purchases were made available to market customers. A total of 17 markets across Nebraska requested copies of the materials. A total of 900 surveys were also sent out to gather information from customers about their knowledge of food safety and usefulness of the resource materials. Unfortunately, out of all the surveys sent out, only 5 were returned. Even this small response will give us an idea of how to further food safety education in our local markets, and will provide something of a baseline to begin development.

Minor to no changes were made by customers on how they bought, stored or prepared foods purchased at their market based on the materials they picked up. Two customers were very concerned about food safety at the farm level, one was concerned and two were somewhat concerned. For food safety at the processing level where they may purchase jams, baked goods or other prepared products, two were very concerned, one was concerned and two were somewhat concerned. For food safety in the home two were very concerned, one was concerned, one was somewhat concerned and one was not at all concerned. Some of the actions the customers said they took to ensure their food is safe is to buy organic whenever possible, ask questions and read up on food safety, properly store, wash and cook all foods, and can their own food according to guidelines. One customer thought food purchased at farmers' markets was much safer compared to food purchased elsewhere. Three felt the food

was a little safer and one customer felt it was a little less safe. Issues that concerned the customers the most about food safety were pesticides on the food, food being in the heat unrefrigerated, bacterial contamination from farm to table, and companies monopolizing control over seed supply. None of the customers listed any further tips or information they wanted to receive from their market that wasn't already in the handouts.

Beneficiaries

The beneficiaries of this project are specialty crop growers in Nebraska, farmers' market managers, and customers who shop at farmers' markets. Increasing the number of growers and market managers that understand GAPs will help decrease the risks of microbial contamination and increase the ability to maintain a safe and local food system. Customers who shop at farmers' markets benefit by learning how to make safe food choices.

Fruit and vegetable growers enhance and diversify the Nebraska economy, adding $66.5 million into the state's economy each year. Although it is not easy to completely gauge the economic impact of this project, it is agreed that decreasing the risk of food borne illnesses increases the safety of our food system. A safe food system increases the trust between consumers and local markets. Understanding that farmers control the quality of their produce is one reason why consumers choose to purchase local foods. Shopping local increases farm profitability and keeps money in the local community.

Lessons Learned

GAPs training participants surveyed continued to find the trainings useful and informative. OCRFM and the Nebraska Farmers' Market Association were able to reach market vendors and managers to increase their participation in GAPs training and knowledge. Goals set for training participants were exceed. Partnering with University of Nebraska – Lincoln Extension and Rural Initiative also worked well.

Food safety education at farmers' markets ought to be increased. Understanding what customers think about food safety will help not only the markets, but also vendors to address those concerns. Also, as more vendors, growers, and producers integrate GAPs into their operation, it will be important to convey the meaning of that to customers. The customers also need to be fully aware that once a product is purchased, it is their responsibility to properly transport, store and prepare that product to keep it food safe. Education will decrease food safety issues. One suggestion is to provide trainings to managers and vendors each year. Materials such as informational handouts could be put in customer bags when products are purchased. Maybe a smaller amount of information given to the customers a few times during the market season would continue to increase their awareness of food safety, what to look for when buying produce and how to safely handle and store it once it has been purchased.

Contact Person

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Additional Information

None.

Project Title

Extending the Chicory Root Processing Campaign Using Potato or Cold Storage

Project Summary

Chicory roots contain carbohydrates in the form of fructans that are long chains of fructose molecules bonded to sucrose. These carbohydrates are called inulin. Inulin is an exciting new functional food ingredient that acts as a source of fiber and stimulates the good bacteria in the human intestine. At the present time, inulin is not being manufactured in the US even though several US food companies including General Mills and Kelloggs are mixing inulin, also called chicory root extract, in their cereals (Fiber One), energy bars and yogurts. In Nebraska we can begin processing chicory roots in mid September and harvest and process fresh roots into mid November. After mid November, freezing temperatures can result in the breakdown of carbohydrates in roots and freezing soil which can inhibit harvest. Preliminary studies conducted in 2010 suggest that if root temperatures are kept at 40 F the carbohydrate breakdown can be retarded. Potato growers in this region routinely store potatoes at temperatures around 40 F. The purpose of this project was to show on a larger scale that chicory roots can be harvested at various times in the fall and placed in cold storage and root quality can be maintained for several months therefore extending the processing campaign from 2 to 4 months.

During the fall of 2011, chicory roots were harvested on September 13, October 12, and November 9. At each harvest, roots were placed in 1200 lb totes and either placed in a commercial 40 F cooler or in temperature and humidity controlled potato storage located near Hemingford, Nebraska. Roots from each harvest date were sampled every 10 days for 60 days for free sugars (glucose, fructose, sucrose), inulin, and water. The maturity of chicory roots was influenced by date of harvest with roots harvested in September less mature than roots harvested in October or November. Roots harvested in September and stored for 60 days lost more water, had a greater increase in free sugars, and a greater decrease in inulin than roots harvested in October. However, roots harvested in November and stored for 60 days had less water loss, did not have an increase in free sugars, and inulin content did not change compared to roots harvested in September or October and stored for 60 days. The logical time to store roots would be near the end of the harvest season because roots harvested early in the fall could be processed immediately while roots harvested in the late fall could go into storage when air temperatures were cooler and roots more mature. The estimated cost for storing chicory roots for two months in a potato storage shed would be $23 per ton.

This project accomplished the goals and objectives of the project by demonstrating that chicory roots harvested in November could be stored for 60 days with minimal carbohydrate degradation for an estimated cost of $23 per ton.

Project Approach

Beginning in mid April, 1 acre of chicory was planted on cropland at the Panhandle Research

and Extension Center. Chicory was grown in a conventional manner through the summer. Beginning in mid September, 0.3 of the chicory was machine harvested to provide 12,000 pounds of roots. Harvests occurred in mid October and mid November and provided an additional 24,000 pounds of fresh roots. At each harvest date, roots were analyzed before being placed in storage.

At each harvest date, 36 random samples of roots were collected from the harvester. Each sample contained 12 roots placed in plastic mesh bags, weighed, and labeled. The 12,000 pounds of roots were divided between 10 ventilated plastic 1200 lb totes. Three to four sample bags were placed in each tote and covered with roots. Five of the totes were placed in a commercial 40 F cooler and five in potato storage. Every 10 days three sample bags were removed from each of the two storage environments. This continued for 60 days. Temperature and humidity were monitored during storage. Therefore, with three harvest dates, two storage environments, six sampling dates, and three replications a total of 108 root samples were analyzed.

At each sampling date, roots were transported to the laboratory, weighed, washed in water, allowed to air dry, and then roots were split longitudinally into quarters. One-quarter from each of the 12 roots was combined and run through a juicer. A portion of the juice was analyzed for soluble dry matter and the remaining juice was analyzed for carbohydrates by HPAE-PAD with a Dionex ICS-3000 system.

Goals and Outcomes Achieved

The goal of this project was to prove that chicory roots, harvested in September, October, or November, can be placed in cold storage (40°F) and kept for several months with minimal carbohydrate degradation. By mid-October chicory root yields can approach 22 to 25 tons per acre, with 23% of the root containing carbohydrates. The composition of the carbohydrates is 10% simple sugars (glucose, fructose, and sucrose) and 84% inulin. Root carbohydrate composition was will be measured at the time of harvest and then from representative samples at 10-day intervals for 60 days from both a 40°F cooler and commercial potato storage. Placing roots in cold storage (40°F) at this stage of development should preserve the carbohydrate composition.

The second goal was to analyze chicory roots every 10 days to show that inulin quality does not degrade appreciably under cold storage. The project was considered a success if the quantities of simple sugars can be kept below 15% for 30 to 60 days. If the quantities of simple sugars, particularly sucrose, become greater than 15% the extraction of inulin becomes more difficult, which leads to increases in processing costs.

The third was to explore the economics of chicory root storage in facilities similar to those already being utilized for potato storage.

2011 Growing Season

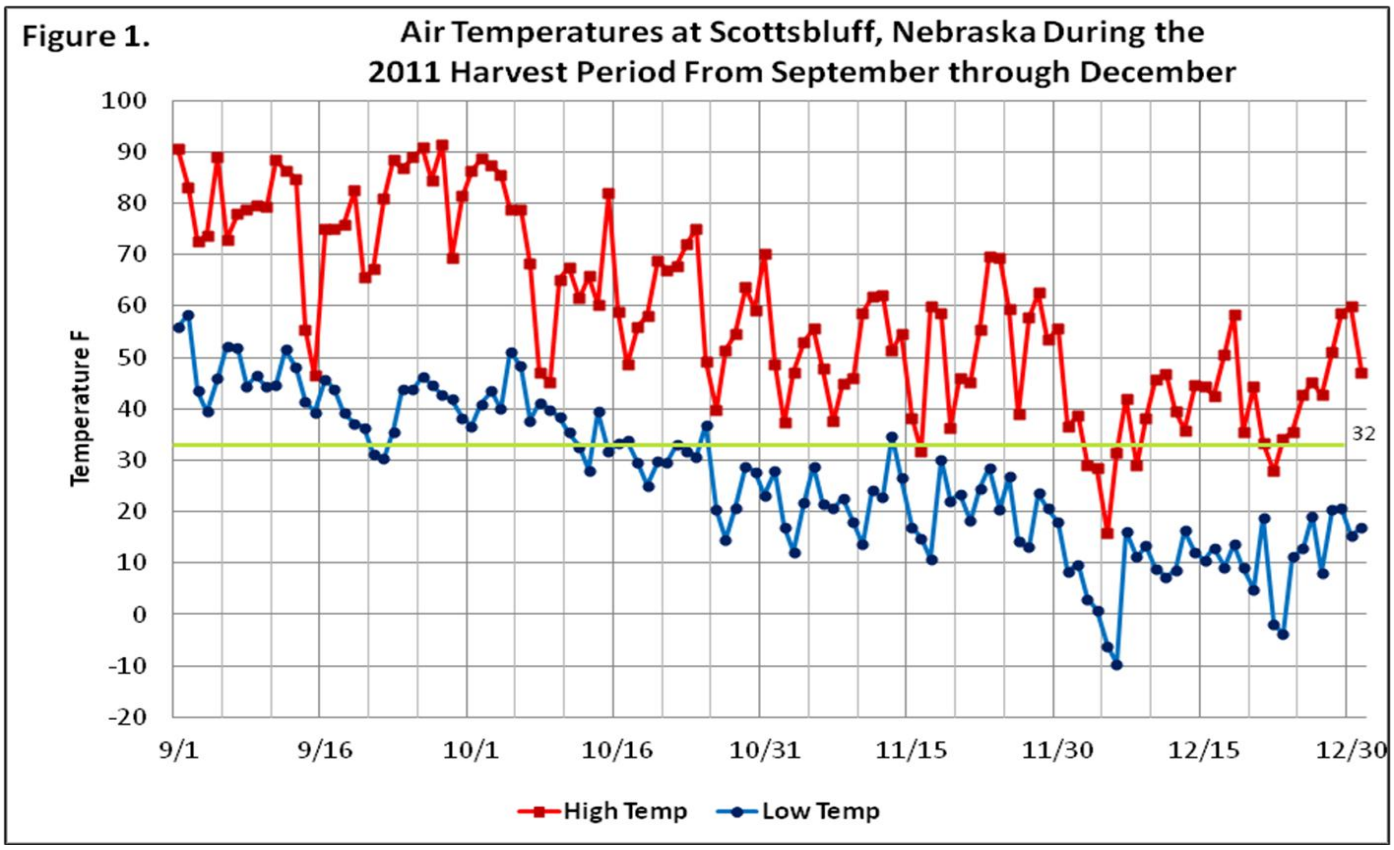
When compared to the meteorological means for the past 100 years, the 2011 growing season

can be characterized by slightly cooler and wetter in May, warmer and drier in July and August, drier in September, and wetter in October (Table 1). During the fall harvest, night-time low temperatures did not fall below 30 F until mid October (Figure 1). As the harvest season progressed from late October into November daily low temperatures ranged from 10 to 30 F and chicory leaves were injured and top growth ceased.

Table 1. Long-Term and Recent Climatological Data Summary for Scottsbluff, Nebraska.

	Average temperature						Average minimum					
Month	Long-term average	2007	2008	2009	2010	2011	Long-term average	2007	2008	2009	2010	2011
	(F)						(F)					
March	36	43	37	38	40	39	21	27	23	21	27	25
April	46	45	44	44	47	45	30	31	28	31	34	33
May	56	59	54	58	54	52	41	44	40	43	41	41
June	67	69	65	64	68	66	51	52	50	52	54	52
July	74	77	74	69	73	76	58	62	57	55	58	62
August	71	74	70	68	73	74	55	59	56	51	56	58
September	61	63	59	62	62	61	43	47	43	46	43	43
October	49	51	48	39	53	49	33	34	31	28	37	33

	Average maximum						Average precipitation					
Month	Long-term average	2007	2008	2009	2010	2011	Long-term average	2007	2008	2009	2010	2011
	(F)						(F)					
March	51	59	51	54	53	52	1.09	1.48	0.06	0.07	0.40	0
April	63	59	61	56	61	58	1.58	0.68	1.04	2.07	2.06	2.51
May	72	74	68	72	67	64	2.77	0.85	1.39	1.82	2.72	5.26
June	83	86	81	77	81	81	2.64	0.22	1.62	4.90	3.76	2.35
July	90	91	91	84	88	91	2.06	0.76	0.94	2.29	0.74	1.05
August	88	89	84	84	89	89	1.07	0.46	2.23	0.56	1.15	0.24
September	78	79	75	78	81	78	1.10	0.34	1.52	0.46	0.07	0.12
October	68	67	65	50	69	65	0.81	1.80	0.74	1.49	1.06	1.70



Establishing the Crop

Chicory seedling emergence was recorded on May 25, June 14, and June 22 (Table 2). On May 25 the plant density for Orchies averaged 44,350 plants/acre (Picture 1). By June 14 the plant density had increased slightly to 47,720 plants/acre, and by June 22 had stabilized at 48,390 plants/acre. During July and August chicory growth continued without problems from insects, diseases, or inclement weather. On August 30, 0.6% of the chicory plants (290 plants/acre) were observed bolting (flowering) which is normal.

Picture 1

Table 2. Plant Density and Late Season Bolting for the Chicory Variety Orchies at Scottsbluff, Nebraska during the 2011 Growing Season.

Chicory variety	Harvest date	Plant stand			Bolting plants	
		May 25	June 14	June 22	August 10	August 30
		(plants/acre)			(% of plants)	
Orchies	September 13	41220	44670	47280	0	.7
	October 12	42530	44190	46570	0	.4
	November 9	49300	54290	51320	0	.7
	AV	44350	47720	48390	0	.6

Harvesting the Crop

Date of harvest influenced root yield with the greatest yield recorded on October 12 and November 9 (Table 3) (Picture 1B). On September 13 root yield averaged 12.3 tons/acre (27.5 tonnes/ha) and 21.7 tons/acre (48.7 tonnes/ha) 29 days later on October 12. Root yields on November 9 were similar to those observed on October 12.

Table 3. Influence of Chicory Harvest Date on Root Yield, Soluble Dry Matter and Carbohydrate Concentration at Scottsbluff, Nebraska during the 2011 Growing Season.

Chicory variety	Harvest date	Root yield		Soluble dry matter
		(tons/acre)	(tonnes/ha)	
Orchies	September 13	12.3	27.5	20.2
	October 12	21.7	48.7	22.5
	November 9	21.4	47.9	23.1
	AV	18.4	41.4	21.9

Picture 1B

On September 13, the percent of the carbohydrates present as glucose and the concentration of glucose (grams/kg) in chicory roots were greater than those recorded on October 12 (Table 4). Reports in the literature indicate that the 1-SST, the enzyme responsible for converting sucrose (S) to DP3 (1-kestose) is active in roots during the summer. Glucose (G) is a product of the reaction (Sucrose + 1-SST → G-F-F + Glucose). When the activity of 1-SST is high then the concentration of glucose is also high. As the second enzyme responsible for inulin metabolism, 1-FFT, becomes more active and 1-SST less active, the concentrations of glucose decline.

The observation of higher concentrations of glucose in chicory roots harvested in late summer suggest high 1-SST activity and the roots were not mature. As the growing season progressed into fall the activity of 1-FFT increased and glucose concentration declined.
The percent of carbohydrate present as free sugars: glucose, fructose and sucrose was 12% and as inulin was 82% at the time of the first harvest on September 13 (Table 4). By November the percent of the carbohydrate present as long-chain length inulin (DP>20) declined to 13%, total inulin declined to 76%, and free sugars: glucose, fructose and sucrose increased to 19%, as inulin was naturally degraded by the 1-FEH enzyme. The enzyme responsible for inulin breakdown, 1-FEH, is stimulated by freezing temperatures in the range from 28 to 30 F which occurred on October 15 and for prolonged periods, starting in late October (Figure 1). The concentration of free sugars: glucose + fructose + sucrose was 6 grams/kg on September 13 and the concentration on October 12 was 8 grams/kg, by November 9 inulin degradation was occurring and the concentration of free sugars was 17 grams/kg. The changes in free sugars during the harvest season are closely associated with changes in inulin metabolism, as inulin is degraded by the 1-FEH enzyme fructose is released.
Table 4. Influence of Chicory Harvest Date on Root Carbohydrate Concentration at

Scottsbluff, Nebraska during the 2011 Growing Season.

		Percent of the total carbohydrates								Concentration of selected carbohydrates					
		Free sugars				Inulin									
Chicory variety	Harvest date	Glucose	Fructose	Sucrose	Total	DP3-10	DP11-20	DP>20	Total	Glucose	Fructose	Sucrose	DP 3	DP 4	DP 5
		- (%) -								- - - - - - - - - - - - - - (grams/kg) - - - - - - - - - -					
Orchies	September 13	3.2	1.4	7.3	11.9	32.9	27.7	21.7	82.3	0.9	0.3	5.1	3.1	3.0	4.9
	October 12	1.0	0.6	8.2	9.8	38.1	27.5	19.9	85.5	0.3	0.1	7.6	5.3	5.5	7.8
	November 9	1.4	6.5	10.8	18.7	40.8	22.0	13.2	76.8	0.6	3.7	13.0	7.6	7.2	9.9
	AV	1.9	2.9	8.8	13.5	37.2	25.8	18.2	81.3	0.6	1.4	8.6	5.3	5.2	7.5

At each harvest date, 36 random samples of roots were collected from the harvester. Each sample contained 12 roots and was placed in plastic mesh bags, weighed, and labeled (Picture 2). At the same time roots were placed in ventilated plastic 1200 lb totes (Picture 3). Six sample bags were placed in the center of each tote and covered with roots (Picture 4). Three totes were placed in a commercial 40 F cooler and three totes were transported to Hemingford, Nebraska and placed in a commercial potato storage shed filled with potatoes (Pictures 5 and 6). In potato storage, totes were placed adjacent to potatoes (Picture 7). Every 10 days for 60 days, three sample bags were removed from totes in each storage environment and taken to the laboratory for analysis. At each harvest date a temperature and humidity monitor was placed inside one of the totes as roots were moved into each storage environment. In addition a similar monitor was placed outside the tote.

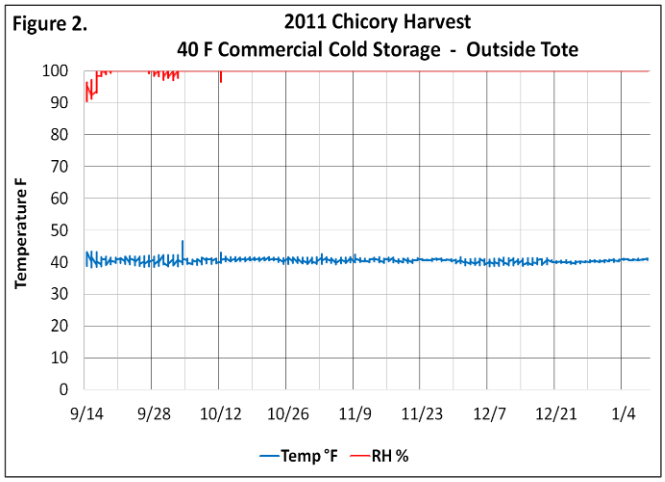
Picture 2

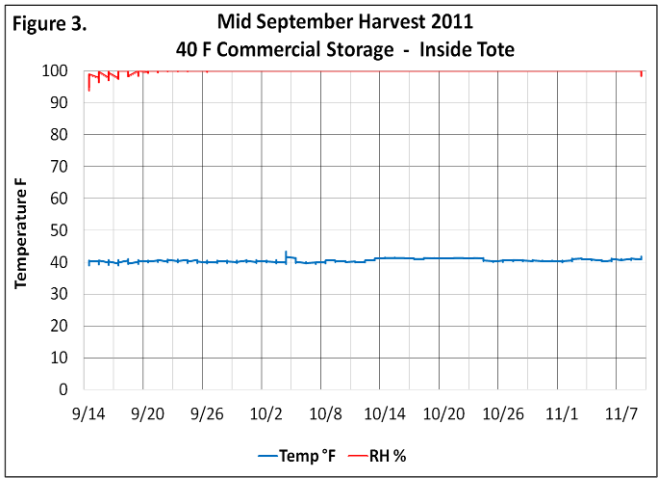
Picture 3

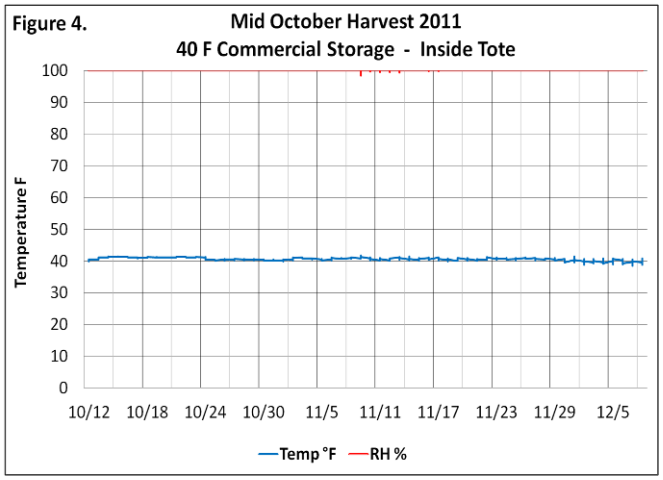
Picture 4

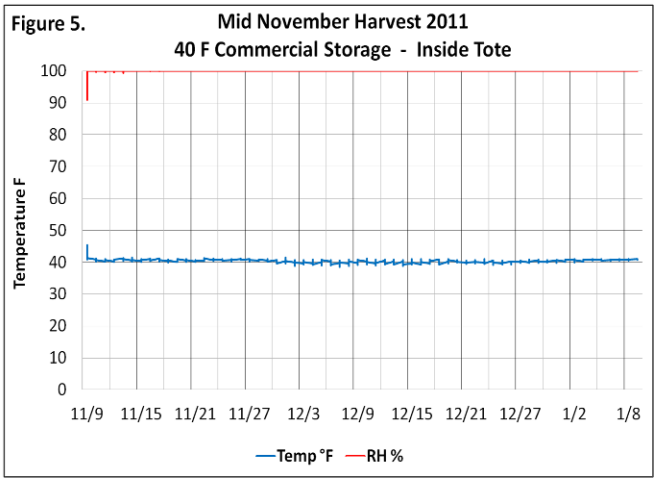
Temperature and relative humidity recorded outside the tote in commercial 40 F cold storage indicated that relative humidity varied from 90 to 100% during the first 30 days and then remained at 100% through January (Figure 2). Air temperature remained near 40 F throughout the study period. Inside the tote buried in roots, the relative humidity only varied by

several degrees from 100% during the first 10 days of storage in September and then remained at 100% and temperature remained near 40 F (Figure 3). During the mid October and mid November storage periods, temperature remained near 40 F and relative humidity was 100% (Figures 4 and 5).





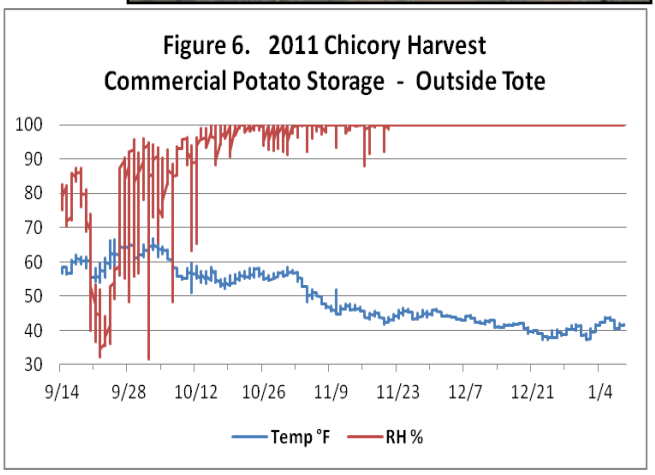


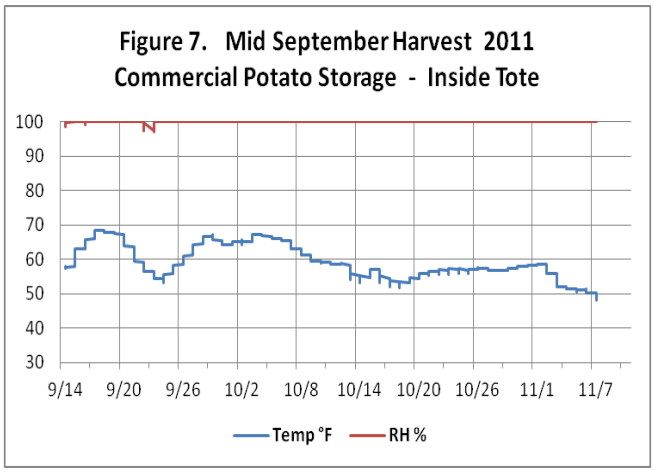


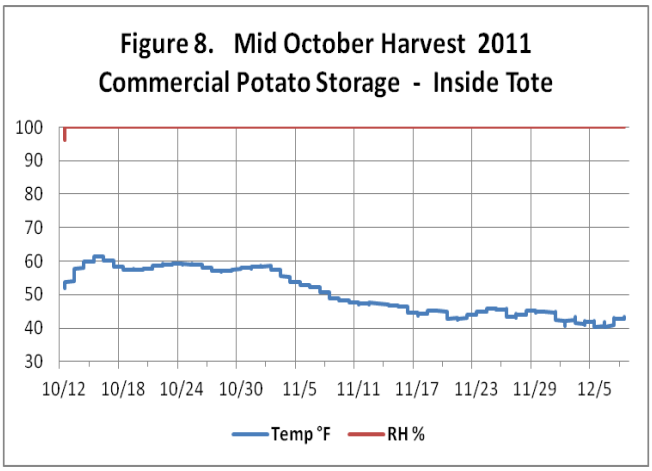
At the time of the September 13 harvest, it was not possible to place totes filled with chicory roots in with potatoes because potatoes had not been harvested. During the period from September 14 through early October, totes filled with chicory roots were placed in a storage shed without temperature and humidity control (Picture 8). During this period relative humidity outside the tote varied from 30 to 95% while temperatures varied from 55 to 65 F (Figure 6). Once potatoes had been harvested and sheds filled, totes were moved next to potatoes and temperature and humidity were regulated (Picture 9). Temperature and humidity monitors outside of totes indicated that humidity varied from 90 to 100 % and temperature varied from 58 to 40 F. Although relative humidity varied outside the tote, inside the tote relative humidity remained near 100% throughout the study (Figures 7, 8 and 9). During the first storage period temperature inside the tote varied from 58 to 69 F during the first 30 days of storage and then remained under 60 F for another 15 days and then dropped to near 50 F for the remaining 15 days of storage (Figure 7). The second storage period was initiated following the mid October harvest. During the first 30 days temperatures inside the tote remained near 60 F and then declined to near 40 F during the final 30 days (Figure 8). The final 60 day storage period utilized roots from the mid November harvest and temperatures inside the tote declined from

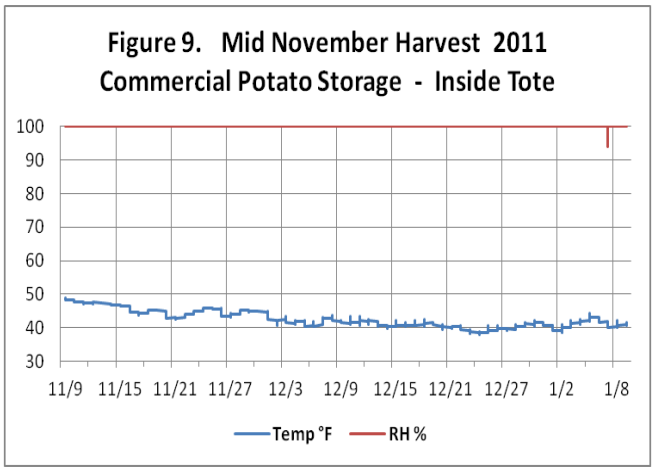
50 to 40 F during the first 30 days and then remained near 40 F the remaining 30 days (Figure 9). The gradual decline in temperatures from the mid 50s to near 40 F is a practice used by potato growers to acclimate potato tubers to storage. Potatoes store better if the temperature is dropped gradually rather than immediately.

Picture 8

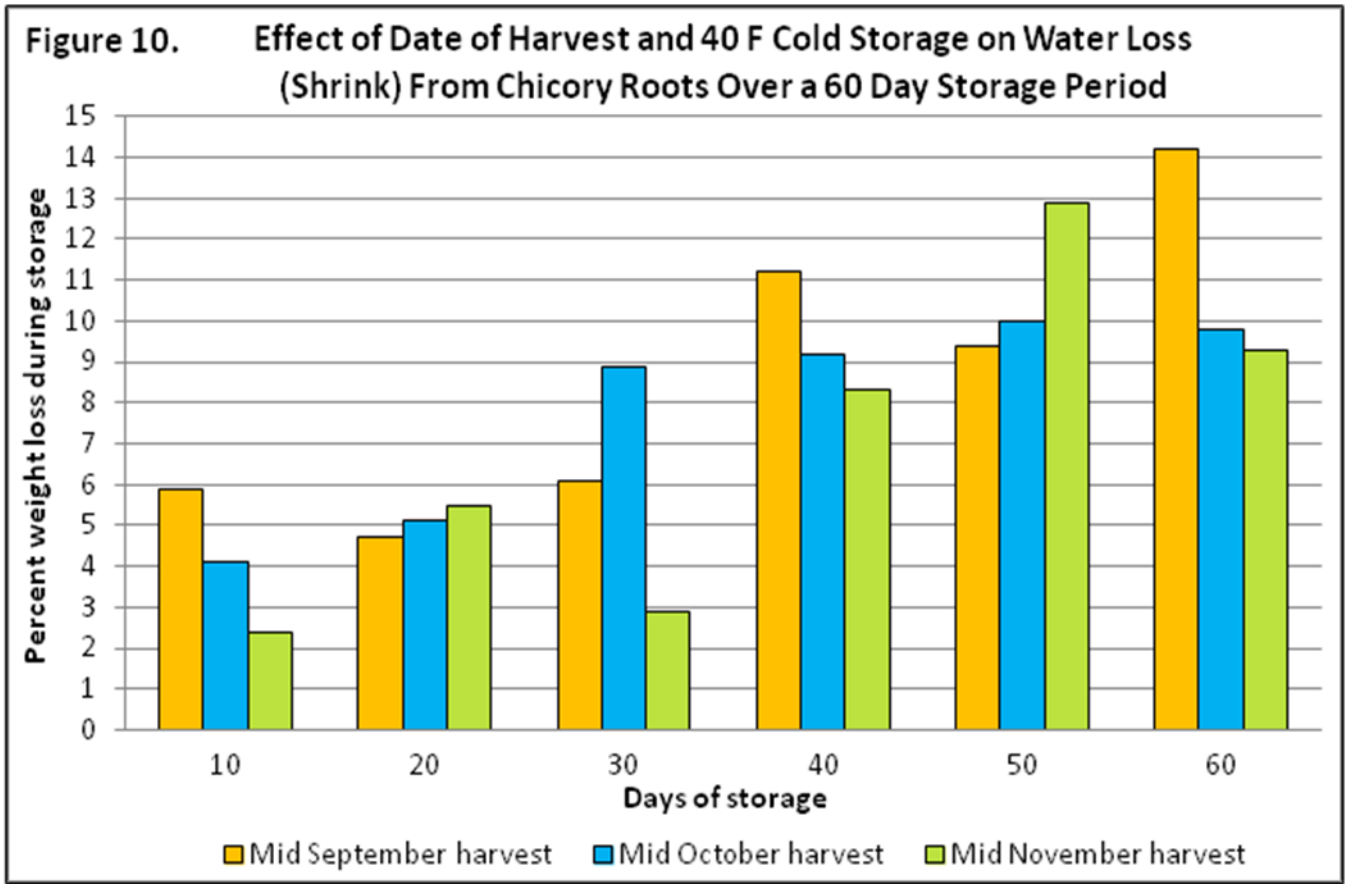








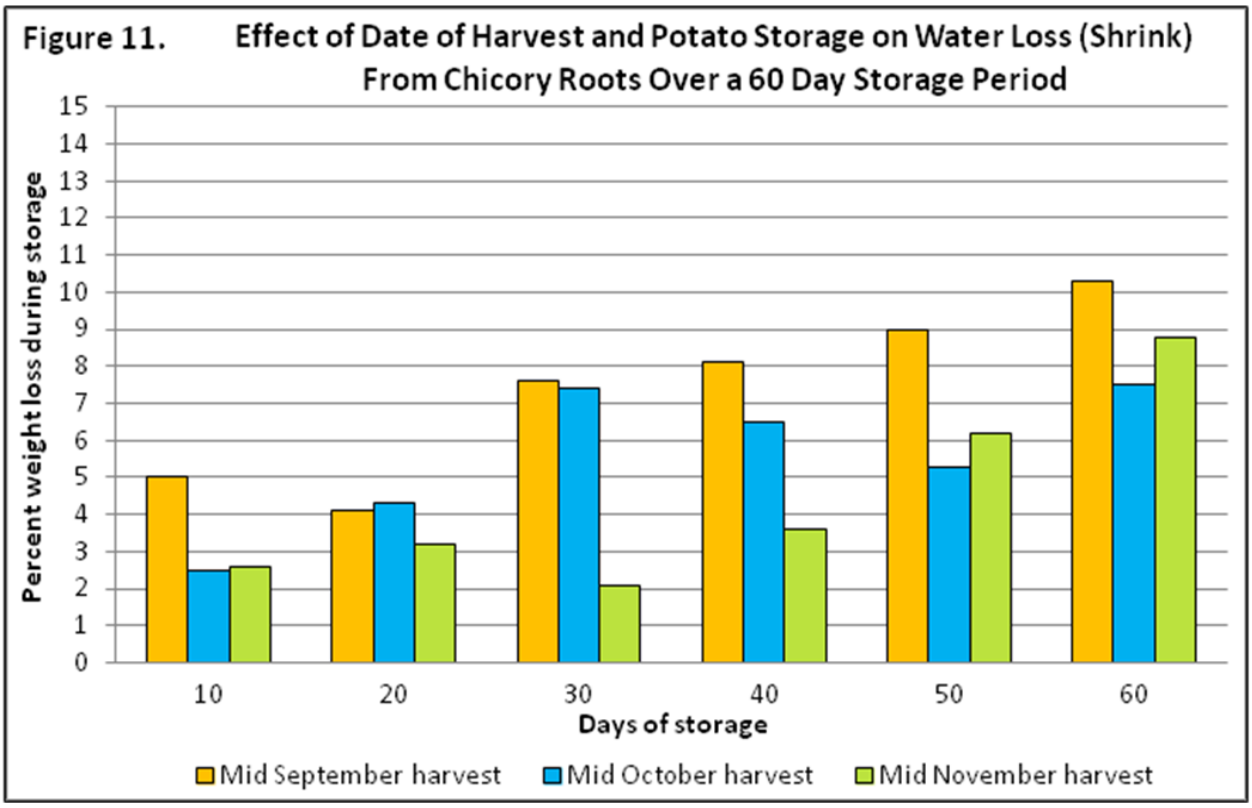
The goal of potato or chicory storage is to keep the respiring biologically active organism in a preserved state for as long a period as possible. During storage, roots respire and lose weight (shrink), bruises that occurred during harvest may start to heal, excess moisture is lost, disease organisms present on roots may start to grow and carbohydrates stored in the root may undergo changes. As indicated in the introduction this study was designed to measure these changes under 40 F cold storage or potato storage.

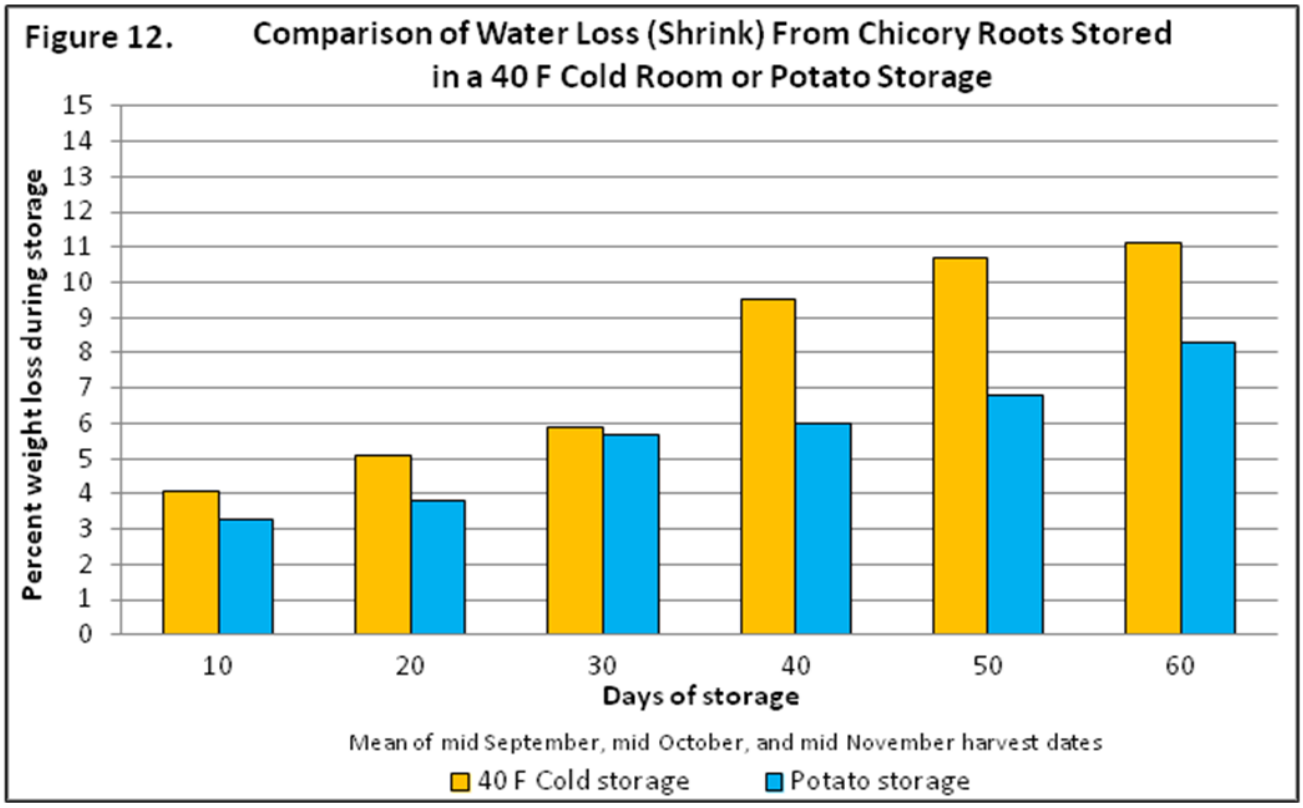


During the first 10 days of storage at 40 F in commercial storage, chicory roots lost between 2 to 6% water (Figure 10 and Table 5). Roots that were harvested in mid September lost more

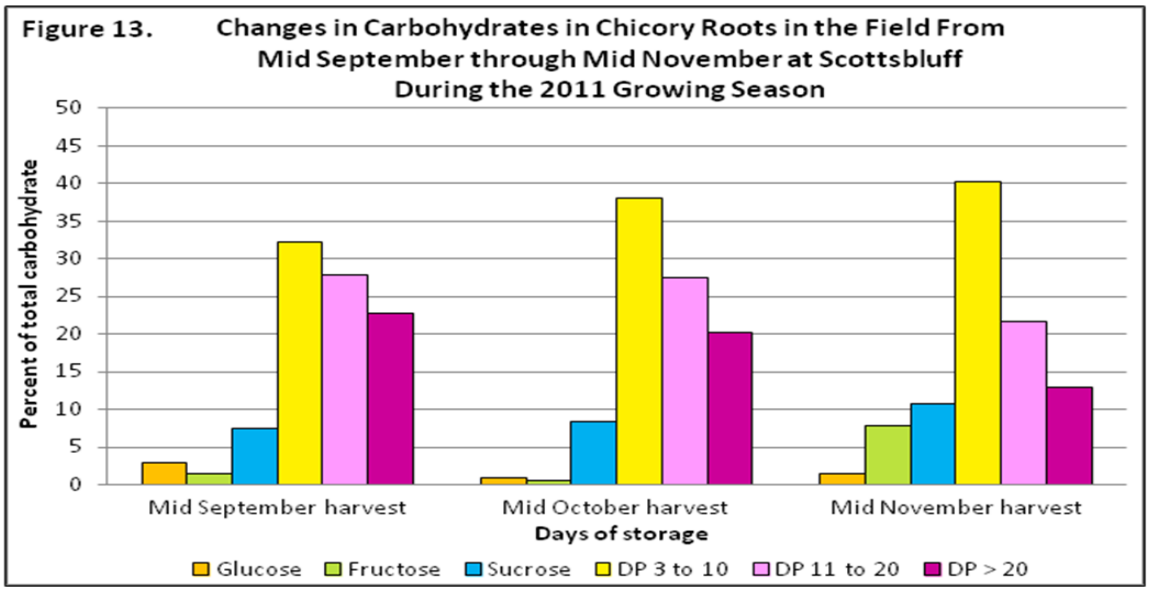
water than roots harvested in November. After 60 days of storage roots harvested in September had lost 14% of their weight while roots harvested in November had lost 9% of their weight.

During the first 10 days of storage in potato storage, chicory roots lost between 2 to 5% water (Figure 11 and Table 6). Again roots harvested in mid September lost more water than roots harvested in November. After 60 days of storage, roots harvested in September had lost 10% of their weight while roots harvested in November had lost 9% of their weight. Mean water loss at each sampling interval was utilized to compare water loss in 40 F commercial storage and potato storage (Figure 12). At each sampling interval chicory roots lost more water in 40 F commercial storage than in potato storage. Even though relative humidity remained near 100% inside totes in both storage environments there was something different in potato storage that reduced water loss. In the 40 F cold room, temperature was constantly maintained by heating and cooling cycles in the refrigeration unit while in potato storage there was a large mass of potatoes that tempered changes in temperature and moisture over the 60 day storage period.

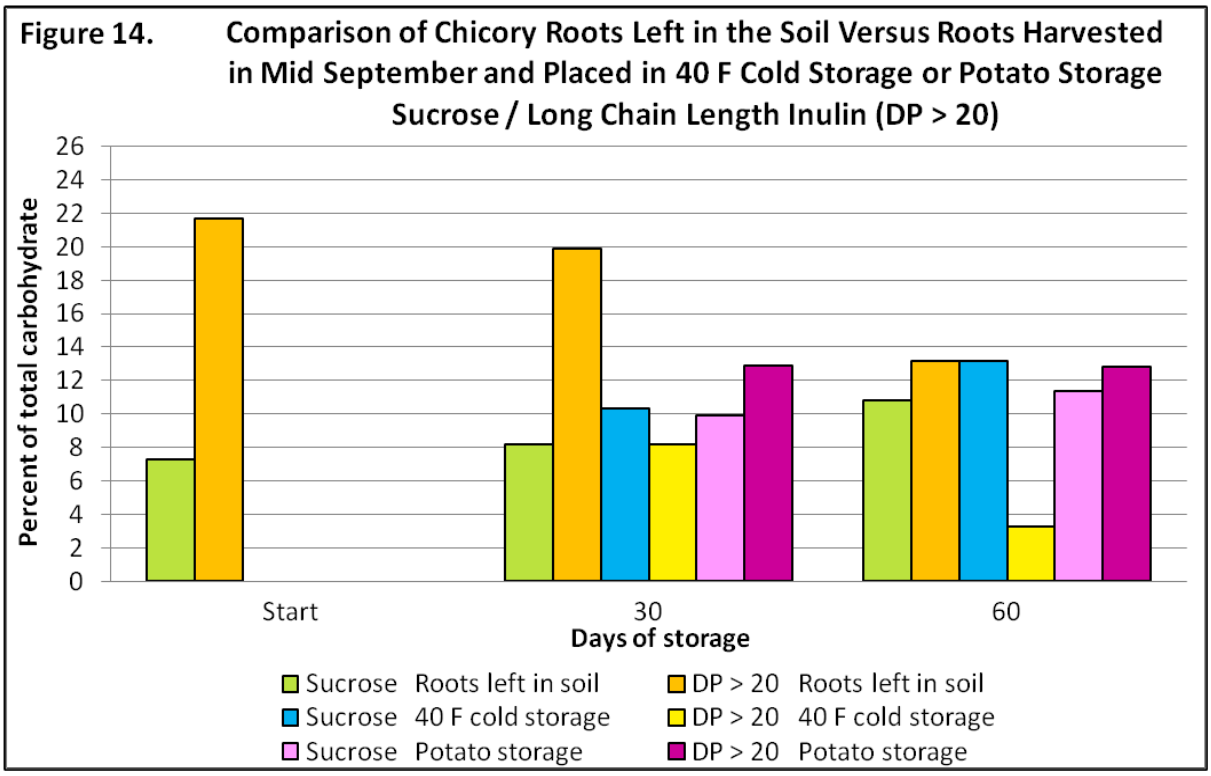




The carbohydrate composition of chicory roots growing in the field changed from mid September to mid November (Figure 13 and Table 4). Inulin comprised 83% of the total carbohydrate when roots were harvested in mid September. The inulin composition was as follows: DP3 to 10, DP11 to 20, and DP>20 comprised 32, 28, and 23% of the inulin, respectively. At the last harvest date in mid November percent of the carbohydrate as inulin had declined to 75% with the composition of inulin in the DP11 to 20, and DP>20 decreased to 22 and 13%, respectively while short-chain length inulin in the DP3 to 10 percent range increased to 40%. Because of the breakdown of inulin, which naturally occurs in November, the free sugars fructose and sucrose increased to 7 and 11%, respectively at the time of the mid November harvest.



One concept for simplifying the discussion of these changes would be to plot the variations in sucrose and long-chain length inulin (DP>20) over time since both are responsive to changes in the environment. As indicated earlier, even if chicory roots are left undisturbed in the soil, sucrose increases and long-chain length inulin (DP>20) decreases. Long-chain inulin decreased from 22 to 8% after 30 days of storage at 40 F and from 22 to 13% in potato storage (Figure 14 and Tables 5 and 6). After 60 days of storage long-chain length inulin declined to 3% at 40 F and remained at 13% in potato storage.



A second approach for comparing root carbohydrates would be to examine the sum of free sugars (glucose + fructose + sucrose) and total inulin. Using these parameters, chicory roots left in the soil for 30 days (mid September through mid October) had similar levels of free sugars and inulin (Figure 15 and Tables 5 and 6). Roots left in the soil for another 30 days until mid November had an increase in free sugars to 19% and percent inulin declined to 76%. Roots harvested in mid September and placed in 40 F cold storage had free sugars increase to 27% and inulin decreased to 66% after 30 days and after 60 days free sugars were 28% and inulin declined to 61% of the total carbohydrates. Changes in carbohydrates were not as great in potato storage, after 30 days free sugars were 18% and inulin 77% and after 60 days free sugars were 21% and inulin was 74%.

Therefore when chicory roots were harvested at the beginning of the harvest season (mid September) changes in free sugars, inulin, and moisture loss were not as great if roots were placed in potato storage compared to 40 F cold storage. However, under both types of storage long-chain inulin (DP>20) decreased while short-chain inulin increased.

Table 5. Effect of 60 Days of 40 F Cold Storage on the Carbohydrate Content of Chicory Roots Harvested Mid September, Mid October or Mid November in 2011.

					Mid September Harvest														
					Percent of total carbohydrate														
					Free sugars				Inulin				Concentration of selected carbohydrates						
Date removed from cooler	Root weight when placed in cooler	Root weight when removed from cooler	Weight Loss	Soluble Dry Matter	Glucose	Fructose	Sucrose	Total	DP3-10	DP11-20	DP>20	Total	Glucose	Fructose	Sucrose	DP 3	DP 4	DP 5
	(kg)	(kg)	(%)		- -% - - - - - - - - - - - -								- (g/kg) - - - - - - -						
Mid Sept Harvest Harvest Day	3.2	3.2	0.0	20.1	2.9	1.4	7.4	11.8	32.3	27.9	22.8	83.0	0.8	0.3	5.0	2.9	2.9	4.7
Mid Sept Harvest 10 DAH	3.3	3.1	5.9	21.4	6.0	15.2	8.9	30.2	30.8	18.3	16.0	65.1	2.4	8.3	9.3	5.3	3.6	5.1
Mid Sept Harvest 20 DAH	3.2	3.1	4.7	21.9	3.8	10.5	9.5	23.8	40.9	18.6	12.4	71.9	1.9	6.9	12.8	7.1	6.6	8.8
Mid Sept Harvest 30 DAH	3.9	3.7	6.1	21.4	4.6	12.5	10.3	27.5	41.3	16.3	8.2	65.8	1.9	7.6	12.4	5.7	5.6	7.7
Mid Sept Harvest 40 DAH	4.1	3.6	11.2	21.6	3.5	14.0	11.9	29.5	43.7	13.8	5.1	62.6	1.7	10.3	17.8	7.4	7.6	9.7

Mid Sept Harvest 50 DAH	4.0	3.6	9.4	21.7	2.6	10.3	11.7	24.6	47.2	14.7	5.1	67.0	1.4	7.6	18.6	8.5	9.2	11.9
Mid Sept Harvest 60 DAH	4.1	3.5	14.2	22.9	2.2	12.7	13.2	28.1	45.3	12.1	3.3	60.7	1.2	10.2	23.9	9.5	10.2	13.0

Table 5. Continued.

					Mid October Harvest													
					Percent of total carbohydrate													
					Free sugars				Inulin				Concentration of selected carbohydrates					
Date removed from cooler	Root weight when placed in cooler	Root weight when removed from cooler	Weight Loss	Soluble Dry Matter	Glucose	Fructose	Sucrose	Total	DP3-10	DP11-20	DP>20	Total	Glucose	Fructose	Sucrose	DP 3	DP 4	DP 5
	(kg)	(kg)	(%)		-- % --								---------------------- (g/kg) ----------------------					
Mid Oct Harvest Harvest Day	4.5	4.5	0.0	22.4	1.0	0.6	8.3	9.9	38.1	27.4	20.2	85.7	0.4	0.1	8.1	5.6	5.8	8.2
Mid Oct Harvest 10 DAH	5.8	5.6	4.1	23.4	2.6	10.3	9.9	22.8	35.3	21.0	16.6	72.8	0.9	4.8	9.2	5.9	4.4	5.9
Mid Oct Harvest 20 DAH	5.3	5.1	5.1	22.7	1.7	6.8	10.1	18.6	39.6	21.6	15.8	77.1	0.6	2.9	9.5	6.1	5.4	7.3
Mid Oct Harvest 30 DAH	4.8	4.4	8.9	22.6	2.1	10.9	11.4	24.5	42.4	18.0	10.3	70.7	1.0	7.5	16.6	9.3	7.6	11.0

Mid Oct Harvest 40 DAH	5.0	4.5	9.2	23.0	1.1	10.1	15.3	26.6	47.7	15.7	5.9	69.4	0.5	5.8	20.7	8.6	7.9	10.2
Mid Oct Harvest 50 DAH	5.1	4.6	10.0	23.0	1.1	6.6	14.1	21.8	51.2	17.4	5.5	74.1	0.5	4.1	19.7	8.8	8.9	11.9
Mid Oct Harvest 60 DAH	4.1	3.7	9.8	22.5	0.7	4.2	15.6	20.5	54.6	15.8	4.1	74.5	0.3	2.4	22.4	10.2	11.1	14.9

Table 5. Continued.

Date removed from cooler	Root weight when placed in cooler	Root weight when removed from cooler	Weight Loss	Soluble Dry Matter	Mid November Harvest													
					Percent of total carbohydrate													
					Free sugars				Inulin				Concentration of selected carbohydrates					
					Glucose	Fructose	Sucrose	Total	DP3-10	DP11-20	DP>20	Total	Glucose	Fructose	Sucrose	DP3	DP4	DP5
	(kg)	(kg)	(%)		%								(g/kg)					
Mid Nov Harvest Harvest Day	5.5	5.5	0.0	23.3	1.4	7.8	10.8	20.1	40.3	21.7	12.9	74.9	0.6	4.6	13.7	7.9	7.6	10.4
Mid Nov Harvest 10 DAH	4.6	4.5	2.4	23.5	1.0	3.2	12.9	17.2	44.7	20.8	11.9	77.4	0.3	1.3	12.3	6.5	6.2	8.5
Mid Nov Harvest 20 DAH	5.5	5.2	5.5	23.5	0.9	2.2	13.3	16.5	48.2	21.4	8.9	78.5	0.5	1.2	18.5	9.9	10.3	13.8
Mid Nov Harvest 30 DAH	4.7	4.6	2.9	23.4	0.6	3.6	14.7	18.9	49.9	19.9	5.8	75.6	0.2	1.8	18.6	9.0	9.8	13.2
Mid Nov Harvest 40 DAH	5.4	5.0	8.3	24.6	0.7	4.4	15.3	20.5	47.9	18.8	7.5	74.2	0.3	2.4	18.3	8.2	8.4	11.2
Mid Nov Harvest 50 DAH	6.5	5.7	12.9	25.5	0.6	5.4	15.9	22.0	51.3	15.9	5.6	72.8	0.2	2.6	18.6	8.3	8.4	11.4

Mid Nov Harvest 60 DAH	5.2	4.7	9.3	25.5	0.4	3.7	14.4	18.5	49.6	19.4	6.9	75.9	0.1	1.7	15.8	7.5	8.1	11.1
LSD at 0.05	0.8	0.8	4.1	1.8	0.8	3.2	1.5	3.6	3.8	3.3	3.6		0.4	3.1	4.0	2.3	2.0	2.6
CV	10.4	11.0	37.6	4.7	23.0	25.7	7.7	10.1	5.2	10.5	21.8		29.7	41.3	15.9	18.6	16.4	15.8

Table 6. Effect of 60 Days of Potato Storage on the Carbohydrate Content of Chicory Roots Harvested Mid September, Mid October or Mid November in 2011.

Date removed from cooler	Root weight when placed in cooler	Root weight when removed from cooler	Weight Loss	Soluble Dry Matter	Mid September Harvest — Percent of total carbohydrate — Free sugars: Glucose	Fructose	Sucrose	Total	Inulin: DP3-10	DP11-20	DP>20	Total	Concentration of selected carbohydrates: Glucose	Fructose	Sucrose	DP 3	DP 4	DP 5
	(kg)	(kg)	(%)		- -% - - - - - - - - - - - -								- (g/kg) - - - - - - -					
Mid Sept Harvest Harvest Day	3.2	3.2	0.0	20.1	2.9	1.4	7.4	11.8	32.3	27.9	22.8	83.0	0.8	0.3	5.0	2.9	2.9	4.7
Mid Sept Harvest 10 DAH	3.6	3.4	5.0	21.8	4.0	8.3	8.5	20.9	31.3	21.4	21.0	73.7	1.3	3.4	6.8	3.9	3.4	4.7

Mid Sept Harvest 20 DAH	3.6	3.4	4.1	20.7	2.5	5.8	9.2	17.5	39.9	20.2	18.0	78.1	0.9	2.8	9.0	5.3	5.5	7.3
Mid Sept Harvest 30 DAH	3.9	3.6	7.6	20.9	2.5	5.6	9.9	18.0	42.2	21.4	12.9	76.5	0.8	2.4	9.1	5.5	5.2	6.9
Mid Sept Harvest 40 DAH	3.9	3.6	8.1	21.5	1.9	4.8	10.6	17.4	41.3	21.9	13.9	77.1	0.6	1.7	8.7	4.8	4.6	6.3
Mid Sept Harvest 50 DAH	3.6	3.3	9.0	21.0	0.8	3.9	12.5	17.2	45.1	19.9	12.0	77.0	0.2	0.9	7.3	4.1	4.1	5.4
Mid Sept Harvest 60 DAH	3.6	3.2	10.3	20.5	1.9	7.2	11.4	20.6	41.7	19.4	12.8	73.9	0.8	3.9	12.9	6.7	5.9	8.6

Table 6. Continued.

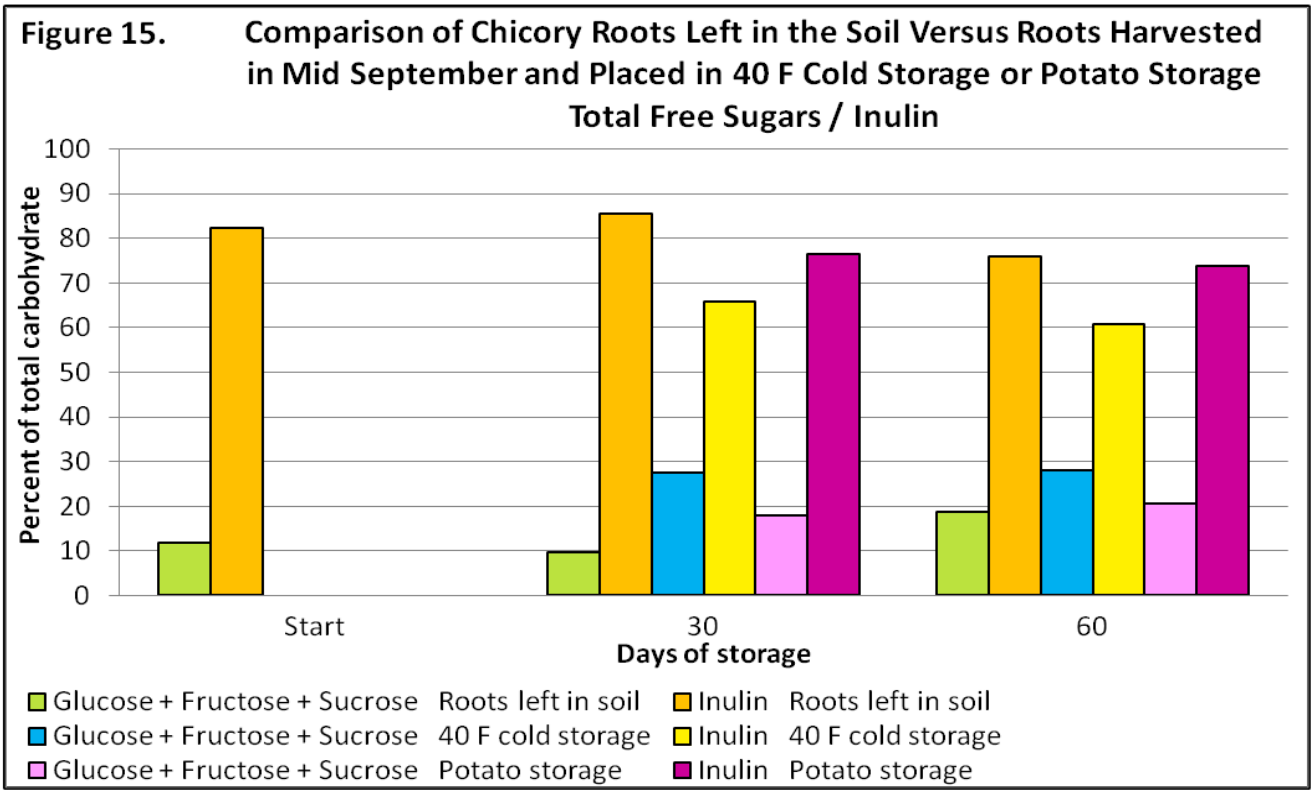
Date removed from cooler	Root weight when placed in cooler	Root weight when removed from cooler	Weight Loss	Soluble Dry Matter	Mid October Harvest													
					Percent of total carbohydrate													
					Free sugars				Inulin				Concentration of selected carbohydrates					
					Glucose	Fructose	Sucrose	Total	DP3-10	DP11-20	DP>20	Total	Glucose	Fructose	Sucrose	DP3	DP4	DP5
	(kg)	(kg)	(%)		-%								(g/kg)					
Mid Oct Harvest Harvest Day	4.5	4.5	0.0	22.4	1.0	0.6	8.3	9.9	38.1	27.4	20.2	85.7	0.4	0.1	8.1	5.6	5.8	8.2
Mid Oct Harvest 10 DAH	4.9	4.8	2.5	22.9	2.1	4.0	8.6	14.8	34.7	23.9	21.1	79.7	0.6	1.3	6.3	4.4	3.5	4.9
Mid Oct Harvest 20 DAH	5.6	5.4	4.3	22.3	1.5	4.3	9.4	15.1	36.7	22.7	19.9	79.3	0.5	1.6	7.4	4.8	4.3	5.9
Mid Oct Harvest 30 DAH	5.0	4.6	7.4	22.5	1.3	4.2	10.6	16.1	39.7	22.2	16.4	78.3	0.4	1.6	9.2	5.7	4.9	6.8
Mid Oct Harvest 40 DAH	4.5	4.2	6.5	22.9	1.1	6.5	11.4	19.0	42.4	20.5	13.6	76.5	0.3	2.6	9.8	5.5	5.4	7.2
Mid Oct Harvest 50 DAH	4.5	4.3	5.3	22.1	1.1	3.4	13.1	17.6	47.2	20.1	9.8	77.1	0.4	1.6	15.3	8.9	8.8	11.5

Mid Oct Harvest 60 DAH	4.6	4.3	7.5	21.3	1.1	4.3	13.9	19.3	45.9	20.2	8.9	75.0	0.3	1.6	11.5	5.3	5.9	8.1

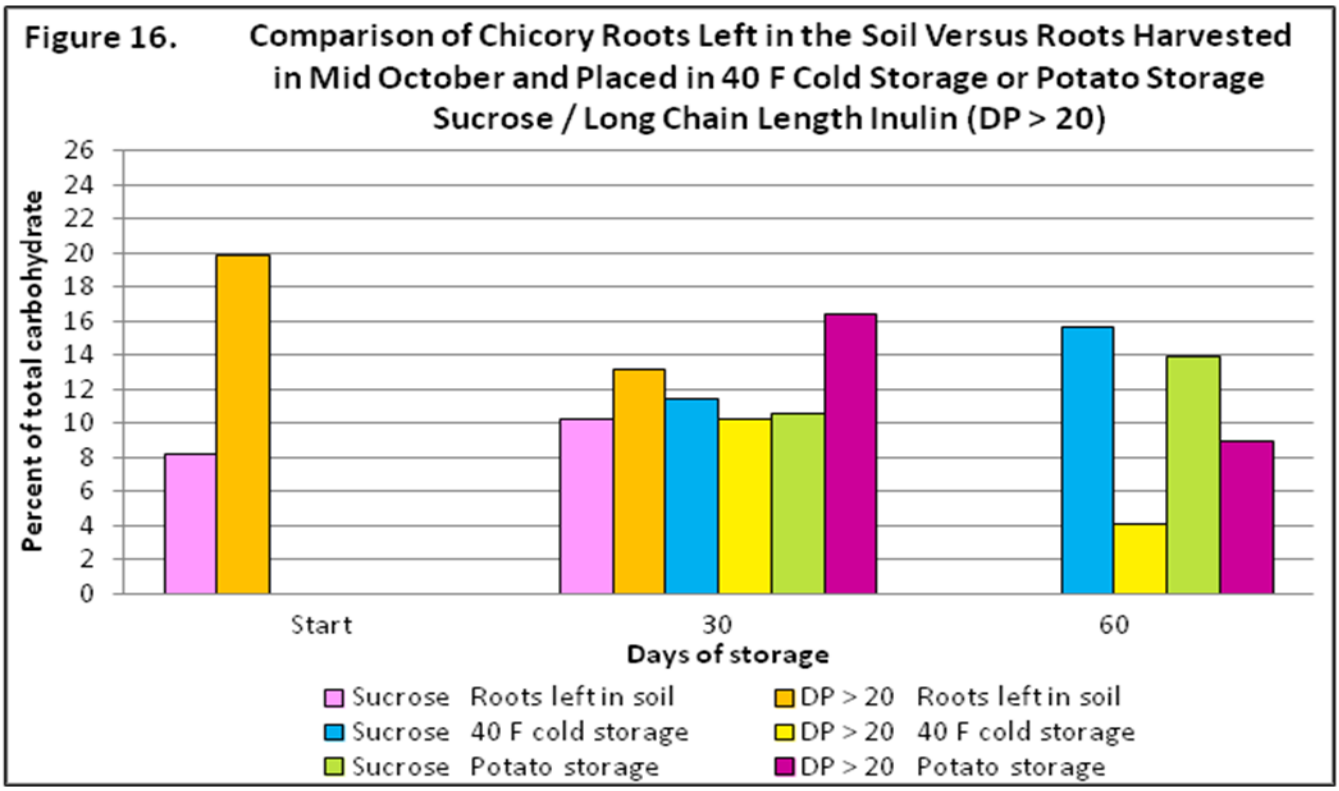
Table 6. Continued.

					Mid November Harvest													
					Percent of total carbohydrate													
					Free sugars				Inulin				Concentration of selected carbohydrates					
Date removed from cooler	Root weight when placed in cooler	Root weight when removed from cooler	Weight Loss	Soluble Dry Matter	Glucose	Fructose	Sucrose	Total	DP3-10	DP11-20	DP>20	Total	Glucose	Fructose	Sucrose	DP 3	DP 4	DP 5
	(kg)	(kg)	(%)		------------------------- % -------------------------								--------------- (g/kg) ---------------					
Mid Nov Harvest Harvest Day	5.5	5.5	0.0	23.3	1.5	7.8	10.8	20.1	40.3	21.7	12.9	74.9	0.6	4.6	13.7	7.4	7.6	10.4
Mid Nov Harvest 10 DAH	6.0	5.8	2.6	23.1	1.2	2.1	11.4	14.7	42.6	23.7	14.1	80.4	0.3	0.7	9.2	5.2	5.1	7.2
Mid Nov Harvest 20 DAH	5.7	5.5	3.2	23.1	1.4	6.0	13.5	20.9	47.2	18.9	7.9	74.0	0.5	3.5	15.6	8.4	7.8	10.1
Mid Nov Harvest 30 DAH	5.2	5.1	2.1	23.2	1.3	4.4	13.0	18.7	47.5	20.7	7.9	76.1	0.5	2.0	13.6	7.3	7.3	10.4
Mid Nov Harvest 40 DAH	5.1	4.9	3.6	22.6	0.8	4.9	14.9	20.7	50.9	17.5	6.2	74.6	0.3	1.5	16.5	7.6	8.3	10.9

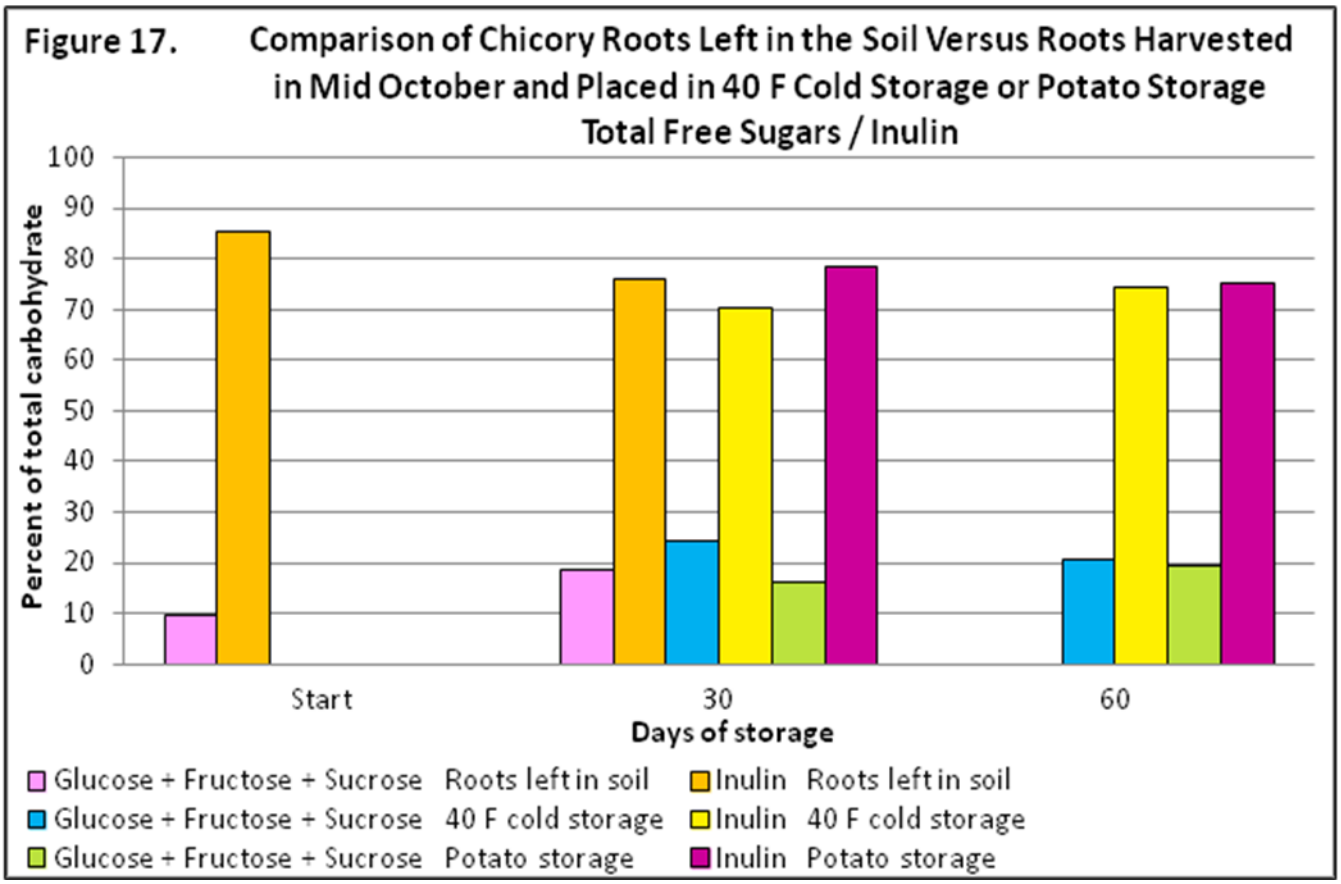
Mid Nov Harvest 50 DAH	5.4	5.1	6.2	23.4	0.4	2.5	15.3	18.3	51.8	19.1	5.0	75.9	0.1	0.9	13.9	7.6	7.6	10.2
Mid Nov Harvest 60 DAH	4.9	4.4	8.8	24.2	0.4	2.4	14.7	17.5	51.6	19.2	5.9	76.7	0.1	1.0	16.3	8.1	9.0	12.3
LSD at 0.05	1.1	1.0	2.5	1.3	0.6	2.9	1.2	3.5	3.0	2.7	3.3		0.3	1.9	3.5	1.6	1.5	2.1
CV	14.3	14.3	31.0	3.5	23.1	38.5	6.5	12.1	4.4	7.5	14.9		34.5	60.7	19.8	16.2	15.7	15.5



The second chicory harvest occurred on October 12 and roots were placed in storage on October 13. Compared to roots left in the field, after 30 days of storage at 40 F or potato storage, sucrose concentration remained near 10% while long-chain length inulin declined slightly in cold storage and increased slightly in potato storage (Figure 16 and Tables 5 and 6). After 60 days of storage at 40 F sucrose had increased to 16% and DP>20 had decreased to 4% while in potato storage degradation was not as great with sucrose increasing to 14% and DP>20 decreasing to 9%.



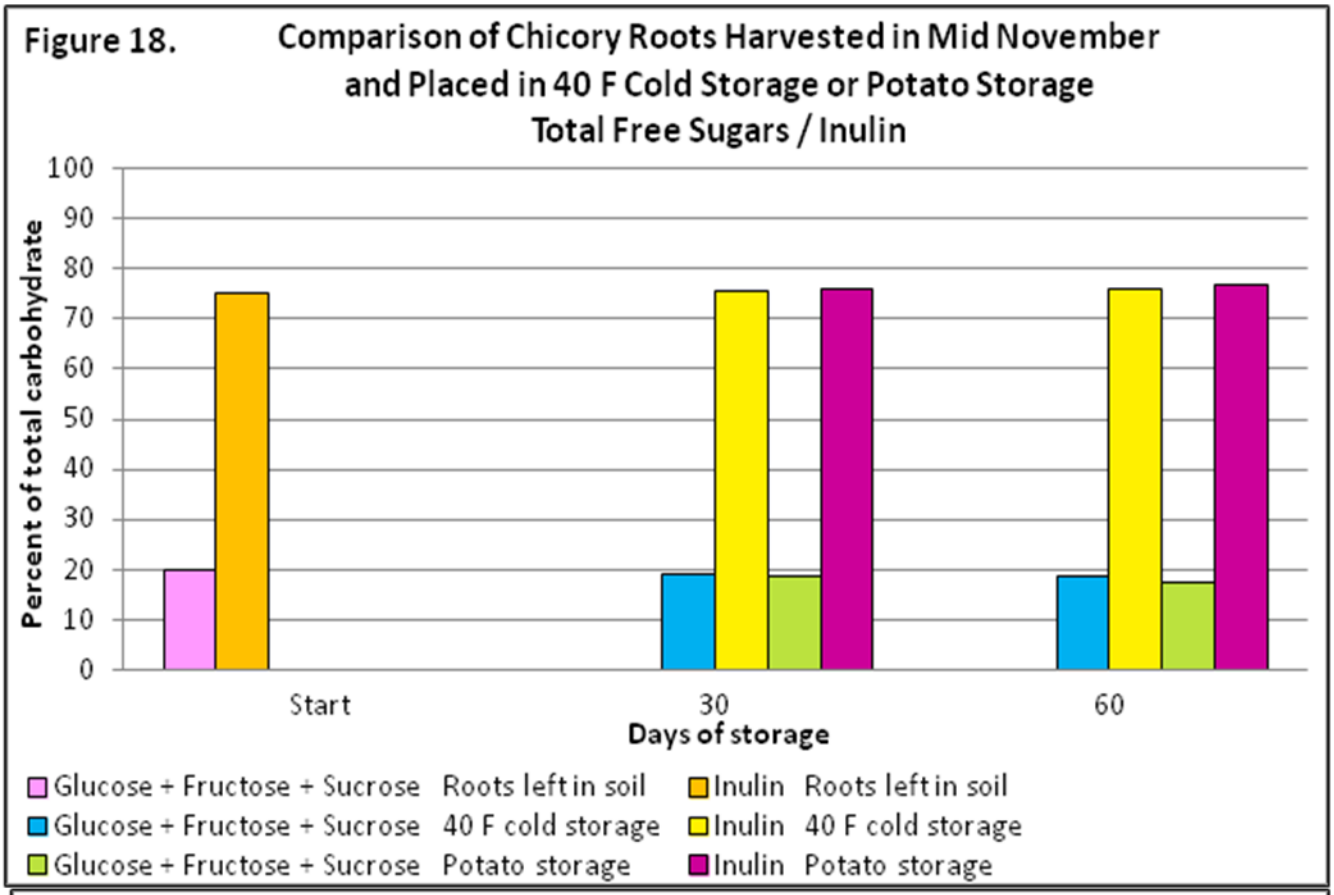
At the time of the second harvest, roots left in soil for an additional 30 days until mid November had a free sugar content of 19% and inulin content of 76% (Figure 17 and Tables 5 and 6). In contrast roots placed in cold storage or potato storage had free sugar contents of 24 and 16%, respectively, and inulin contents of 70 and 78%, respectively. After 60 days of storage roots in cold storage or potato storage had similar free sugars and inulin contents of 19 and 75%, respectively.

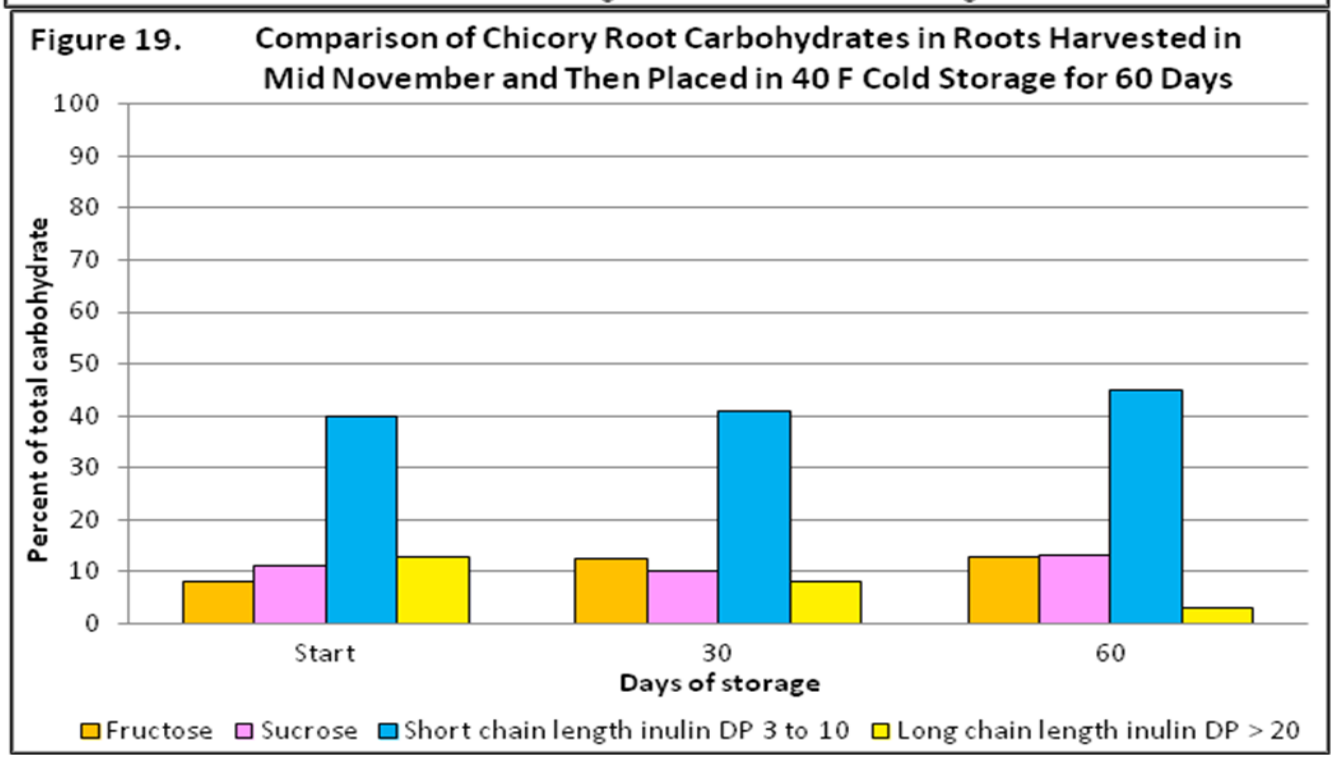


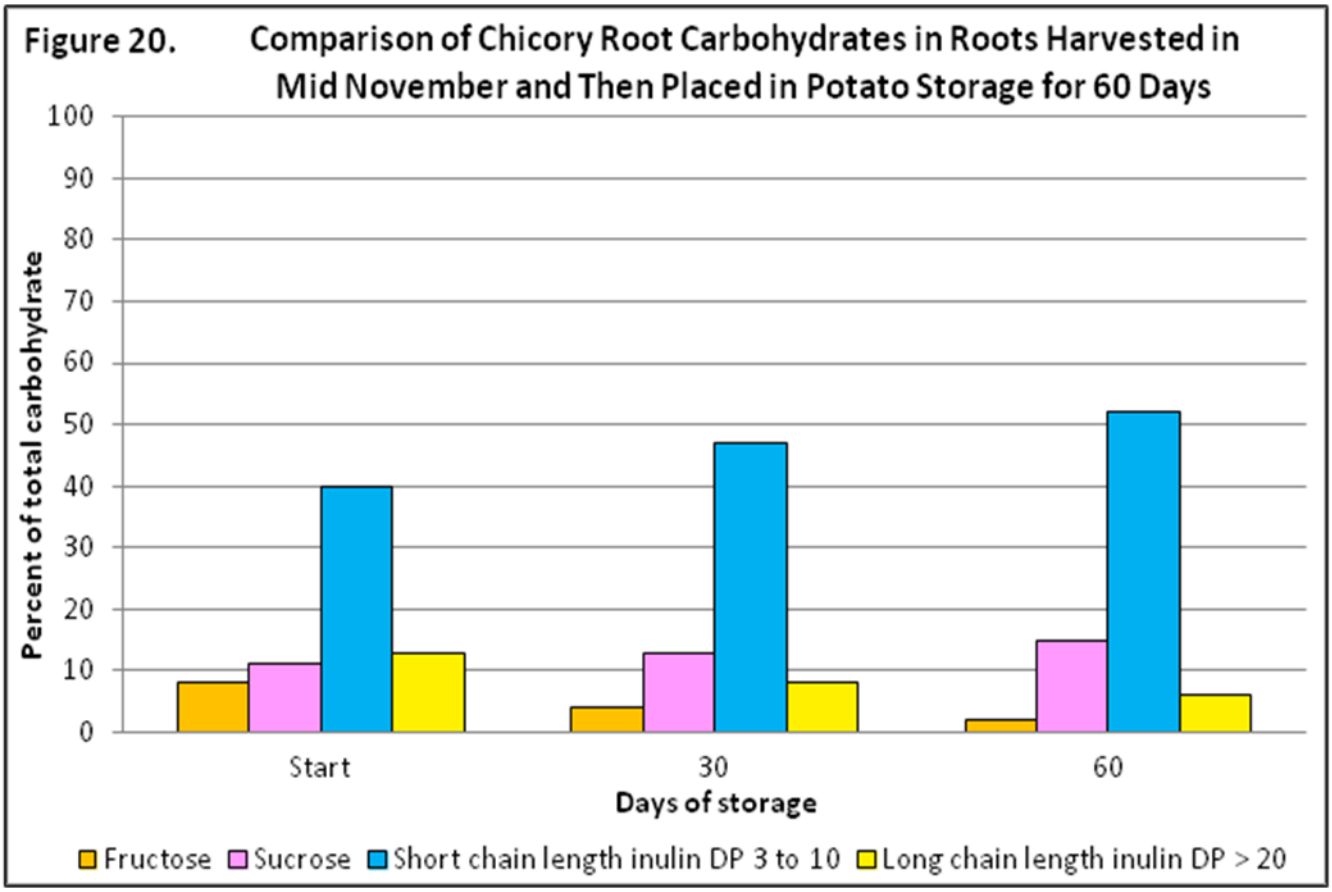
The data collected from roots harvested in mid October and stored for 60 days had smaller changes in free sugars and inulin than roots harvested in mid September and stored for 60 days in both cold and potato storage.

At the time of the November 9 harvest, air and soil temperatures had decreased and chicory plants had been exposed to freezing temperatures (Figure 1). As mentioned earlier, roots placed in storage only contained 13% of the total carbohydrate as long-chain length inulin (DP>20) (Figure 13 and Table 4). The total inulin content however, still remained near 75% and free sugars totaled 20% of the total carbohydrates. To the processor these roots had value when placed into storage on November 10. In both 40 F commercial cold storage and potato storage, the total inulin content and total free sugars did not change over 60 days of storage (Figure 18 and Tables 5 and 6). There were subtle differences in fructose, sucrose, and short and long-chain inulin between the two storage environments (Figures 19 and 20 and Tables 5 and 6). In 40 F cold storage fructose concentrations increased while in potato storage fructose concentration

decreased. Short-chain length inulin (DP3 to 10) increased in potato storage to 52% after 60 days while in cold storage DP3 to 10 was 45% of the total carbohydrate.







Chicory roots harvested in mid September had the greatest amount of inulin and the lowest amount of free sugars while roots harvested in mid November had been exposed to freezing temperatures and plants were preparing for winter. Compared to carbohydrate changes that occurred during the first storage period with those that occurred during the last storage period, roots harvested in November could be stored in potato storage for 60 days with minimal changes in carbohydrates while roots harvested in mid September did not store as well.

Chicory roots harvested in November could be successfully stored in potato storage for a 60 day period without appreciable changes in free sugars or inulin. For a chicory processor extending factory operation for an additional 60 days may be profitable depending on the cost of storage. The economics of potato storage have been examined in several excellent articles published in the American Potato Journal (J.F. Guenther 1995 and W.C. Sparks 1975) and Chapter 18 in Potato Production Systems.

An analysis of storage costs can be examined from the position of constructing storage or renting storage. There are a number of expenses associated with owning storage. Ownership costs include depreciation, insurance, repairs, taxes, and interest on the investment. Operating costs include labor, utilities, chemicals, shrink, and interest on capital during the storage period. If you make the assumption that potato storage could be rented for $0.25 per cwt (100 lbs) for 6 months, storage capacity of the shed is

60,000 cwt, interest at 6%, shrink for 6 months at 7%, value of potatoes at $5 per cwt, and operating costs of $0.17 per cwt, the total cost for storing 60,000 cwt for 6 months would be $6.36 per cwt (Table 7). Therefore at the end of 6 months if the grower could receive more than $6.36 per cwt storage would be profitable. If you convert the analysis for potatoes to chicory roots you can estimate the costs for storing chicory roots (Table 7).

Table 7. Potato storage versus chicory root storage.

Potato		Chicory	
$5 per 100 lbs (cwt)		$90 per 2000 lbs (ton)	
60,000 cwt		3,000 tons	
Value at harvest = $300,000		Value at harvest = $270,000	
Interest per 6 months = $5,271		Interest per 6 months = $4,744	
Storage rent per 6 months, $0.25/cwt		Storage rent per 6 months, $5.00/ton	
(0.25/cwt)(60,000 cwt) = $15,000		($5.00/ton)(3,000 tons) = $15,000	
Shrink 7% per 6 months = $21,000		Shrink 10% per 6 months = $27,000	
Operating (fill, empty, utilities) = $10,000		Operating = $10,000	
Total	$351,271		$326,744
Cost per cwt	$6.30	Cost per ton	$121

In the above example over a 6 month period you lose 7% of the initial potato weight to water loss or 4,200 cwt. Therefore when potatoes are removed from storage there will only be 55,800 cwt removed and total costs of $351,271 are divided over 55,800 cwt to achieve a cost of $6.30 per cwt. A similar calculation was utilized to calculate the cost per ton for storage of chicory roots. In the above example it is estimated it would cost $121 per ton to store chicory roots for 6 months. Therefore if the processor paid the grower more than $121 per ton for roots it would be beneficial for the grower to store roots. In the storage experiment, chicory roots were only stored for 2 months and it is not known if they could be stored for 6 months. The costs for interest and shrink would decline but costs to rent storage and operating would probably remain the same. A revised calculation would drop the breakeven cost to $113 per ton. Therefore if the grower received more than $113 per ton for storing chicory roots for 2 months it would be profitable. The value of chicory going into storage was $90 per ton, the value coming out of storage was calculated at $113 per ton; therefore, the cost of 2 months of storage was estimated to be $23 per ton.

Expected Measurable Outcomes

By mid October chicory root yields can approach 22 to 25 tons per acre with 23% of the

root containing carbohydrates. The composition of carbohydrates is in the range of 9 to 12% simple sugars (glucose, fructose, and sucrose) and 80 to 85% inulin. Root carbohydrate composition was measured at the time of harvest and then from representative samples at 10 day intervals for 60 days from both a 40 F cooler and commercial potato storage. Placing roots in cold storage (40 F) at this stage of development should preserve the carbohydrate composition. The project will be considered a success if the quantities of simple sugars can be kept below 20% for 30 to 60 days. If the quantities of simple sugars, particularly sucrose, become greater than 20% the inulin processing becomes more difficult which leads to increased costs.

Beneficiaries

Discussions with Sensus have indicated that the company expects the demand for inulin in the US will expand over the next few years. Sensus at that point will not be able to meet US demand for inulin production in the Netherlands and will need to expand to North America. This proposal is designed to position Nebraska as the location for future expansion. Successful completion of this project will demonstrate on a large scale that roots can be stored inexpensively, under controlled conditions therefore allowing a longer processing campaign. The addition of a new value-added crop to Western Nebraska will increase grower income, add new jobs, and help stabilize local economics. Sensus estimates a factory to process 15,000 acres of chicory would cost approximately $125 million and provide gross income of $1,800 per acre to growers. The results of this project clearly demonstrate that chicory roots harvested in November can be successfully maintained for 60 days in commercial potato storage. This benefits the processor (Sensus) by allowing a two-month extension to the processing campaign, to growers who have underutilized potato storage, and to chicory growers who will have access to a market for their crop. Outreach activities have included providing a study report to Sensus USA and Sensus in the Netherlands. Reports will also be provided to Florimond Desprez in France and other potential chicory processors interested in the Nebraska growing area. As crop development moves from the research stage to commercial production growers will have the opportunity to utilize the results of this project to determine how they want to market chicory roots to the processor.

Lessons Learned

The results of this study clearly indicate that chicory roots harvested in September do not store as well as roots harvested in mid October through mid November.

Contact Person

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Additional Information

None.

Project Title

Ability of Great Northern Beans and Pinto Beans to Modulate DNA Conformation to Protect Against Inflammation

Project Summary

Dry edible beans are an important Nebraska Specialty Crop with our state being the No. 1 and No. 3 producer of the GNB and pinto beans PB, respectively. A significant issue facing the Nebraska industry is the current price of competing field crops as well as the influx of dry edible beans from international sources. A significant issue facing the US dry edible bean industry is the current price of competing field crops, such as corn, and the influx of dry edible beans from international sources, i.e., particularly GNB. As a result, the number of acres dedicated to dry edible bean has been declining in most US states. Nebraska regions most affected by this decline include several counties located throughout our state, but particularly those in the Panhandle area. This geographic region has a clear need for higher paying jobs as 100% of these Nebraska counties have a median household income 22% below the state average. Additionally, population growth in these regions has been flat between 2000 and 2006 with the participating counties experiencing a 6% population decline in Nebraska. As the number of acres of dry edible bean production declines, so too does their economic viability, which, in turn, adversely affects the rest of the economies in the region. It is expected that accumulation of scientific based data showing the disease preventing benefits, particularly those afflicting western societies, of dry beans will increase demand and prices within on own societies, which will help to stabilize the dry edible bean industry in our state. This project is therefore *important and timely* as it is the first to determine the ability of dry edible beans to remediate inflammation DNA conformation phenotypes.

Dry edible beans have been characterized as a nearly perfect food due to its high protein content, fiber, complex carbohydrates, vitamin B, and other micronutrients agents. In particular, many secondary metabolites (phenolic compounds) present in beans have been shown to reduce silent inflammation, i.e., an insidious cellular stress particularly prevalent in obese individuals and linked to multiple metabolic diseases (diabetes, cancer, and heart disease). However, a critical gap in knowledge exists on the mechanistic effects of great northern beans (GNB) and pinto bean (PB) consumption on the inflammatory response. Therefore, the objective of the project was to determine the ability of PB and GNB to modulate (or prevent) changes in cellular DNA conformations (or DNA phenotypes) to protect against inflammation. It was expected that the information generated will facilitate the development and promotion of PB and GNB as potent health promoting food systems, with an emphasis on preventing obesity related diseases.

The objective of this proposal was thus accomplished by completing the following specific aims.

- Specific Aim 1*: To characterize the phenolics content of the GNB / PB that will be used for Specific Aim 2-3.*
- Specific Aim 2: *To determine non-toxic dosage levels of GNP and PB using Marine Raw 264.7 macrophages.*
- Specific Aim 3: *To determine the ability of bean extracts to modulate DNA conformation to an anti-inflammatory phenotype.*

As an outcome, information was generated that directly linked pinto beans, but not great north northern beans, to a biologically significant health benefit thereby potentially increasing demand for this crop. This research thus supports Nebraska Specialty Crops program by promoting the consumption of dry edible beans.

This project builds on projects that were funded through the Nebraska Department of Agriculture via a Specialty Block Grant in 2008 and 2010. The former study focused on characterizing potential health-promoting components in GNB and PB. The latter study provided support needed to study the health promoting effects of dry beans (split and whole GNB and PB) using in vitro and biochemical approach and FTIR methodology. Both projects provided the information to proceed with the project described herein. All of these projects have allowed us to set the next stage in our work, which is to move into animal studies

Project Approach

Specific Aim 1 *(completed)*: *To characterize the phenolics content of the GNB / PB that will be used for Specific Aim 2-3.* During the first quarter of this project, a student was identified to complete the project. This student was thus trained to work with immortal cell lines (macrophages) during the 2nd quarter. During this time Specific 1 of the proposal was completed. Both pinto beans and great northern beans were received in-house after the 2011 harvest (Oct-Nov 2011). However, analysis of these samples was completed in Summer 2012 in order to involve students in the training process. *A notable change to the proposal was that three different lines of pinto beans and of great northern beans were analyzed instead of the intended single line from each market class to determine the optimal PB –GNB cultivar to use for Specific Aim 3. The selection was largely based on the levels of phenols – flavonoids and their antioxidant capacities.* It was also determined that Major component analysis was also determined, including total proteins, total fat, ash, moisture and carbohydrate. Data for these analyses are provided in Table 1 and 2)

Table 1. Proximate composition of different lines of pinto beans (PT) and great northern (GN).

Beans	Moisture (%)	Ash (%)	Protein (%)	Lipid (%)	Carbohydrate (%)
PT - Baja	11.08 ± 0.22	3.83 ± 0.05	18.81 ± 0.25	0.94 ± 0.01	65.32 ± 0.55
PT - Poncho	10.60 ± 0.08	3.71 ± 0.04	18.68 ± 0.70	1.10 ± 0.15	65.89 ± 0.96
PT - LaPaz	11.19 ± 0.04	3.83 ± 0.03	19.16 ± 0.48	1.31± 0.16	64.22 ± 0.52
GN - Gemini	11.33 ± 0.06	4.12 ± 0.02	21.19 ± 0.08	1.12 ± 0.10	62.22 ± 0.27

GN - Orion	11.26 ± 0.04	4.12 ± 0.03	19.80 ± 0.66	1.63 ± 0.05	63.18 ± 0.79
GN- Coyne	11.44 ± 0.06	3.92 ± 0.04	19.16 ± 0.48	1.30 ± 0.16	64.16 ± 0.74

- Results are shown as mean +/- standard deviation of three replicate analyses.

Table 2. Phenol (Total Phenolic and Flavonoid) and ORAC Data of three lines of Pinto Beans (PT) and Great Northern (GN)

Beans	Total Phenols (mg/g)	Flavonoids (mg/g)	ORAC* (umole TE/100 g)
PT - Baja	1.42 ± 0.07	0.79 ± 0.04	13144 ± 975
PT - Poncho	1.41 ± 0.02	0.73 ± 0.00	14425 ± 1724
PT - LaPaz	2.05 ± 0.15	1.36 ± 0.03	17080 ± 1528
GN - Gemini	0.68 ± 0.02	0.16 ± 0.00	4605 ± 1750
GN - Orion	0.83 ± 0.01	0.22 ± 0.00	7003 ± 1724
GN- Coyne	0.73 ± 0.03	0.19 ± 0.00	4547 ± 313

- Analysis shown as mean +/- standard deviation of three replicate analyses.

* ORAC – oxygen radical absorbance capacity (antioxidative capacity).

Specific Aim 2 (*completed*): *To determine non-toxic dosage levels of GNP and PB using Marine Raw 264.7 macrophages.* Based on Specific Aim 1, LaPaz pinto beans and GN-ORION were used for the remaining experiments. Specific Aim 2 was completed by first determining an appropriate bean dosage levels that did not promote significant cytotoxicity (catastrophic cell death) in the macrophages. Briefly, the cells were purchased, maintained and cultured as described by Park et al. (*1*). The culture medium was removed and the cells were subjected to different concentrations of bean extracts (10-1000 mg/ml of residue) obtained from a 50:50 water:methanol extract. Treated and untreated cells were then monitored for toxicity indicators with the tetrazolium salt [3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide] assay, which detects cell viability by measuring cellular respiration. As shown in Table 3, concentrations levels were sporadic across the dosage levels, especially for the GNB. (It should be noted that the results generated from the 100 mg/ml concentration was probably due to problems with the control. Nonetheless, based on these data, 10 mg/ml and 20 mg/ml were used as both represent a semi toxic (10 mg/ml) and non-toxic (20 mg/ml) treatment for each market class. These results may seem counterintuitive considering the higher dose was less toxic than the lower dose. However, such trends appear throughout the literature, which is referred to as the low dose affect (2-3). These effects have been attributed to the ability of the cell to compensate at certain dosages and thus even exhibit negative response greater than higher doses. A 5 mg/ml response was also used for Specific Aim 3 than so to provide a lower dose that did not negatively impact the cells. At this time, we do not have MTT assay for this dosage but plan to obtain such results for publication purposes.

Table 3: Results from MTT assay to determine toxicity levels.

mg/ml	Average Lapaz*	Average Orion*	Control	% Death PB	% Death GNB

10	**0.694 +/- 0.111**	**0.727 +/- 0.065**	**0.9682**	**-28.2896**	**-24.8261**
20	**0.803 +/- 0.283**	**0.749 +/- 0.070**	**0.605**	**32.80992**	**23.89532**
50	**0.371 +/- 0.160**	**0.804 +/- 0.285**	**0.6505**	**-42.9003**	**-23.7151**
100	**0.534 +/- 0.135**	**0.284 +/- 0.049**	**0.0472**	**1032.627**	**1032.627**
200	**0.546 +/- 0.187**	**0.298 +/- 0.274**	**0.762**	**-28.3115**	**-60.8005**
400	**0.329 +/- 0.071**	**0.726 +/- 0.288**	**0.4062**	**-18.8823**	**78.77893**
800	**0.294 +/- 0.065**	**0.265 +/- 0.093**	**0.7715**	**-61.8233**	**-65.647**
1000	**0.210 +/- 0.053**	**0.296 +/- 0.136**	**0.6065**	**-65.3201**	**-51.0745**

* Average of 3 replicates

Specific Aim 3: (*Completed)*, *To determine the ability of bean extracts to modulate (or protect) DNA conformation to an anti-inflammatory phenotype.* Preliminary data for Specific Aim 3 was initially collected to ensure that the phenotype of the pro-inflamed (+lipopolysaccharide (LPS)) vs anti-inflamed (-LPS) phenotype of Murine Raw 264.7 macrophages could be distinguished before application of the bean treatments. Using macrophages, we were able to show significant phenotypic differences between the +LPS treated and -LPS cells, as indicated by second derivative (Figure 1) subtraction data and the ensuing dendrograms (Figures 2 and 3). These results are significant as the data indicate that different LSP dosages affect the biochemical conformation of several cellular components with the most significant impacts occurring with 100-200 ng/ml doses. Thus, 200 ng/ml dose was be used for to complete this Specific Aim 3. *But perhaps more importantly, this is the first study to show the biochemical conformation as effected on LPS induced macrophages from a global perspective. This data alone provides information of how the entire cell is affected by inflammation and thus will be compiled as a single paper once additional cytokine data is also obtained (not part of this grant).*

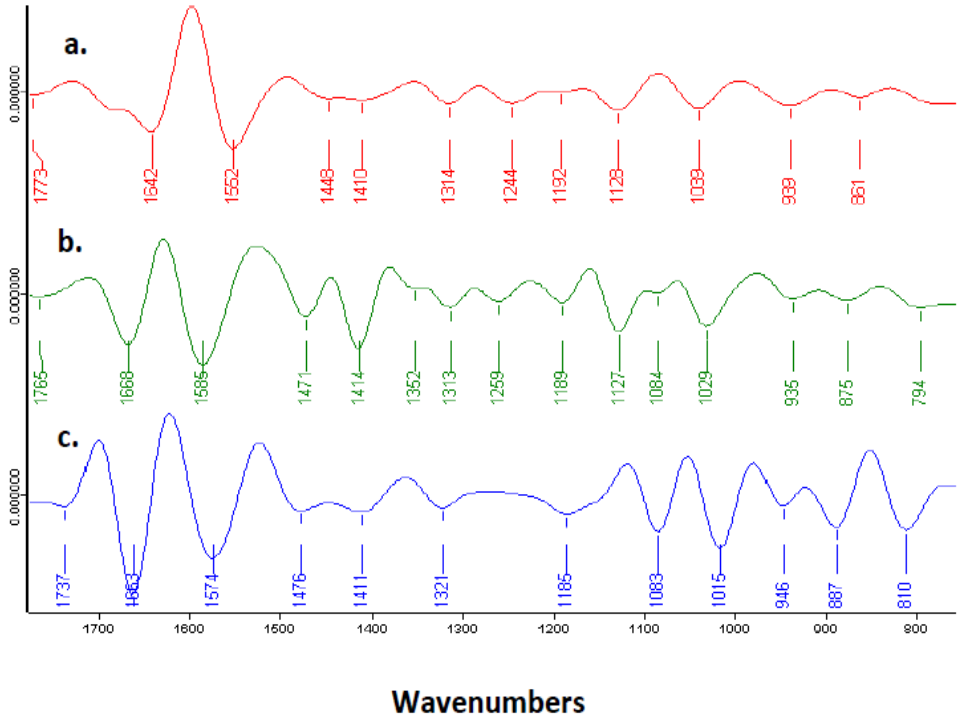

Figure 1: Subtraction FTIR second derivative data of LPS induced macrophages of regions that correspond to proteins, carbohydrates and nucleic acid bands **a**. 50 ng/ml LPS – control, **b**. 100 ng/ml LPS – control, and **c**. 200 ng/ml LPS - control (average spectrum of n = 3 biological reps).

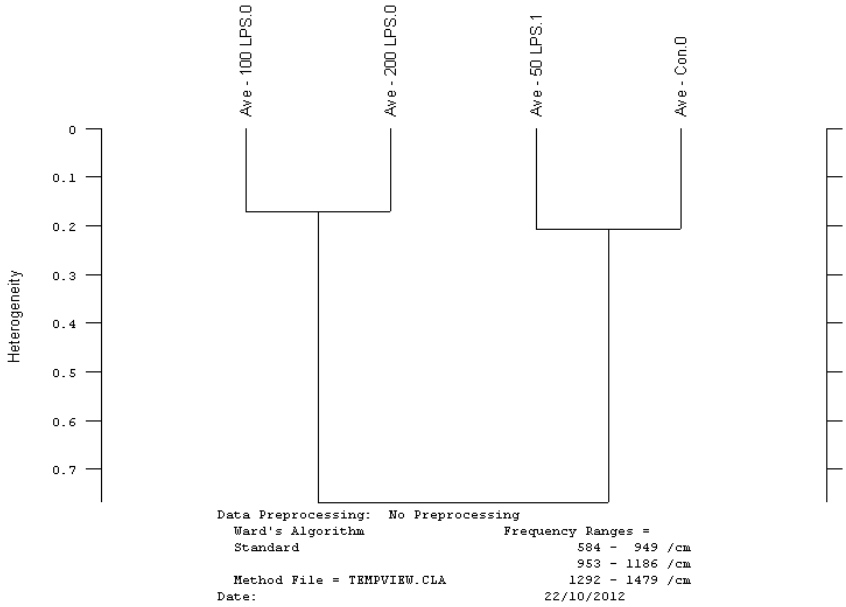

Figure 2: Dendrogram of zero order data of LPS induced (0-200 ng/mL) macrophages.

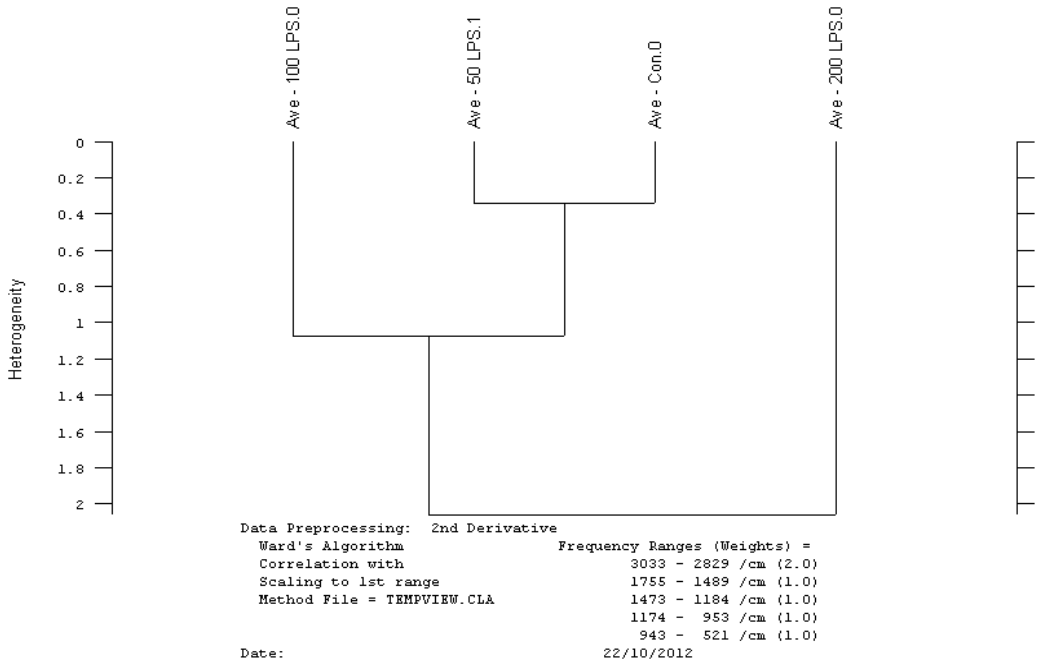

Figure 3: Dendrogram of second order data of LPS induced (0-200 ng/mL) macrophages.

The macrophages were again grown but treated with 0, 5, 10, and 20 □g/ml PB and GNB beans for 16 hours. The inflammatory activator, 200 ng/ml, was then incubated with the samples for 4 hours. The samples were harvested, centrifuged, and washed several times with 0.1 phosphate buffered saline (PBS). The cells then were suspended in PBS, placed on a FTIR BioWheel sampler, and dried under vacuum until a biofilm was formed. The resulting data was preprocessed by background correction. (Additional pre-processing approaches are described in the Figure captions. Figure 4 shows the spectra of activated and inactivated macrophage with the biologically significant regions highlighted. These regions include the lipids (W1), proteins (W2), mixed regions (lipids, proteins, and nucleic acids) (w3), polysaccharides (W4) and the fingerprint (w5) regions. Bands that are associated with the DNA conformation changes are also distributed throughout W2-4, which are listed in Table 3. As many of these bands are obscured in the zero order date due to the presence proteins, carbohydrates and lipid bands (Figure 5 shows their general location); t the first and second order derivative of the effects of treatments were also obtained to deconvolute the spectra (Figure 6). The deconvoluted spectra were then analyzed by hierarchal clustering analysis (Ward's algorithm).

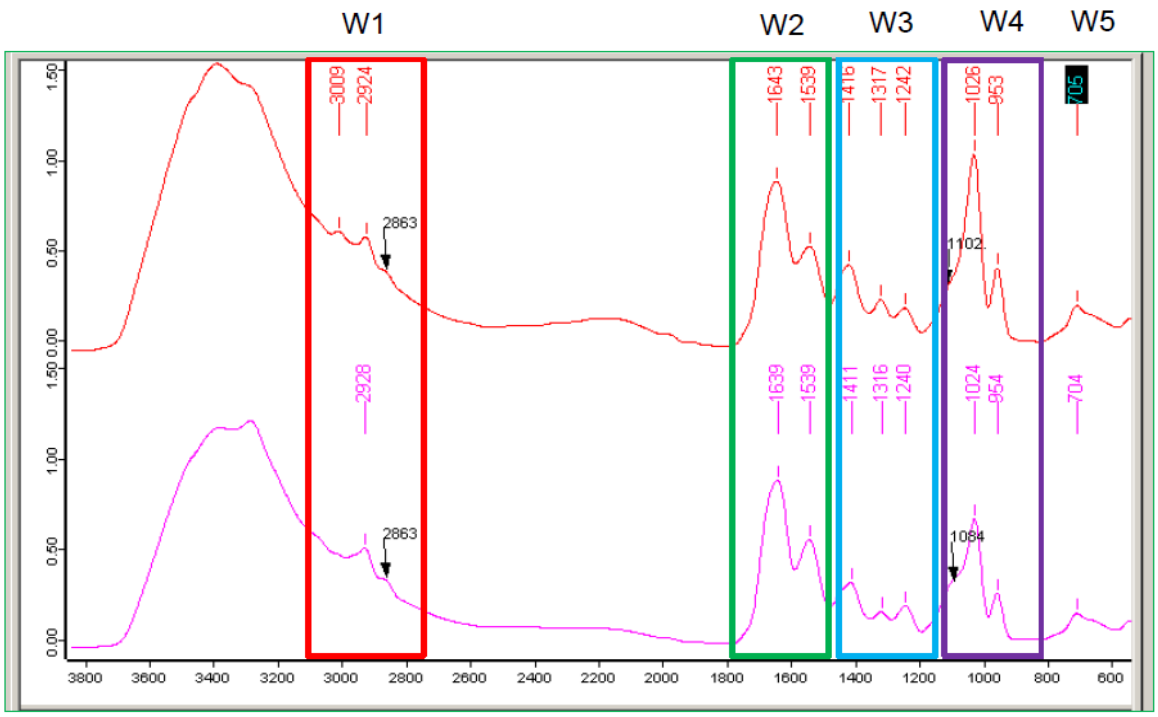

Figure 4: Zero order spectra (average spectrum of n = 3 biological reps). of inactivated (red) and LPS activated macrophages (pink).

Table 3: General regions of nucleic acid bands

Region (cm-1)	DNA Contribution
1703-1717	Ring Breathing Modes of Nucleic Acid, Base pair packing
1620-1650	Ring Breathing Modes of Nucleic Acid, Base pair packing
1420-1459	DNA base modification (C1 endo to C2 endo).
1240-1222	Asymmetric PO2 vibration of phosphate ribose DNA backbone
1075-1085	Symmetric PO2 vibration of phosphate ribose DNA backbone
1050-1069	Ribose band of nucleic acid sugar.
970-940	AT base vibration

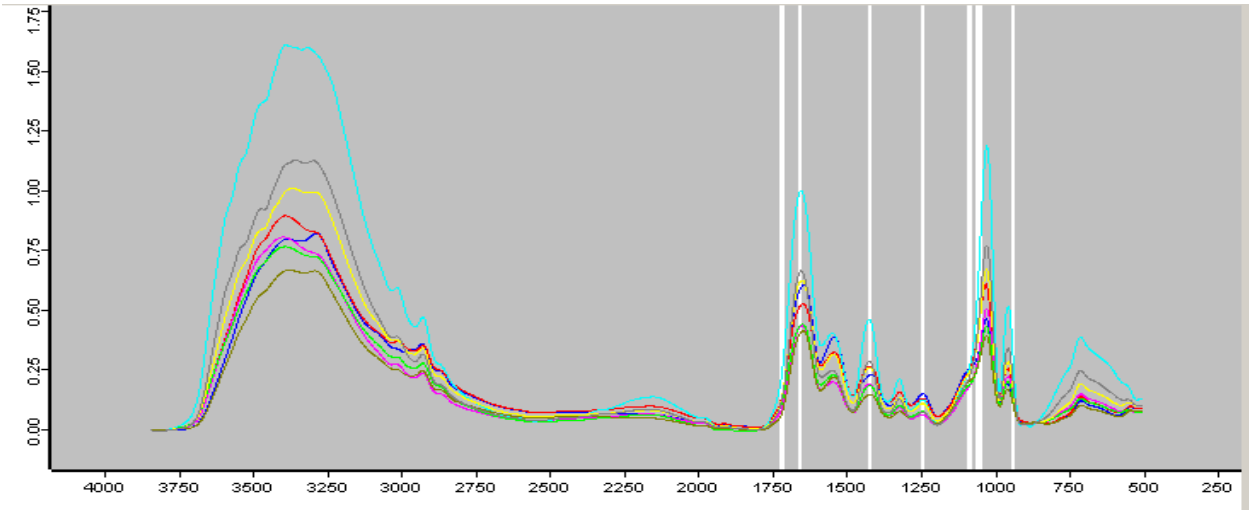

Figure 5: Zero order spectra of inactivated, LPS activated macrophages, and macrophages treated with either 5, 10, 20 ng/ml bean extract +/- LPS. White highlights show nucleic acid regions.

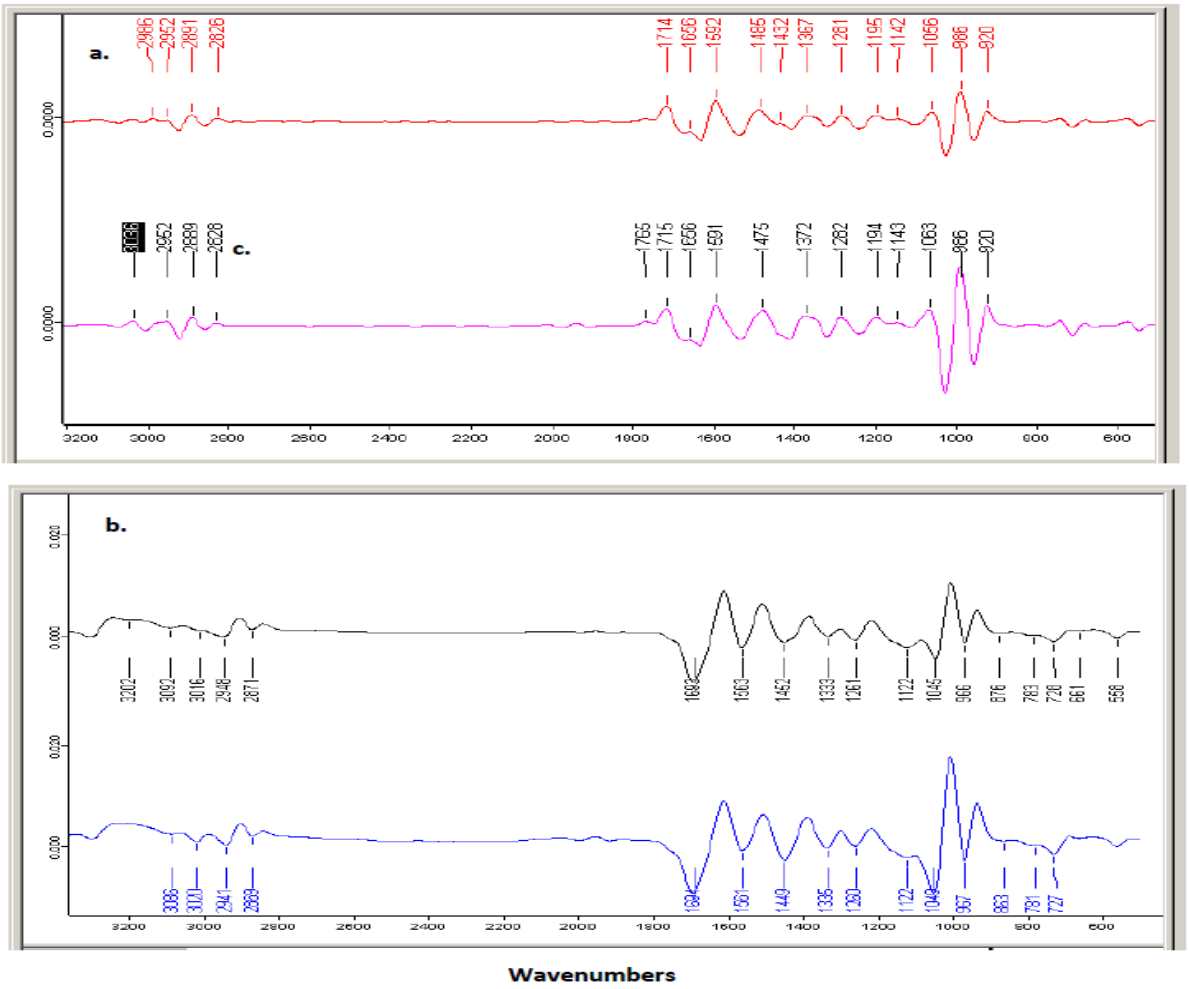

Figure 6: a. Second order spectra of LPS activated (red) and inactivated (pink) macrophages. **b.** First order spectra of LPS activated (black) and inactivated (blue) macrophages. Each spectrum represents the average of 3 biological replicates.

Figure 7 shows the dendrogram of the second derivative spectra produced by PB treated (5, 10, 20 ng/ml) +/- LPS macrophages. In this case, the entire biological region (W1, W2-4) was analyzed. The cluster profiles indicate that PB treatments did not affect the majority of the biochemical region as the PB treated macrophages – LPS clustered with the control – LPS. Although the PB treated cell + LPS separated from this cluster, there was a clear separation from the control + LPS samples. These results indicate that certain regions of the macrophages were affected by the LPS or PB while others were not. Upon further analysis, the protein region (W2) was affected by the PB treatment as the dendrogram targeting this region showed random clustering of the samples (data not shown). However, the lipid region (W1) was highly protected as a similar dendrogram was obtained as shown in Figure 7 except the PB treated + LPS clustered with the control and the PB – LPB separated from this branch (data not shown).

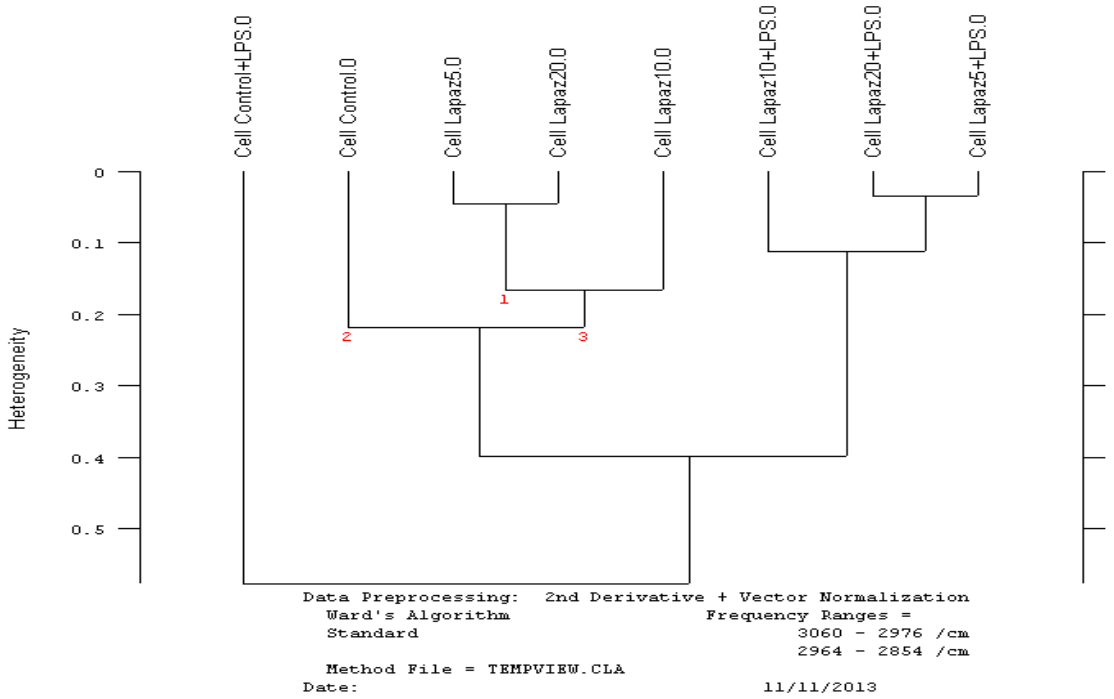

Figure 7: Dendrogram of second derivative spectra of macrophages treated with different doses of PB (5, 10, 20 ng/ml) +/- LPS, a control-LPS, and a control + LPS.

Most importantly, analysis of the nucleic acid regions showed PB protection against LPS activation at all the doses used (Figures 8) when applying the first derivative to the raw data and weighting the different bands evenly, with the notable exception of the 1092-1072 cm-1 region. When weighting this band 10X higher than the other regions, the separation increased between the control + LPS sample, and the remaining

samples. This region has been attributed to the DNA backbone phosphate – sugar backbone stability and degree of coiling. The data suggest that the conformation of the DNA backbone is impacted by LPS. The PB is probably preventing the DNA backbone from changing its anti-inflammatory conformation. Analysis of the second directive data does show clustering of the 10 ng/ml PB dose with the control + LPS. This may be due to the lower viability that resulted from this treatment (Table 3). Interesting, the 10 ng / ml dose still appeared to be protecting the cells from LPS as the sample clustered with the cells-LPS and the other treatments (Figure 9).

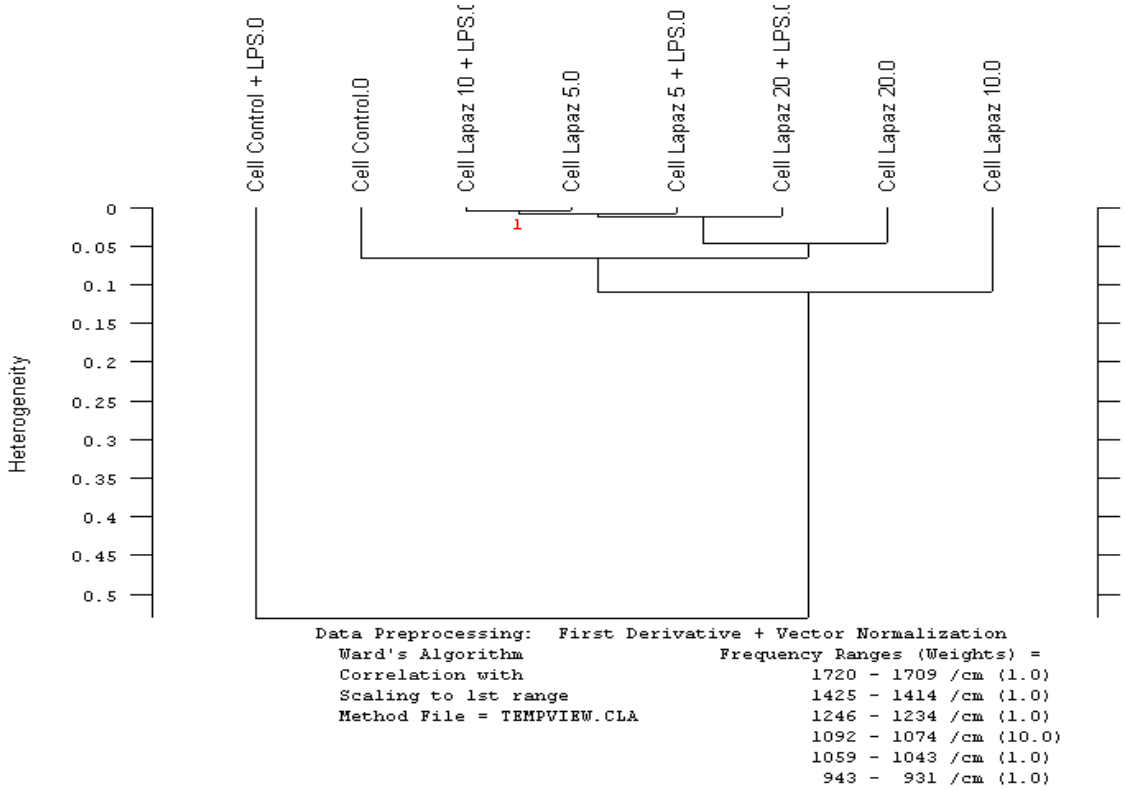

Figure 8: Dendrogram of first order data of macrophages treated with different doses of PB (5, 10, 20 ng) +/- LPS, a control-LPS, and a control + LPS. Nucleic acid bands were targeted as shown above (frequency range).

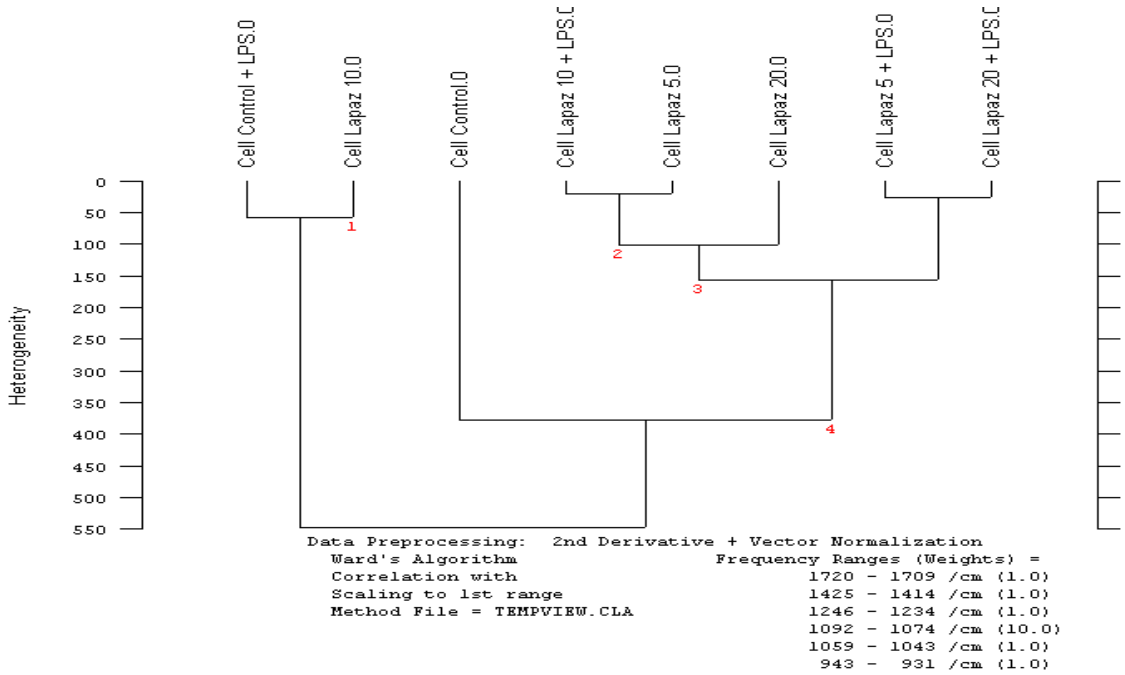

Figure 9: Dendrogram of second order data of macrophages treated with different doses of PB (5, 10, 20 ng) +/- LPS, a control-LPS, and a control + LPS. Nucleic acid bands were targeted as shown above (frequency range).

An extract obtained from GNB were also analyzed for their ability to protect the DNA phenotype from LPS effects. However, GNB did not show the same positive impact as the PBs. Instead, the controls +/- LPS always clustered together while the GNB treatments +/- LPS formed a different cluster (Figure 10). These results suggest that the macrophages were adversely affected by the GNB extract, at least at the doses tested and for this particular extract.

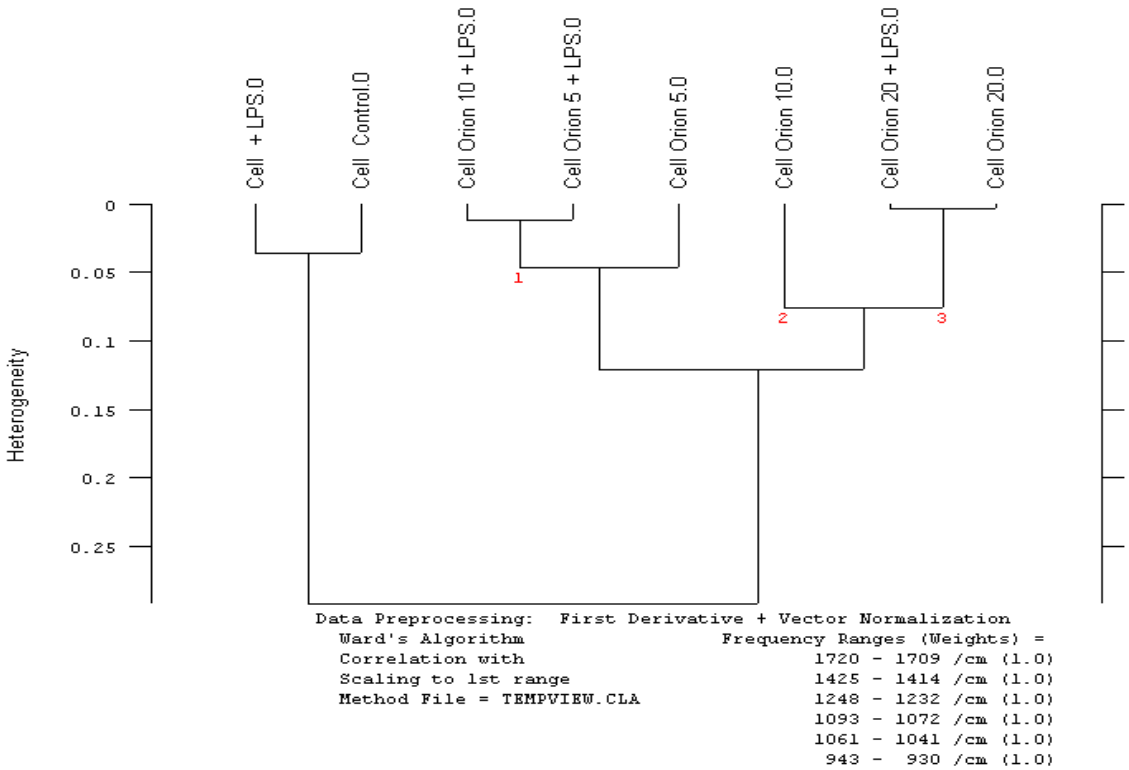

Figure 10: Dendrogram of first order data of macrophages treated with different doses of GNB (5, 10, 20 ng) +/- LPS, a control-LPS, and a control + LPS. Nucleic acid bands were targeted as shown above (frequency range).

Goals and Outcome Achieved

Activities completed to achieve performance goals and measurable outcomes for the project.

All experimental related activities were completed for this project, and we are now able to disseminate the information to our producers, distributors, etc. One-two manuscripts are expected from this work and 2-3 poster – oral presentations. Dissemination of the information is also expected via newsletters and websites.

The hypothesis of this project was that dry beans are able to modulate (protect) the DNA phenotype to an anti-inflammatory phenotype. Based on FTIR analysis, this hypothesis tested true for the PB at all the dosages levels used. In fact, the PB also appears to provide protection in other potential target areas (such as the lipid group). However, the GNB did not provide any protection against LPS. But, it must be emphasized that isolation of a different extract may produce different results. As such, more in depth compositional analyses of each extract is currently in progress to determine the possible responsible agents for producing the positive effects provided by the PB extract. The data reported herein is also under evaluation to determine the biological significance of the shifts detected by the FTIR for both sets of beans. Nonetheless, comparison of the GNB and PB clusters show significant differences between the FTIR biochemical fingerprints as affected by bean market classes

indicating that the type of beans target different cellular pathways when subjected to the same extraction procedures. This could be due to the amount of phenolics present or the combinations of components present. Dr. Carlos Urrea (UNL Panhandle Research and Extension Center) grew and provided the pinto beans for this project. Dr. Vicki Schlegel has been providing continual oversight of the project to date.

This project has essentially long term outcomes with except for the following, i.e., FTIR was a viable tool to screen the biochemical response of macrophages to an inflammatory activator and possible protective dietary agents. Such a tool is very important as multiple extracts can be initially screened for their ability to protect against inflammation. The most potent extracts can then be exposed to bone marrow derived macrophages, i.e., cells that originate from an animal source, but have a limited life span. This information will enable us to deconstruct the complex bean matrix and the components responsible for preventing or remediating this effect. These results then can then be fed back to bean breeders and also downstream processors to ensure that responsible components are not compromised.

This project also direct links dry edible beans, particularly the PB, to a biologically significant health benefit. The data showed that the PB has a more direct impact on the preventing inflammation compared to the GNB, particularly on its ability to maintain the DNA conformation. However, more extracts must be tested along with other market classes to fully understand how anti-inflammatory benefit of each type of bean. Nonetheless, this is the first study to show that the DNA conformation of LPS treated macrophages was similar to that of the un-activated form when treated with PBs prior to LPS exposure.

To produce longer term outcomes, the next step of the project is to disseminate this information to Nebraska bean producers, distributors, and food companies, so as to promote the consumption, and thus demand, of dry edible beans (1-5 years). This research has, in part, provided the data for leveraging funds from other agencies to continue to study the health benefits of a currently under-utilized specialty crop in terms of its functional food and nutraceutical attributes.

Each specific aim was completed within the time frame shown in Table 4. However, analysis of data is still underway using other statistical approaches, (specifically as it applies to Specific Aim 3) and further dissemination of the data through conferences, papers, newsletters, etc., is anticipated. Moreover, we are following up some of our experiments that go beyond the scope of this project but became evident as it was being completed, such as further compositional profiling of each extract. Moreover, experiments are now underway to use even lower dosages in an attempt to overcome the dosage effect caused by the GNB. Lastly, we are accumulating more data for to confirm the inflammation phenotype as shown by the FTIR approach (Figure 2 and 3), such as monitoring other inflammatory markers, i.e., pro-inflammatory cytokines.

Table 4*:* 2011 SCBGP Time Line

1st Year	1st Quarter (Winter)	2nd Quarter (Summer)	3rd Quarter (Fall)

	Identification of Student	Training of Student and Collection of Data	Collection of Data
• Specific Aim 1 • Specific Aim 2 • Specific Aim 3	Not Started Not Started Not Started	**Completed** Not Started Not Started	**Completed** Not Started **In Progress**
2nd Year	**1st Quarter (Winter)**	**2nd Quarter (Summer)**	**3rd Quarter (Fall)**
• Specific Aim 1 • Specific Aim 2 • Specific Aim 3	**Completed** **In Progress** **In Progress**	**Completed** **In Progress** **In Progress**	**Completed** **Completed** **Completed**

Beneficiaries

It is anticipated that multiple beneficiaries will be impacted from this research particularly producers and distributors of dry edible beans in the Nebraska Panhandle and other counties that grow dry beans. The companies with a presence in Nebraska who will benefit from determining the health benefits of dry beans include large and small food based companies, such as Cargill, Archer Daniel Midlands, AGP, Abengoa, and Twin Valley Mills.

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A presentation on virtues of consuming dry edible bean to remediate inflammatory stress was presented to a group of nurses and dietitians (approximately 40-50 individuals) on Nov 2, 2012, in Scottsbluff, NE. It is further expected that the results generated from this project will be presented in next several issues of The Bean Bag*, which has a circulation of approximately 3000 readers located in* 24 states and Canada. Recipients include growers, landowners, politicians, other dry bean organizations, processors, advertisers, University personnel, et cetera. Other presentations, via poster or oral, at regional or national conferences are also anticipated.

Lessons Learned

In general, the project progressed smoothly after a graduate student was identified and trained. However, a statistician knowledgeable in bioinformatics is also essential considering that the data will require further analysis to determine the biological significances of the bean treatments. Such collaboration is currently being established.

These results have significant implications for determining the types of beans beneficial for protecting against the inflammation response, specifically in maintaining the anti-inflammatory DNA phenotype. If left unprotected, DNA conformation changes can lead to multiple negative impacts associated with chronic inflammation.

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Additional Information

References:

1.) Park, YK, Pham, T. X., Lee, J. (2012). Lipopolysaccharide represses the expression of ATP-binding cassette transporter G1 and scavenger receptor class B, type I in murine macrophages. Inflame. Res. 61:465-472.

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3.) Casagrande, F., Darbon, J. M. (2001). Effects of structurally related flavonoids on cell cycle progression of human melanoma cells: regulation of cyclin-dependent kinases CDK2 and CDK1. Biochem. Pharmacol. 61:1205-1215.

Project Title

Fenugreek: A Novel Anti-Diabetic and Anti-Cancer Crop in Nebraska

Project Summary

Fenugreek, an annual legume and seed is known to possess a numbers of medicinal properties (anti- diabetic, anti-cholesterol and anti- cancer), is grown under conditions (mostly in India), very similar to that found in western Nebraska. The three most important nutraceutical compounds for the medicinal properties are diosgenin, galactomannans and 4-hydroxyisoleucine. Therefore, fenugreek may be a new and industrially (nutraceutical) important crop in western Nebraska. To succeed however, high yielding fenugreek cultivars with high levels of the nutraceutical compounds and best production practices must be available to the growers, but these are not available. This new crop was never tested in Nebraska for its seed yield potential. Fenugreek germplasm available in USDA-ARS system were never screened for finding source of high levels of the compounds, which can be used in fenugreek breeding program. Long-term goal of this project is to develop fenugreek cultivars, which are adaptable in Nebraska, with high seed yield and nutraceutical compounds. Specific goal of the project was to evaluate fenugreek germplasm (PI lines) for nuraceutical compounds and available varieties for seed yield. Suitable PI lines either can directly be released as cultivar after genetic purification or can be used as source of high nutraceutical compounds in fenugreek breeding program. These data will serve as a source for developing cultivar with high seed yield and nutraceutical compounds for western Nebraska and neighboring regions.

Project Approach

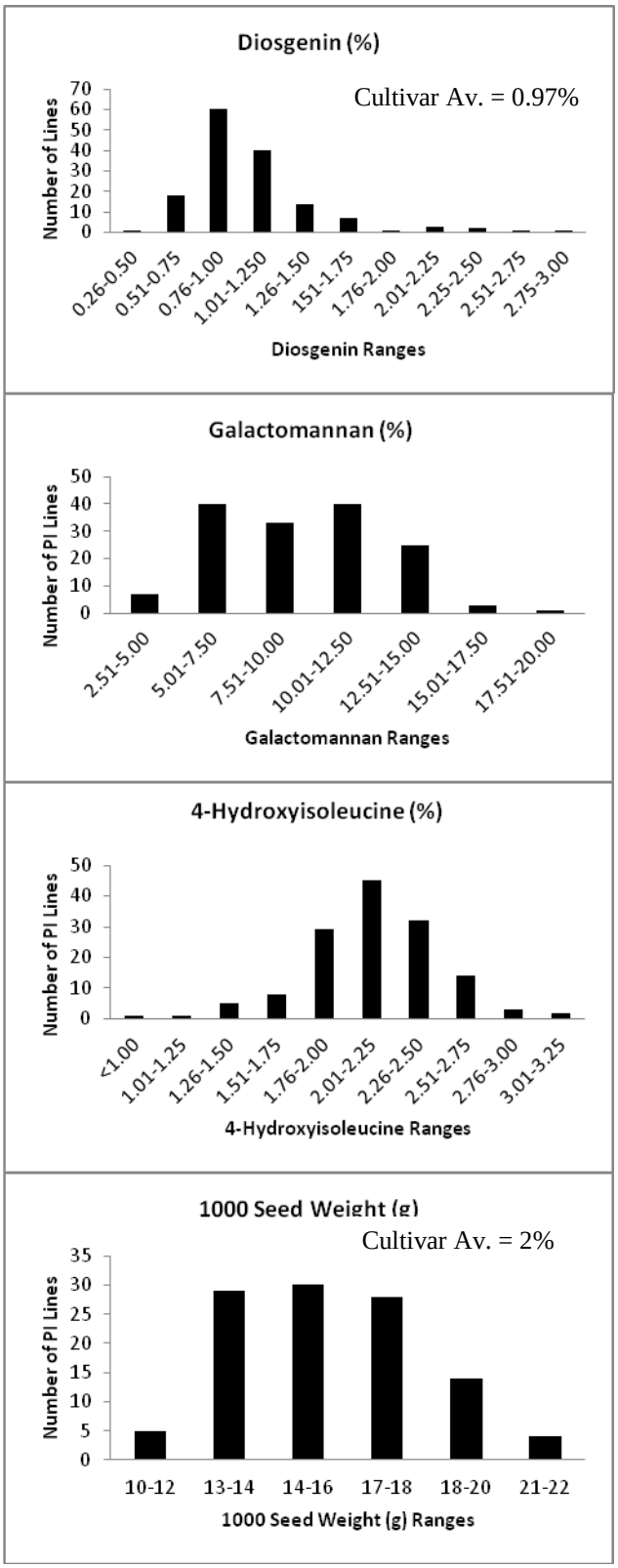
The 170 PI lines were originally obtained from USDA-ARS western Regional Plant Introduction Station, Pullman, WA and the lines were increased in 2011 season (before this funding cycle). Eight varieties were obtained from Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada. Of the 170 PI lines, 150 from 19 different countries (Table-1) were planted (4/17/2012) as 10 feet long row under full irrigation using linear-move overhead sprinkler irrigation system at Scottsbluff, NE. Eight varieties were planted with 4 replications at Scottsbluff, NE under irrigation (4/17/2012) and at High Plains Ag. Lab (near Sidney, NE) under both irrigation (4/17/2012) and dryland/rain-fed (4/1/2012). The trials were planted as 8-rows plot (5ft x 25ft) with 7.5 inches row spacing using seeding rate of 20 kg/ha. Sonolan @1.5 pints/acre was used as pre-plant herbicide in irrigated trials. The irrigated trials were applied with 0.25 inches water within 24 hrs after planting for emergence. The dryland trial was not irrigated. The irrigated trials were irrigated fully throughout the season. Seeds harvested from the trials were used for yield, seed size and nutraceutcal compounds assay. The PI lines were harvested at different dates between 7/20/2012 and 9/30/2012 due to maturity variation among the lines. Fenugreek growth continues even toward the end of the season because of its indeterminate growth habit and optimum harvesting period is not available in the literature. Therefore, variety trial at Scottsbluff was harvested (1 sq.

meter) early by hand on 7/20/2012 and the remaining of the plots was harvested later by small-plot combine on 8/6/2012. Variety trials at Sindey were harvested on 8/1/2012 (dryland) and 9/28/2012 (irrigation).

There was significant variation in plant stand among the plots, which could be due to the planting dates (no optimum planting date is available in literature for fenugreek in Nebraska). There were lots of weeds in all the trials, which was controlled manually, even after pre-plant herbicide (Sonolan). Dryland trial was heavily infested with weed since Sonolan could not be used due to lack of incorporation method and no manual weeding was possible. Therefore, plots were extremely variable. Plants from a section of the plots (variable sizes) were manually harvested from dryland variety trial. Significant results and accomplishments are listed below in the "Goals & Outcomes Achieved" so the conclusions and recommendations are summarized here. Very high variability in all three nutraceutical compounds was found among the PI lines. When compared with the varieties, the PI lines with almost 3 fold, 2.5 fold and 1.5 fold higher levels of diosgenin, galactomannan, and 4-hydroxyisoleucine were identified. Average 4-hydroxyisoleucine among the varieties was higher under dryland (2.38%) compared to that under irrigation (1.85%). Seed yields of the varieties were not significantly different in any of the three variety trials. Among the varieties, there was very little variation in diosgenin concentrations; however, galanctomannan and 4-hydroxyisoleucine varied significantly.

Goals and Outcomes Achieved

This project resulted in the identification of at least a few genotypes of fenugreek with extremely high concentration of the anti-cancer and anti-diabetic bioactive compounds. Seven and four PI lines with 2-folds higher diosgenin and galactomannan, respectively, and 5 PI lines with about 1.5-fold higher 4-hydroxyisoleucine were identified among the germplasm. The trait values among the PI lines were extremely variable in both lower and higher ranges compared to the cultivar averages (Figure 1). Summary of the trait values among the PI lines is presented in Table 1. All these traits varied significantly within the PI lines from a same country. Diosgenin, galactomannan, and 4-hydroxyisoleucine ranged from 0.35% to 2.97%, 3.48% to19.25%, and 1.38% to 3.08%, respectively. Seed weight among the PI lines ranged from 10g to 22g per 1000 seeds. The data suggests that the PI lines are extremely valuable genetic resource for fenugreek cultivar improvement and genetic research of the traits in the future.



Cultivar Av. = 8.6%

Cultivar Av. = 11.7g

Figure.1: Frequency distribution of diosgenin, galactomannan, 4-hydroxyisoleucine, and 1000 seed weight among 150 fenugreek PI lines.

Table 1. Country of origin of 150 PI lines and their trait values based on field trials in 2012 at Scottsbluff, Nebraska.

Country	Number of Lines	Diosgenin %	Galactomannan %	4-hydroxyisoleucine %	1000 seed weight (g)
Afghanistan	11	0.76-2.33	6.74-14.68	1.8-2.42	13-17
Angola	1	1.03	6.23	1.79	-
Armenia	1	2.41	11.43	1.79	18
Australia	2	1.0-1.07	10.15-13.85	2.18-2.41	17
Bulgaria	5	0.85-2.05	3.48-11.58	1.93-2.79	17-18
Egypt	5	0.80-1.60	5.47-11.40	2.11- 2.28	18
Ethiopia	11	0.60-1.44	4.64-11.52	1.58-2.69	13-21
Greece	1	0.83	12.75	2.25	14
India	26	0.64-1.58	5.5-17.66	1.49-2.58	10-18
Iran	31	0.62-2.14	3.73-14.04	1.41-2.60	13-18
Italy	1	0.92	7.18	2.73	22
Jordon	2	0.89-0.95	8.69-14.43	0.63-2.03	16
Morocco	6	0.65-1.62	4.10-12.52	1.38-2.67	21
Nepal	4	0.61-1.38	4.31-13.39	1.91-2.52	15-19
Pakistan	20	0.70-2.97	4.95-14.20	1.88-3.08	12-19
Spain	3	1.0-2.6	9.92-11.80	1.84-2.17	15-19
Syria	2	0.58-1.48	7.01-16.53	1.77-2.45	19-20
Turkey	16	0.35-1.15	5.34-19.25	2.45 - 2.03	16-20
Yemen	1	0.93	6.87	1.41	-
Unknown	1	0.88	11.78	1.92	20

This project also resulted in the identification of one or two well-adapted fenugreek cultivars with high seed yield potential in western Nebraska. No single variety with consistently high seed yield across the three trials could be identified. However, ‘L3308’, ‘Amber’ and ‘F70’ were the three highest yielding varieties at dryland, Sidney (274 kg/ha); irrigation, Sidney (737 kg/ha); and irrigation, Scottsbluff (519 kg/ha), respectively. Variety trials data from the three trials were presented in Table 2-4. Seed yields of the varieties were not significantly different in any of the three variety trials. Averages of seed yield of the varieties were 210 kg/ha (ranged from 149 kg/ha to 274 kg/ha) under dryland at Sidney; 616 kg/ha (ranged from 508 kg/ha to 737 kg/ha) under irrigation at Sidney; and 386 kg/ha (ranged from 311 kg/ha to 519 kg/ha) under irrigation at Scottsbluff. There was some difference in seed weight among the varieties when tested at Sidney (both dryland and irrigation); however, no difference was observed when tested at Scottsbluff. Averages of 1000 seed weight of the varieties were 11.3g (ranged from 10g to 13g) under dryland at Sidney; 11.1g (ranged from 10g to 11.8g) under irrigation at Sidney; and 12.8g (ranged from 12.2g to 13.2g) under irrigation at

Scottsbluff. There was very little variation in galanctomannan and 4-hydroxyisoleucine compared to diosgenin among the varieties. Variety average values for diosgenin, galactomannan, and 4-hydroxuisoleucine, and 1000-seed weight were 0.97%, 8.6%, 2%, and 11.7g, respectively based on data of all the varieties from the three trials.

Table 2: Variety testing data for 2012 dryland trial at HPAL, Sidney, NE.

Variety	**Seed Yield (kg/ha)**	**1000 Seed Weight (g)**	**Diosgenin (%)**	**Galactomannan (%)**	**4-Hydroxyisoleucine (%)**
Amber	149 A#	12.2 AB	0.94 A	5.70 E	3.03 A
F18	208 A	11.0 CD	0.94 A	9.52 B	2.35 AB
F70	241 A	11.2 BC	0.85 A	8.69 BC	2.03 B
L3068	208 A	10.0 D	1.03 A	7.79 CD	2.46 AB
L3308	274 A	11.5 BC	1.07 A	7.50 CD	2.20 B
L3375	204 A	10.5 CD	0.90 A	6.66 DE	2.39 AB
L3708	174 A	13.0 A	1.06 A	11.07 A	2.52 AB
Tristar	220 A	10.7 CD	0.91 A	7.28 D	2.06 B
Mean	210	**11.30**	**0.96**	**8.03**	**2.38**
LSD (0.05)	150	**1.00**	**0.25**	**1.26**	**0.71**

= Numbers followed by the same letter are not significantly different at 0.05 level.

Table 3: Variety testing data for 2012 irrigated trial at HPAL, Sidney, Nebraska.

Variety	**Seed Yield (kg/ha)**	**1000 Seed Weight (g)**	**Diosgenin (%)**	**Galactomannan (%)**	**4-Hydroxyisoleucine (%)**
Amber	737 A#	11.0 AB	1.04 A	8.07 CDE	2.57 A
F18	665 A	11.8 A	1.05 A	6.58 E	2.05 ABC
F70	632 A	11.1 AB	0.88 A	7.71 DE	1.71 BC
L3068	727 A	11.8 A	0.98 A	9.13 BC	1.81 BC
L3308	595 A	11.8 A	0.93 A	9.65 BC	1.98 C
L3375	541 A	10.5 AB	0.96 A	11.56 A	1.80 BC
L3708	508 A	10.0 B	0.96 A	8.49 BCD	2.02 ABC
Tristar	520 A	11.3 AB	1.03 A	9.84 AB	2.21 AB
Mean	616	**11.10**	**0.98**	**8.88**	**1.95**
LSD (0.05)	359	**1.6**	**0.21**	**1.75**	**0.69**

= Numbers followed by the same letter are not significantly different at 0.05 level.

Table 4: Variety testing data for 2012 irrigated trial at Scottsbluff, NE.

Variety	**Seed Yield (kg/ha)**	**1000 Seed Weight (g)**	**Diosgenin (%)**	**Galactomannan (%)**	**4-Hydroxyisoleucine (%)**

Amber	311 A#	13.2 A	1.03 A	11.15	1.88 BC
F18	311 A	12.7 A	1.05 A	9.00 AB	2.00 AB
F70	519 A	12.5 A	1.19 A	10.65 AB	1.69 CD
L3068	423 A	12.7 A	0.60 B	11.75 A	1.56 D
L3308	461 A	13.0 A	1.06 A	7.90 B	1.78 BCD
L3375	358 A	13.0 A	1.02 A	9.55 AB	2.18 A
L3708	313 A	12.2 A	0.70 B	10.01 AB	1.64 CD
Tristar	387 A	13.0 A	1.15 A	10.62 AB	1.70 CD
Mean	386	**12.80**	**0.98**	**8.88**	**1.80**
LSD (0.05)	216	**1.6**	**0.17**	**3.27**	**0.28**

= Numbers followed by the same letter are not significantly different at 0.05 level.

Beneficiaries

The results and findings of this study were disseminated to the target audiences and it will continue even after end this project. The target audiences are growers, general public, Ag. industry personnel and scientists. A list of presentations/publications during 2012-13 included the following:

1. 'Fenugreek trial at HPAL', presented at HPAL Field day on June 21, 2012. Target audience = 75.

2. Participated 'Farm and Ranch Museum Harvest Festival', Sept. 15-16, 2012, Gering, NE. In 'Alternative Crops breeding' booth, a poster on fenugreek was predented. Fenugreek seeds, pods, and plants were on display. Target audience = 200.

3. "Alternative Crops for western Nebraska", High Plains OCIA NE #2 Annual Meeting, March 3, 2012, Sidney, NE. Target audience = 40
4. "Alternative Crops for Certification", Nebraska Seed Improvement Conference, January 18, 2012, Kearney, NE. Target audience = 60.

5. 'Evaluation of fenugreek (Trigonella foenum-graecum L.) as new crops in western Nebraska'. 24th Annual AAIC Meeting. Industrial Crops, November 12-15, 2012, Sonoma, CA. Target audience = 200.

6. On-line news release on fenugreek and its current research at Panhandle Research and Extension Center http://liferaydemo.unl.edu/web/panhandlerec/at_the_center_72. Target audience = 1,000 (approximately).

Lessons Learned

Fenugreek seems to have production potential. Developing optimum production practices (planting and harvesting period, and weed management) seems to be important factor for better seed yield.

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Additional Information

None.

Project Title

Japanese Beetle Survey

Project Summary

Japanese Beetle is a highly destructive plant pest of great concern to the Nebraska Nursery (Horticulture) industry. This pest poses an obstacle to the interstate and international trade of Nebraska produced nursery stock. Nebraska currently has seven counties infested with Japanese Beetle. However, interceptions have increased in recent years, as the leading edge of the generally infested area creeps closer to Nebraska. Numerous states and foreign countries have imposed trade restrictions in the form of exterior quarantines on nursery stock, including Nebraska's nursery stock, due to the potential spread of this pest on nursery stock. These exterior quarantines require additional survey, inspections and certification in order to certify nursery stock being shipped to non-infested areas. Nebraska currently has over 1,200 licensed nursery dealers and growers potentially impacted by these restrictions. While states such as California, Washington, and Oregon have had restrictions in place for some time, Colorado only recently implemented a Japanese Beetle State Exterior Quarantine, which became effective on January 1, 2010. This quarantine has had a significant, direct impact on the movement of Nebraska nursery stock into Colorado. Nurseries must meet these additional certification requirements, as spelled out in Colorado's quarantine, to ship to Colorado. The Nebraska Department of Agriculture (NDA) Entomology Program proposed a coordinated, comprehensive survey for Japanese Beetle in Nebraska. This assisted in keeping interstate and international markets open to Nebraska nursery stock. The monitoring will help confirm the status of the pest in our state. That status is then used to determine what steps, if any, are necessary to certify the nursery stock for interstate or international trade. Additionally, if beetles are found, the producer is able to implement best management practices to mitigate pest problems.

The goal of this project was to conduct a comprehensive survey of nursery dealers and growers to determine the presence or absence of Japanese beetle populations at those facilities. This was accomplished through the following objectives: (1) Set, monitor and retrieve approximately 250 Japanese Beetle traps at nurseries, statewide, with a focus on high volume importers and nurseries that ship interstate and internationally; (2) Conduct soil sampling for Japanese beetle grubs at specific nursery locations where Japanese beetles are detected, for firms that ship interstate and internationally; (3) Monitor treatment of nursery stock for Japanese beetle grubs, when applicable. The trapping and soil survey work was used to determine the presence or absence of Japanese beetle in Nebraska. This was used to maintain Nebraska's Category 2 designation under the U.S. Japanese Beetle Harmonization Plan. Each of these objectives were used in the process of certifying nursery stock as being free of Japanese beetle life stages. This certification is often necessary in order to ship the nursery stock into other states and foreign countries, including Colorado.

Previously this effort was funded through USDA Pest Detection funds under the Cooperative Agriculture Pest Survey Program (CAPS). Those funds were not available for this survey in FY2012. Each year of survey work builds on previous work. Locations for survey are chosen based on a variety of criteria, including potential for introduction of the pest, shipping habitats of the nursery, past interceptions of the pest, or need to reaffirm negative status. It is also not possible to survey the entire state each year and so traps are set at different locations each year to maximize the information obtained relevant to positive or negative status of the county. The value of survey data for any particular year is enhanced when there is additional years of survey to support those findings.

Project Approach

In 2012, a total of 199 JB traps were set in 38 non-infested counties catching over 825 beetles. Seventy-one traps were set in four of the known infested counties, catching 78,311 beetles. Traps were located at airports, state parks, special quarantine compliance areas, and nursery growers and dealers. Nursery dealers and growers in non-infested counties that import balled and burlapped nursery stock are considered high-risk sights and, therefore, are trapped individually.

Positive traps were found in the following counties: Adams, Buffalo, Burt, Cass, Cheyenne, Colfax, Custer, Dakota, Dawes, Douglas, Gage, Hall, Holt, Lancaster, Lincoln, Phelps, Red Willow, Sarpy, Scotts Bluff, and Thayer.

After the 2012 trapping season, NDA declared three more counties as being infested with JB. Buffalo, Cass, and Hall counties joined the infested list that already included Dakota, Dodge, Douglas, Hamilton, Lancaster, Saline, Sarpy, Saunders, and Washington counties.

Soil sampling was conducted March through May, 2012, at select firms in known infested counties, where Japanese beetle (JB) populations had previously been confirmed via trapping. Firms were selected based on several factors, including level of infestation and nursery production methods. A total of 565 soil samples were collected over 365 acres, for 7 firms in six counties. No Japanese beetle grubs were found.

Firms in known infested areas that wished to ship interstate or internationally may request to certify their nursery stock, based on application of specific chemicals. While this was an option available to nursery stock shippers, none exercised this option, and as a result, NDA inspection staff witnessed zero chemical treatments for JB certification in 2012.

Goals and Outcomes Achieved

The goal of this project was to conduct a comprehensive survey of Nebraska nursery dealers and growers, to determine the presence or absence of Japanese beetle (*Popillia japonica*) populations at those facilities. This information is then used to certify

Nebraska grown nursery stock for international and interstate movement, to areas that have enacted quarantines to prevent the introduction of Japanese beetle.

Measurable outcomes for this project include 1) disseminating survey information in the NDA Entomology Program Annual Report; 2) direct mailing of JB certification requirements to licensees; 3) incorporating project results on the NDA web site; 4) inclusion of survey results on the NDA Entomology Program display booth at Nebraska Green Expo; and 5) submission of relevant articles to the NNLA newsletter. Each of these objectives either has been met, or is on track to be met. The supporting documentation for this is given below.

Information on NDA Japanese Beetle Survey Activities was disseminated at the Nebraska Green Expo Conference in Council Bluffs, January 2012. This included information on the 2011 survey results, historical finds, and upcoming survey plans for 2012. Information on how to request a site be surveyed was available at this event, along with information on interstate and international shipping and receiving requirements. This event had 723 registered attendees from the nursery, landscape and turfgrass industries. Additional outreach was conducted at the Nebraska Arborists Association (NAA) Annual Winter Meeting, held February 2012, with approximately 200 attendees; the Governor's Ag Conference, held March 2012, with 200 attendees; NNLA/NAA Summer Field Day, August 2012, with approximate attendance of 75 individuals from the nursery and arborist industries.; and the Nebraska State Fair, August 2012, with attendance of 333,043 individuals. This outreach included display boards and informational handouts with specific information on Japanese beetle, the NDA Entomology Program Annual Report, survey and trapping work, and interstate and international shipping and receiving requirements.

As of October 31, 2012, NDA Entomology staff had recorded over 374 hours and 6,123 miles driven, spent in meeting the goals of this project. Since the beginning of this project, NDA has issued 47 state and federal phytos to facilitate the movement of nursery stock interstate and internationally, certifying 13,200 individual plants as meeting the Japanese Beetle requirements of the receiving state or country. NDA has also entered into three compliance agreements with firms that regularly ship nursery stock interstate. These firms generally have a strong track record of interstate shipping, and have demonstrated their willingness and ability to understand and follow requirements under the Nebraska Plant Protection and Plant Pest Act, and those of the receiving state. Firms under a compliance agreement must sign an agreement with NDA, attesting that they will meet certain standards. They are then able to certify their own shipments as meeting a specific state's JB entry requirements. NDA staff continues to survey, inspect and oversee the firms, and will terminate the agreements if used improperly.

Beneficiaries

The primary beneficiaries of this project are Nebraska's nursery dealers and growers. The project assists these firms in meeting the entry requirements of receiving states and

countries, when exporting their products. Secondary beneficiaries include the general public and other plant and plant product producers. Japanese beetle presence/absence data can assist these individuals in determining if treatments are warranted, make them aware of potential problems early on, and improve their ability to scout for this pest.

All distributors of plants benefit from the results of the Japanese Beetle survey. In 2012, NDA licensed over 355 nursery stock growers growing nearly 2,000 acres of nursery stock, and 955 nursery stock dealers. The requirements for shipping their nursery stock interstate is directly tied to the existence of an annual survey, and the results of the survey. If the results for their county are negative, a grower can generally ship their nursery stock without needing special certification documents to mitigation steps, such as application of chemical treatments or additional production safeguards. If results are positive, trapping may be conducted in their immediate production area, and certification based on negative results of that survey. If both are positive, then soil survey may be used to meet certification requirements, or NDA staff may work with the producer to add production methods that will enable them to meet certification requirements. Three firms chose to enter into compliance agreements with NDA in 2012, for the purpose of certifying large volumes of product as free of Japanese Beetle. Sod and annual plants are not regulated by the Nebraska Department of Agriculture, but survey results can be used by producers of these agricultural products when shipping their products to states with Japanese Beetle quarantines, also. Without the survey, the entire state would be considered infested with Japanese Beetle, and all producers would need to add additional production measures or use chemical applications in order to certify plant material for movement to non-infested states.

Lessons Learned

This survey has been conducted for several years, but we review our procedures and protocols each year to ensure that we are performing the work correctly based on survey standards. We also review the activities of individual nursery producers in the state to determine their needs related to Japanese beetle monitoring and mitigation. We’ve learned that outreach always helps, educating the industry on concerns related to this pest.

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Additional Information

None.

Project Title

Farmer's Alternate Crop: Winter Production of Greenhouse Strawberries

Project Summary

The overall goal of this project was to enhance Nebraska's economy by growing high 'value' horticultural crops during the winter months. To accomplish this project, the University of Nebraska – Lincoln (UNL) developed and tested methods to:

1. Optimize the system by determining the strawberry cultivars best suited for sustainable crop production;

2. Quantify the crop value not just in terms of profitability but also in terms of contributions to human health; and

3. Reduce fixed and variable costs for structures, water, fertilizer and especially, energy inputs

Nebraska, the heartland of America, is well known nationally and internationally for its abundant and profitable agricultural field crop production during spring, summer, and fall. This is due to sunshine, warm temperatures and plentiful moisture. However, what is not well known is that some of the sunniest, but coldest days of the year, occur during the winter months. Winter time solar energy can be utilized for controlled environment agriculture (CEA), in this case, greenhouses. Greenhouse food production has yet to be fully explored and developed in Nebraska. With increasing transportation costs, concerns about imported food safety, human health/obesity issues, and the need to improve local economies, increasing local production of fresh fruits and vegetables would be a logical step for CEA in Nebraska. Additionally, growing food using CEA would allow Nebraska farmers an additional source of income outside of the usual field season. Research by Hoagland et al., 2008 found that the average corn/soybean farmer has labor and/or time available from December through March, which could be utilized to grow alternate crops.

By completing this years' project we now have enough data to write two strawberry production publications. The plan is to submit these to international horticulture journals such as *HortScience*.

Project Approach

We modified a typical Quonset, double polyethylene commercial style production greenhouse located on UNL's East Campus by installing a gas meter and rerouting the heat tubes to under two benches. We also assembled an automatic water/fertilizing system, again with a water meter, in order to utilize capillary mat technology for growing the strawberry plants. We also installed a wireless system to monitor the production environment in the greenhouse – specifically temperature, humidity, light quality,

quantity and energy, soil moisture and heating/cooling events. This instrumentation was supported by funds from the USDA/CSREES NE 1035 Commercial Greenhouse Production: Component and System Development (Dr. George Meyer, Principal Investigator).

Six cultivars, 2 of which were purchased as + grades (larger root system), of strawberry plants were purchased, potted up and grown on the capillary mats from October through April 2011. Berry harvest began mid-November/early December. Berries were harvested (counted and weighed weekly). In March, we selected berries from each cultivar and Dr. Vicki Schlegel's lab analyzed them for health-promoting phytochemicals (total phenols, flavonoids and antioxidant capacity) as well as sugars. The nutraceutical and sugar content of the strawberries will confirm which cultivars will be selected for commercial production. Berries were frozen in liquid nitrogen immediately after harvest and stored at −80 ^{o}C prior to further analysis. The samples were then extracted with 1.2 N HCl in 50:50 water:methanol. After centrifugation, the Folin-Ciocalteu method was used to determine total phenol levels in the sample supernatants as described by Singleton and Rossi (1965). To quantify total flavonoids and antioxidant capacity, the sample supernatant was prepared as cited above and measured according to Adom and Liu (2002) and Cao et al. (year), respectively. Moreover, simple sugar analyses will be performed to determine sweetness of the different sample as described by Keutgen and Pawelzik (2007).

Albion, Chandler, Cavendish, Evie-2 (as standard and + grade) and Seascape (as standard and + grade) and Portola were once again successfully grown. Of the 299 plants in this study, we harvested 9,937 berries (compared to 7,061in 2010-2011). The total weight of those berries was 234.5 pounds (compared to 156.7 pounds in 2010-2011). Evie 2+, Albion and Seascape + produced the greatest number of berries per plant (2-3 per week) during the peak price times of December – February. Water usage was 42 gallons total for the growing season (compared to 65 gallons for 2010-2011). We measured ^{o}Brix on these cultivars and it ranged from 4.6 – 9.2. This measurement was important for winemakers as it indicates the total soluble solids in the berries and thus, how much sugar would need to be added to make wine. Grapes usually run in the high 20's and 30's so for these cultivars a substantial amount of sugar would be need to be added in winemaking (focus is dessert wine). Nutraceutical and antioxidant measurements were consistent with the previous year and we may consider an informal taste test to highlight the attributes of each berry type (a statistical taste testing costs $1,500 per day).

Overall, we are making excellent progress towards providing farmers and growers a cost effective way to produce strawberries during the winter. As the lead Principal Investigator, I ran oversight for all facets of the project. My technologist, Liz Conley, and hourly student labor were responsible for all data collection. Ben Loseke, a graduate student with Dr. Paul Read performed the ^{o}Brix measurements. Dr. Blankenship and I analyzed and interpreted this current year's data and will be working on the past 3 seasons to create a referred publication. Dr. Schlegel's lab ran all the analyses on the nutraceutical and sugar properties of the strawberries and again we are

working on compiling all 3 seasons. Associate Professor Stacy Adams provided expertise in the design and installation of the capillary mat system and overall benching, heating and greenhouse structure. Dr. Meyer and his team installed the computer, web cam, sensors for measuring light and mix water holding capacity as well as the recording software for the data associated with the sensors. Associate Proffessor Dave Lambe compiled start-up and production costs for our publication.

Goals and Outcomes Achieved

Goal# 1: Complete final growing season with 6 cultivars to determine berry production peaks. Accomplished as indicated above. Cutivars Cavendish and Portola were not deemed suitable for our greenhouse conditions. The other 4 cultivars grew and produced well.

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Goal #2: Determine/confirm nutraceutical and sugar content. Accomplished as indicated above. We plan to look at the data from all 3 years for final recommendations.

Goal #3: Finalize construction, equipment and operating costs for double poly Quonset greenhouse. Accomplished. Lambe, D., S. A. Adams and E. T. Paparozzi. 2012. Estimating Construction Costs for a Low-Cost Quonset-Style Greenhouse. UNL Extension Publication EC 104. 8 pp. (http://www.ianrpubs.unl.edu/epublic/live/ec104/build/ec104.pdf)

Goal #4: Enhance web site and extend grower/farmer outreach via *NebGuides* and *Backyard Farmer* appearance. Accomplished. The *Backyard Farmer* video was completed, but has yet to air. They are looking for additional strawberry reports or features to add more of homeowner flavor. A *NebGuide* was peer-reviewed and has been published then posted on the site.

(http://agronomy.unl.edu/c/document_library/get_file?uuid=901db732-851d-4a5b-8133-2b5be05a3fee&groupId=4128273).

Dr. Paparozzi also presented a poster at the American Society for Horticulture Science. In partnership with Dr. Meyer, she also wrote a popular article for *Greenhouse Grower* magazine (http://www.greenhousegrower.com/article/30434/capillary-mats-are-back). Both were also posted on the web site.

Goal #5: Publish results in scientific journals. One journal article has been published and one is in preparation. The published article can be found on the Internet. Meyer, G.E., E.T. Paparozzi, E A. Walter-Shea, E.E. Blankenship, and S.A. Adams. 2012. "An Investigation of Reflective Mulches for Use Over Capillary Mat Systems for Winter-Time Greenhouse Strawberry Production." *Applied Engineering in Agriculture* 28(2):271-279 (http://elibrary.asabe.org/abstract.asp?search=1&JID=3&AID=41345&CID=aeaj2012&v=28&i=2&T=1&urlRedirect=[anywhere=&keyword=&abstract=&title=&author=on&refere

nces=&docnumber=&journals=All&searchstring=Paparozzi&pg=&allwords=&exactphrase=Paparozzi&OneWord=&Action=Go&Post=Y&qu=]&redirType=newresults.asp).

The results of this project can also be found in the following publications.

Paparozzi, E. T., G,E. Meyer, S. A. Adams , M. E. Conley, B. Loseke and P. E. Read 2012. "Greenhouse Production of Strawberries in Winter." *HortScience* 47(9): S326-327).

Paparozzi, E. T. and G. E. Meyer. 2012. "The Return of Capillary Mats." *Greenhouse Grower* magazine. August issue p. 78-84 (http://agronomy.unl.edu/c/document_library/get_file?uuid=b0a0e41e-a645-48bd-ad16-ffd5b907b7a8&groupId=4128273&.pdf).

Beneficiaries

Aquamat is a company that produces totally enclosed capillary mats. Ours are the "do-it-yourself" version. They contacted us in late September and were very pleased to see our article in *Greenhouse Grower* magazine on the capillary mats. They would like us to trial their product. We told them it would not work for strawberries and they said that it would be fine if we used it for another crop in the future. So we added them to our mailing list.

Bartlett Instrument Company also contacted us after the capillary mat article was posted. The owner, Dave Bartlett, was curious about the automatic irrigation system and how it was possible that we used so little water. After our explanation, he too joined the mailing list.

In August, Dr. Paparozzi gave a poster presentation on the information contained in this report at the National American Society for Horticultural Sciences. There were 1,100 attendees at this meeting and usually at least half of them will visit the posters. The abstract is posted at http://hortsci.ashspublications.org/content/47/9/suppl/DC1. The poster can be found on the web site (http://ashs.confex.com/ashs/2012/webprogram/Paper9753.html).

From this meeting, Dr. Paparozzi has made a connection with Dr. Kevin Folta at the University of Florida and has been in contact to determine if Nebraska could benefit from their field practice, dormant crown producers and their use of informal taste tests. Additionally, Dr. Paparozzi noticed that other states, such as Texas are now, suddenly, promoting the idea of growing greenhouse strawberries for the winter market. Below there is a table of unique views (first time visitors) to the web site.

Date	Number of unique views of website	Comments
October 2012	44	
September	46	Capillary mat article added

		to site 9/6/12
August	36	
July	14	
June	36	-2012 ASHS Poster presentation added to site. -Colored Plastic mulch article added to site.
May	24	
April	52	
March	27	
February	32	
January 2012	Not available	
December 2011	21	
November	13	
October	8	

Lessons Learned

Fruit phylloidy – According to the literature, this condition of the achenes (seeds) germinating by producing little leaves on the berry can be either environmental or a phytoplasma (type of virus). In the two previous years, we had never seen it. Therefore, we discarded all plants with this condition and it disappeared. Unfortunately, a very productive and flavorful cultivar, Portola, had the most plants with this condition. Therefore, it is off the recommendation list.

Biodegradable pots – for one replication of all plants, we potted the strawberries in wood fiber biodegradable pots. Within a few weeks, all pots (not plants) had powdery mildew. Rather than treat the mildew (and there are organic ways to do this) we repotted all plants into clean new pots. It seems that the continual moistness of the mat system does not work well with uncoated/treated pots – coir slick pots (which are only somewhat biodegradable) could work – but others that are not coated will not.

Insect problems – at the start of this experiment in August 2011, we sprayed 25% hypochlorite solution over all permanent, non- metal structures in the greenhouse. We had no insect problem until January and then mainly on one particular cultivar. This cultivar, Cavendish, has a very tight growth habit and no spray was effective in ridding it of mites. Thus, it too has been removed from the recommended list.

Contact Person

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Additional Information

Web site http://agronomy.unl.edu/cea

Selected References

Singleton, V. and Rossi, J. 1965, Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. Vitic.,* 16: 144-158.

Adom, K. and Liu, R. 2002. Antioxidant activity of grains. *J. Agric. Food Chem*.50: 6182-6187.

Cao, G., Alessio, H.M., Cluter, R. G., 1993. Oxygen-radical absorbance capacity assay for antioxidants. *Free Radical Biological Medicine* 14:303-311.

Hoagland, L., Hodges, L., Helmers, G., Brandle, J. and C. Francis. 2008. Does the corn/soybean farmer have time for alternative crops? *HortScience* 43:1228.

Keutgen, A.J., & Pawelzik, E. 2007. Modifications of taste-relevant compounds in strawberry fruit under NaCl salinity. *Food Chemistry*: 5:33.

Project Title

Great Northern Bean Flour as a Functional Ingredient in Gluten-Free Foods

Project Summary

Nebraska-grown dry beans are mainly marketed without further processing. Dry edible beans have a huge potential in becoming functional ingredients in commercial food processing operations. The availability of high levels of proteins, fiber, and other important nutrients in dry edible beans could be exploited in finding new opportunities in value added products. Great Northern (GN) beans make up the largest portion of Nebraska dry edible bean production. GN beans are unique compared to other dry beans, due to their lack of color and tannins, therefore could be utilized as a functional, gluten-free food ingredient. This project focused on developing a food ingredient formulation that will use GN bean as a major raw material in its composition. The objective was to develop a food ingredient/pre-mix from GN beans, in order to increase the utilization of the commodity in commercial food processing operations. A successful completion of this project would positively impact the Nebraska dry bean industry by increasing the demand for GN beans for new food applications.

Project Approach and Goals and Outcomes Achieved

The main objective of this project is to evaluate the potential of GN beans to be used as a main raw-material in a commercial food pre-mix that could be used in manufacturing gluten-free snack-type foods.

The specific objectives of this project were to:

1. Characterize the physical and chemical properties of processed GN beans;

2. Evaluate the functional properties of GN bean flour, in combination with other ingredients, for selected food applications; and

3. Create a prototype ingredient pre-mix that could be used in gluten-free snack food manufacturing processes.

We are pleased to report that all project activities were completed as outlined in the submitted project proposal. The accomplishments are listed below.

1. Five selected hybrids of Great Northern bean, Orion, Gemini, Marquis, Coyne, and Beryl-R, currently used by Nebraska farmers, were identified with the assistance of Dr. Carlos Urrea of University of Nebraska-Panhandle Research and Extension Center for the studies of this project.

2. The proximate composition of each hybrid was analyzed by standard methods. Starch, which is the main component, was isolated from each hybrid. Isolated and purified starch fractions were analyzed for thermal and physicochemical properties.

3. Starch and Great Northern bean flour functionalities were tested and specific properties that are important for commercial ingredient applications were identified.

4. Project outcomes were presented and shared with the food industry at the following venues/events:

    a. 2012 Institute of Food Technologists (IFT) Annual Meeting, Las Vegas, Nevada (June 25 – 28).

    b. 2012 Sino-U.S. Health and Nutrition Forum, Beijing, China (August 24).

    c. University of Nebraska Annual Research Fair (April 5, 2012).

    d. Meeting with the Chinese food manufacturers during Reverse Trade Mission to Nebraska (July 2, 2012).

    e. Meeting with Nissin-Jinmailang Foods Company (Research and Development Executives) in Beijing, China (August 22, 2012).

5. One Master's level Graduate Research Assistant (Ms. Hui [Mary] Wang) completed all the tasks proposed in this project as a part of her thesis research. She continues to be involved in planned future research projects.

6. Characterization of physical and chemical properties of processed GN bean

    a. We comprehensively analyzed the selected Great Northern bean hybrids to determine the proximate composition of nutrients. We found that the major component, starch, which accounts for approximately 40 percent of weight, could play a major role in determining the functionality of flour and ingredients made out of Great Northern beans. Starch fraction of Great Northern bean (all five hybrids) was isolated by a modified wet-milling method. We analyzed physical, chemical, and thermal properties of isolated Great Northern bean starches, to determine their functionalities as ingredients. We found that physico-chemical properties of Great Northern bean starches were different from the starches, such as maize, that are traditionally used in food processing.

7. Evaluation of functional properties of GN bean flour, in combination with other ingredients, for selected food applications

    a. Our goal was to develop a food ingredient that could be comparable to traditional ingredients used in food processing. In order to accomplish this goal, we milled beans using a laboratory hammer mill and tested flour for selected properties. This step was conducted to evaluate the bean flour properties that influence ingredient functionality. The results of these studies were reported in the presentation Korte & Ratnayake (2012).

8. Creating a prototype ingredient pre-mix that could be used in gluten-free snack food manufacturing processes.

    a. A prototype food ingredient mix, free of gluten, was developed and tested with promising results. We used all purpose flour as the reference and three gluten-free formulations of Great Northern bean flour with Xanthan gum, potato starch, and rice starch were tested for pasting/viscosity using rapid visco analyzer (RVA). The Xanthan gum-bean flour mixture behaved very similar to the reference (all purpose flour) showing potential for use in food processing applications. Out of the three tested formulation, rice starch-bean flour formulation showed least viscosity, and accordingly we eliminated the formulation as a potential replacement for all purpose flour (Korte & Ratnayake, 2012). The outcome was two gluten-free, bean flour-based ingredient formulations that could replace all purpose flour in food processing operations.

9. The following research publications were presented based on this project's outcomes:

    a. Ratnayake, W. S. and Wang, H. 2012. Food ingredients & products from dry-edible beans. Global Food Industry - Food Technology: Submitted for publication.

    b. Wang, H., Korte, S., Kerrigan, M., Ratnayake, W. S. and Flores, R. A. 2012. Partial characterization of Great Northern bean starch in: Institute of Food Technologists Annual Meeting: Las Vegas, NV. (Poster No. 192-17).

    c. Korte, S. and Ratnayake, W. S. 2012. Development of food ingredient mixes with dry bean flour in: University of Nebraska Research Fair: Lincoln, NE. (April 05).

10. The dissemination of research outcomes were presented at the following events:

    a. Institute of Food Technologists (IFT) Annual Meeting: Las Vegas, NV. 2012 June 25 – 28.

    b. University of Nebraska Research Fair: Lincoln, NE. 2012 April 05.

    c. Chinese Food Industry Reverse Trade Mission to the State of Nebraska, Lincoln, NE, 2012 July 02.

    d. Life Sciences Symposium, University of Nebraska–Lincoln, Lincoln, NE, 2012 Sep. 25.

    e. Meetings with Nebraska Dry Bean Producers, Nebraska Dry Bean Commission, and UNL Dry bean breeding program. Scottsbluff, NE. 2012 Oct. 04 – 06.

    f. Meetings with Chinese Food Manufacturers (more than 20) at Sino-U.S. Nutrition and Health Forum. 2012 Aug. 24

Beneficiaries

Approximately 1,900 dry-bean farmers and dry-bean processors in the State of Nebraska were the primary beneficiaries of this project. The outcomes of the project revealed the potential of dry-edible beans in food processing applications, especially in developing ingredients, in combination with traditional product formulations to improve the nutritional value and quality of final processed products. As a result, the food industry, especially convenience food manufacturers, both national and international, would also benefit from the outcomes of this project.

Lessons Learned

The following critical information was gathered at the end of this project.

1. Physicochemical and functional properties of Nebraska grown Great Northern beans are acceptable for food ingredient applications.

2. Starch could be separated from Great Northern beans by wet-milling techniques.

3. Great Northern bean starch has thermal properties that are suitable for various food applications, to maintain structure and texture of final products.

4. Great Northern bean starch is relatively more resistant to enzymatic hydrolysis than most other common cereal starches, and therefore could carry potential health benefits, accompanied by slow digestion rates.

5. Numerous opportunities exist for dry-edible beans to be used in value-added product processing in the food industry.

Based on the outcomes of this initial project, we have planned further activities in collaboration with the UNL Dry bean Breeding Program (Dr. Carlos Urrea of Panhandle Research and Extension Center, Scottsbluff, Nebraska), Nebraska dry bean processors (Kelley Bean Company, New Alliance Bean Company, and Stateline Bean Co-op), bean milling companies, and food processing companies. Our goal is to introduce new application and processing technologies to the food industry to increase the utilization of the commodity in commercially processed foods.

We are continuing to conduct investigations to find new opportunities for commercial food processing applications for Nebraska dry edible beans. The following projects are planned (and some parts are already underway) for our future applied research work in improving the utilization of dry edible beans in the food industry.

1. Incorporating dry edible bean flour in common processed/convenience foods, such as instant noodles.

2. Dry-milling and fractionation of starch-, fiber-, and protein-rich fractions of dry edible beans for food applications.

3. Wet-milling and fractionation of dry edible bean components for commercial food processing applications.

4. Development of prototype products and analyzing their properties.

5. Collaborative research and development work with both dry bean and food industries to improve utilization of different dry edible bean market classes for specific food applications.
6. Special product development projects, coordinated and supervised by Dr. Devin Rose, have been planned for UNL Food Science and Technology students (Spring 2013). Dr. Devin Rose (Assistant Professor, Department of Food Science & Technology) served as the Co-Principal Investigator of this project.

Contact Person

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Additional Information

This project received attention at both national and international events.

The following publications were presented based on this research project's outcomes:

1. Ratnayake, W. S. and Wang, H. 2012. Food ingredients & products from dry-edible beans. Global Food Industry - Food Technology: Submitted for publication.

2. Wang, H., Korte, S., Kerrigan, M., Ratnayake, W. S. and Flores, R. A. 2012. Partial characterization of Great Northern bean starch in: Institute of Food Technologists Annual Meeting: Las Vegas, NV. (Poster No. 192-17).

3. Korte, S. and Ratnayake, W. S. 2012. Development of food ingredient mixes with dry bean flour in: University of Nebraska Research Fair: Lincoln, NE. (April 05).

4. Another manuscript on Great Northern bean starch characterization and functionality is in preparation for publication in the Journal of Agricultural and Food Chemistry (published by American Chemical Society).

Copies of poster presentations are attached.

Partial Characterization of Great Northern Bean Starch

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Abstract

The functionality and utilization of Great Northern beans, as a food ingredient, are influenced by its composition. Starch, being the major component, plays an important role in Great Northern bean's functionality as a food ingredient. This study investigated the physicochemical properties of Great Northern bean starches, isolated from five selected hybrids. Granular structure and polymer composition seem to be more responsible, compared to molecular level attributes, for the observed differences among thermal properties and functionalities of Great Northern bean starches.

Introduction

Dry-edible beans are known for their extensive nutrition benefits, but the commercial utilization of dry beans is still limited to traditional products such as canned beans, soups and refried beans. This is mainly due to insufficient availability of bean-based ingredients. Great Northern bean is one of the most popular dry beans produced in the U.S. Great northern bean is preferred for food ingredient development due to light color and lack of tannins & off flavors, and thermal stability. There is a dearth of information about the physicochemistry and functionality of Great Northern bean starch, in relation to ingredient development.

Materials and Methods

Five selected Great Northern bean hybrids: Beryl-R, Coyne, Orion, Gemini, and Marquis, were obtained from the University of Nebraska - Panhandle Research and Extension Center, Scottsbluff, NE.

Proximate compositions were analyzed by standard methods. Starch from each hybrid was extracted by wet processing, followed by freeze-drying to remove moisture. General size distribution, shape, and surface characteristics of isolated starch granules were observed by scanning electron microscopy. Amylose contents were determined by dual-wavelength iodine binding method. High-performance size exclusion chromatography was used to estimate the molecular weights of starch polymers. Thermal properties were analyzed by differential scanning calorimetry. Statistical analyses were performed using JMP software.

Results

- Total starch contents ranged from 37.1 to 40.2% (w/w, d.b.) among the hybrids.

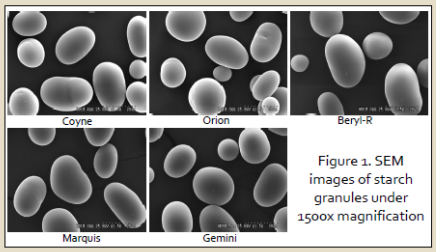

Figure 1. SEM images of starch granules under 1500x magnification

Table 1. Starch polymer compositions

Hybrid	Amylose (%)*	Amylopectin (%)**
Coyne	40.1^{a}	59.9
Orion	38.9^{bc}	61.1
Marquis	37.9^{c}	62.1
Gemini	39.4^{ab}	60.6
Beryl-R	38.7^{abc}	61.3

*Means followed by the same superscript, within the same column are not significantly different ($p > 0.05$).

**By subtraction.

Table 2. Molecular weights of starch polymers detected by high-performance size exclusion chromatography

Hybrid	Molecular weight of Amylose*	Molecular weight of Amylopectin
Coyne	$9.6 \times 10^{5\,a}$	$1.6 \times 10^{8\,a}$
Orion	$9.0 \times 10^{5\,a}$	$1.4 \times 10^{8\,a}$
Marquis	$9.7 \times 10^{5\,a}$	$1.9 \times 10^{8\,a}$
Gemini	$9.7 \times 10^{5\,a}$	$1.7 \times 10^{8\,a}$
Beryl-R	$9.4 \times 10^{5\,a}$	$1.5 \times 10^{8\,a}$

Table 3. Thermal properties of raw starches

DSC parameter \ Hybrid	Beryl-R	Coyne	Gemini	Marquis	Orion
Onset temperature (°C)	69.0^{a}	68.4^{a}	69.5^{a}	69.6^{a}	69.5^{a}
Peak temperature (°C)	78.3^{a}	79.5^{a}	78.7^{a}	78.9^{a}	79.6^{a}
End temperature (°C)	85.3^{a}	86.3^{a}	84.9^{a}	86.3^{a}	86.1^{a}
Range(°C)	16.3^{a}	17.9^{a}	15.3^{a}	16.7^{a}	16.6^{a}
Enthalpy (J/g)	11.0^{bc}	11.2^{abc}	9.7^{c}	12.9^{ab}	13.4^{a}

*Means followed by the same superscript, within the same column are not significantly different ($p > 0.05$).

Discussion & Conclusions

- All five hybrids have similar general size distributions, shapes, and surface characteristics of starch granules.
- The amylose contents of the tested hybrids range from ~38% to 40%.
- There were no significant differences of molecular weights of starch polymers among hybrids.
- The difference in amylose and amylopectin polymer proportions may have an influence on starch thermal properties.
- Significant differences in DSC transition enthalpies were observed among hybrids; Orion being the highest and Gemini being the lowest.

Future Research

- Physicochemical characterizations: % Relative crystallinity and starch granule size distribution.
- Functional properties of bean starch: viscosity (RVA) analysis, enzyme digestibility, and acid hydrolysis.
- Overall influence of starch properties on flour/ingredient functionalities.

Reference

Ratnayake, W. S. and D. S. Jackson (2007). A new insight into the gelatinization process of native starches. Carbohydrate Polymers 67(4): 511-529.

Acknowledgements

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The Food Processing Center

http://fpc.unl.edu/

Applied Research and Engineering

Presentation Number: 192-17

Development of Food Ingredient Mixes with Dry Bean Flour

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Introduction

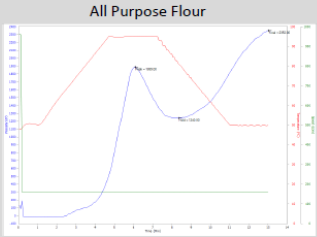
The United States is one of the top global dry bean manufacturers and Nebraska is the third largest producer of dry edible beans in the U.S. Celiac disease affects roughly 1 in every 133 people in the United States, creating a need for gluten-free products. The goal of this research was to create a flour blend using Great Northern beans, starches, and gums that will mimic the functionality of all purpose wheat flour. This study was conducted to investigate the potential of incorporating Great Northern bean flour in food ingredient formulations.

Methods and Materials

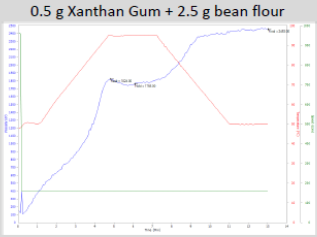
Dry-edible bean flour was prepared by grinding Great Northern bean seeds using a laboratory micro-hammer mill (Polymix/Micro Hammer Cutter Mill, GlenMills, United States) at 3600rpm speed. Samples were analyzed using a rapid visco-analyzer (RVA – 4S, Newport Scientific, Australia) using standard-1 profile. A total of 3 grams of dry sample was mixed with 25 ml of water (adjusted to 14% moisture) before RVA analysis. All purpose four was used for comparison purposes. The Great Northern bean flour was mixed with various amounts of xanthan gum, potato starch, and rice starch in order to adjust viscosity profiles, to obtain comparable profiles to that of all-purpose flour.

Results (RVA viscosity profiles)

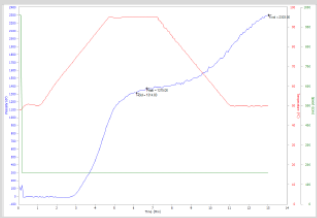
All Purpose Flour



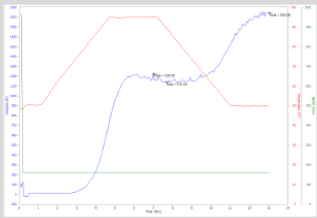
0.5 g Xanthan Gum + 2.5 g bean flour



1.2 g Potato Starch + 1.8 g bean flour



1.5 g Rice Starch + 1.5 g bean flour



Discussion

- The goal was to obtain a viscosity profile comparable to that of all purpose flour, using bean flour and selected additives.
- The xanthan gum/bean flour mixture resulted in a very similar (to all purpose flour) final viscosity, with no breakdown of paste viscosity after the first peak. This is an advantage compared to all purpose flour, in food applications.
- Potato starch & bean flour provided a final viscosity similar to that of all purpose flour. The viscosity profile, however, was not comparable with all purpose flour.
- The rice starch/bean flour, and potato starch/bean flour mixtures showed less breakdown, which would be desired in certain food applications.
- The final viscosity was lowest in rice starch/bean flour mixture.

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Project Title

Incorporating the Use of Nebraska Dry Edible Beans into the Chinese Diet

Project Summary

One of the world's largest producers of dry edible beans does not traditionally consume these beans in their diet. Consequently, in recent years, most of the beans have been exported to countries that have been served by the Nebraska/U.S. dry bean industry. Increased competition from China has decreased Nebraska/U.S. dry bean marketing options. This has led to low/fluctuating prices and an unstable environment that threatens the dry edible bean industry.

This project, "Incorporating the Use of Nebraska Dry Beans into the Chinese Diet," attended to the problem by incorporating the use of dry edible beans into the Chinese diet. The common Chinese diet consists of rice and noodles, and the protein content usually comes from pork or chicken. As the prices of meat have increased, the amount of pork and chicken consumed by a large share of the population has decreased because of the price of these protein sources. Key Chinese government officials are concerned about the lack of protein in the Chinese diet and see it as a problem.

Dry edible beans can serve as a reasonably priced protein-rich replacement, provided Chinese companies have helped incorporate the use of dry edible beans into their products that will be consumed by the general Chinese population.

Ultimately, the purpose of this project was to grow the demand for dry edible beans in the Chinese market, which will lead to improved marketing channels for Nebraska and U.S. dry edible beans. This was accomplished by selecting four Chinese manufacturers who tested methods with which to incorporate dry edible beans into the instant noodle cup formula. Increasing the use of Nebraska dry edible beans into the Chinese diet will improve their health by increasing their protein intake. As a result, some of the Chinese dry edible bean production will be removed from the international marketplace, thus creating new export opportunities for Nebraska dry edible beans.

Project Approach and Goals and Outcomes Achieved

The purpose of this project was accomplished though the identification and selection of Chinese manufacturers who tested methods with which to incorporate dry edible beans into the instant noodle cup formula. Meetings with four major food companies were held to finds ways to include beans into their menu items. Below are the Expected Measurable Outcomes of this project.

Expected Measurable Outcome #1: Set-up Meetings with Chinese Manufacturers and Major Food Companies to Discuss the Inclusion of Dry Edible Beans into Formulas and Menu Items.

The first goal was to set-up one-on-one meetings with Chinese manufacturers and major food companies who attended the Nebraska Dry Edible Bean Conference held in Beijing, in China on August 18, 2011. NDBC choose the companies who attended the August 18th Dry Edible Bean Conference. Those selected were based upon three criteria:

1. The amount of interest the companies have in adding dry edible beans to their products;

2. The compatibilities between the manufacturer and food company systems and UNL's Food Processing Center; and

3. Brand recognition in the Chinese market.

One-on-one meetings with four manufacturing companies and five food companies were held. This goal was measured by surveying the number of manufacturers and companies who agreed to participate in the meetings. A total of 4 manufacturers and companies were selected and agreed to participate in the meetings. This first goal was accomplished.

Expected Measurable Outcome #2: Develop New Methods and New Recipes.

The second goal was to develop methods of incorporating dry edible beans into the instant noodle cup formula and menu items. UNL determined how to process dry edible beans into a functional ingredient that could be incorporated into Chinese food products.

Researchers and UNL Food Processing Center staff members met with the selected Chinese companies via a reverse trade mission to Lincoln, Nebraska, in late June – early July 2012, to discuss their manufacturing processes and menu items and ideas for developing products with dry edible beans. Laboratory experiments were conducted at UNL to teach the Chinese manufacturers how dry edible beans could be incorporated into their food products. The Chinese delegation observed the methods used to prepare the noodles with dry bean flour. They participated in a seminar to learn about Nebraska's dry bean industry, conducted taste tests, and visited grocery stores to observe packaging and marketing techniques. These efforts piqued the delegation's interest in adding flavored dry whole beans to instant noodles and using dry beans as an ingredient for instant noodle seasoning bags. Nebraska's dry bean industry met with key Chinese food manufacturers, including Nissin-Jin Mai Lang, the world's largest instant noodle producer, to discuss technical applications and new market opportunities for U.S. dry bean products. In September 2012, this project was a feature article on USDA's Blog (http://blogs.usda.gov/2012/09/24/fas-helps-pack-protein-punch-across-the-pacific/).

The experiments allowed the delegation to learn how to take advantage of the low-cost, high protein supply of dry beans. The Foreign Agricultural Service's (FAS) Agricultural Trade Office (ATO) in Beijing partnered with the U.S. dry edible bean industry to launch

this program that aims to pack more protein into Chinese diets. Traditionally, China has used dry beans for bean paste or soup, but little else.

In 2013, instant noodles with high dry-edible bean contents were tested using a noodle processing machine that mimics industrial processing conditions. Attempts were made to collaborate with both the Chinese and U.S. instant noodle industry to introduce new, dry-edible bean technologies that would improve the nutritional value of instant noodles. A number of new tests were performed using noodles made of 10, 15, 20, 30, and 60 percent dry bean flour. Five new recipes were developed that used Great Northern bean powder. A taste test panel consisting of Chinese consumers was established. The panel taste tested the noodle samples during a Chinese reverse trade mission held in Nebraska from August 4 – 8, 2013, at UNL's Food Processing Center. The panel consisted of two Chinese noodle company executives, representatives from the FAS ATO office in China, and a student from Northwest A&F University in Shaanxi, China. They sampled the new formulas. Panel feedback was collected and reviewed during the trade mission and it was determined that the recipes would be desirable to Chinese consumers and would meet Chinese customer acceptance and expectations. It was further communicated by the panelists that the Great Northern bean powder, made of up to 20 percent dry bean flower, were comparable or better than the traditional noodles made with 100 percent wheat flour. However, panelists did not approve of noodles containing more than 25 percent bean powder due to noodle quality and cost concerns. This goal was also accomplished.

Expected Measurable Outcome #3: Identify the Number of Manufacturers and Food Companies Who Will Request Samples of Nebraska Dry Edible Beans.

The third goal was to have Chinese manufacturers and food companies request samples of Nebraska dry edible beans. Instead of sending a Nebraska delegation to China, the Chinese companies traveled to Nebraska to attend product demonstrations that utilized Nebraska dry edible beans in food processing. The meetings, discussions, and laboratory and product demonstrations were held at UNL's Food Processing Center August 4 – 8, 2013. Demonstrations were provided to showcase how to prepare, cook, and serve the new dry edible bean recipes. The delegation witnessed the incorporation of dry edible bean powder in varying percentages into dry (instant) noodles, muffins, and brownies. The target was set that four food companies would attend the demonstrations and two manufacturers and two food companies would request samples of dry edible beans from a Nebraska bean processor. Four food companies traveled to Nebraska to attend this event. Nissin Jinmailang Foods Company requested bean powder samples to test on prototype products. Samples were sent in January 2013. It was projected that two of the manufacturers would actually make a future purchase from a Nebraska processor, thus accomplishing this goal of growing the demand for dry

edible beans within the Chinese market. The success of this goal was measured by surveying which manufacturers and food companies requested samples and how many companies will make a purchase from a Nebraska processor.

The participants of the reverse trade mission also toured ConAgra's Flour Milling facilities in Omaha, Nebraska, and the International Spice Company in Fremont, Nebraska. These tours were not paid for with SCBGP funds.

Manufacturers are in the process of making a purchase from a Nebraska processor, but are doing some additional test before they proceed forward.

Three Chinese companies are working on the samples. Once this is complete, the purchasing process will move forward.

Beneficiaries

In 2010, the state ranked first in the production of Great Northern Beans with 186,000 cwt produced, and second for overall dry edible bean production with 1,650,000 cwt. Dry edible bean production in Nebraska is valued at over $70 million annually. While Nebraska producers plant between 140,000 to 200,000 acres of dry edible beans annually, they often deal with a fluctuating market. In 1995, U.S. producers of Great Northern Beans exported 804,323 ctw, compared to 2005 where the amount exported dropped to 370,215 cwt. In 2009, U.S. producers of Great Northern Beans exported 467,083 cwt of beans. Based upon this data and the accomplishments met via this project, several people are impacted. They are listed below.

1. Chinese manufacturers. A number of new tests were performed using noodles made of 10, 15, 20, 30, and 60 percent dry bean flour. Five new recipes were developed that used Great Northern bean powder. Four companies tested methods with which to incorporate dry edible beans into their instant noodle cup formulas. Three companies are working on product samples. Once complete, the purchasing process will commence.

2. Chinese consumers. The Chinese diet will improve through the protein consumption of dry edible bean powder included in the instant noodle cup formulas.

3. Nebraska dry bean processors, U.S. dry bean producing states, and their respective products. An increased demand for dry edible bean s will create new export opportunities for bean producers and processors.

Lessons Learned

Demonstrating the perceived need of dry edible beans and how it can be met was the first step. Once the relationships with the manufacturers were established, recipes were created demonstrating the use of dry edible bean powder. The recipes illustrated the

compatibility of using dry edible bean powder to make instant cup formula noodles. Recipes and research strengthened the relationships and need and were key components of this project that piqued the interest of the manufacturers to look at changing their formulations and ingredients.

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Additional Information

The following presentations, targeting the Chinese food industry, were made based on the results of this project:

1. Ratnayake, W.S. (2012) Incorporating dry-edible beans into convenient foods. Presentation to the reverse trade mission from China. The Food Processing Center, University of Nebraska-Lincoln, Lincoln, July 2.

2. Ratnayake, W.S. (2012) Incorporating dry-edible beans into convenient foods. Presentation to Research & Development team of Nissin-Jinmailang Foods Co, Beijing, China. Aug. 22.

3. Ratnayake, W.S. (2012) Food ingredients and products from dry-edible beans. Sino-U.S. Health and Nutrition Forum, Beijing, China. Aug. 24.

4. Ratnayake, W. S. and Wang, H. 2012. Food ingredients & products from dry-edible beans. Global Food Industry - Food Technology [Submitted for publication].

5. Wang, H., Korte, S., Kerrigan, M., Ratnayake, W. S. and Flores, R. A. 2012. Partial characterization of Great Northern bean starch in: Institute of Food Technologists Annual Meeting: Las Vegas, NV. (Poster No. 192-17).

6. Korte, S. and Ratnayake, W. S. 2012. Development of food ingredient mixes with dry bean flour in: University of Nebraska Research Fair: Lincoln, NE. (April 05).

7. Another manuscript on Great Northern bean starch characterization and functionality is in preparation for publication in the Journal of Agricultural and Food Chemistry (published by American Chemical Society).