Specialty Crop Block Grant Program
FY2012 Final Performance Reports

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Project Title

Farmer's Alternate Crop: Winter Production of Greenhouse Strawberries

Project Summary

Nebraska, the heartland of America, is well known nationally and internationally for its agricultural field crop production during spring, summer, and fall. This is due to abundant sunshine, warm temperatures and plentiful moisture. However, what is not well known is that the sunniest days of the year occur during the winter months when it is cold. 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

As a result, a three-year research study, comprised of three experiments, was conducted which focused on cultivar selection for yield, number, sweetness and phytonutrient value of berries. Using a capillary mat growing system with heat under the benches within a double-layer polyethylene greenhouse, strawberries were grown in the Great Plains Region during the winter. Use of a capillary mat for fertigation to save water and time, heat under the benches and a white reflective plastic on top of the mat resulted in successful flowering and fruiting of 13 cultivars. Economically, for fall 2010- April 2011, we grew 305 plants of 13 cultivars using only 6,500 gallons of water. These plants produced 7,061 berries weighing 157 pounds. In 2011-2012, we grew 299 plants of four select cultivars using only 4,200 gallons of water which produced 9,937 berries weighing 235 pounds. We also calculated that initial construction costs for the greenhouse structure and benching, mats and other equipment will be $22,624-$26,526.

Over the three year-period, a winter crop production schedule and one extension guide for constructing a double poly greenhouse can be found at on our website at http://agronomy.unl.edu/cea.

Thus, despite opinions to the contrary, there is enough natural light coming into a double polyethylene greenhouse during the winter in the Great Plains to successfully grow substantial numbers and mass of strawberries. However, no one cultivar produced the desired combination of highest yield, healthiest and sweetest berries when grown under winter conditions. Issues of labor for harvesting, cost of transportation to market and startup costs were not explored. Thus, this research has set the stage for future technology transfer research focused on cost accounting to determine if winter strawberry production is profitable.

Project Approach

A research study comprised of three experiments was conducted which focused on cultivar selection for yield, number, sweetness and phytonutrient value of berries. Using a capillary mat growing system with heat under the benches within a double-layer polyethylene greenhouse, strawberries were grown in the Great Plains Region during the winter. Additionally, we addressed three issues brought to us as questions by potential growers.

a. Will leaving these stolons on the plant affect the number of strawberries grown? (Removing stolons (runners) is labor intensive.)

b. Can these stolons be rooted for strawberry production so that growers will not have to rely on other producers?

c. Can strawberries be grown using a pre-mixed commercially available medium? (Most start-up growers do not have the soil pasteurization facilities the University has. Thus, for the third and final study we used a commercially available peat-based mix.)

For all three experiments, to determine the quantity and quality of light, soil moisture and ambient temperature, sensors were placed within and external to the potted strawberry plants. Data from the sensors were recorded hourly and stored in the computer via the LabView program. Additionally, water and natural gas usage was initially recorded and at the end of each experiment.

Goals and Outcomes Achieved

Goal #1 - Prototype and test a cost effective and energy efficient system for sustainable CEA winter fruit and vegetable production. With the double polyethylene house, under the bench heating and capillary fertigation system we estimated a farmer could have the house completely set up for $22,624-$26,526. The under the bench heating utilized 329,000 cu. ft. of natural gas each growing season. The fertigation systems used less than 1 bag of fertilizer per year and the water utilized was approximately 4,200 gallons (the last year). This equates to 18 gallons per day, which is approximately equal to the amount of water used daily by one person for flushing the toilet. Given the above information, we feel this is a cost effective growing system for winter production of fruits and vegetables.

Goal 2 - Evaluate fruit quantity, quality, nutritional value and marketability. During the initial screening experiment, all cultivars flowered and fruited under late winter/early spring greenhouse conditions. During this time Albion and AC Wendy plants produced a high number/mass of berries, had the highest sugar content but a lower level of phytonutrients than other cultivars. Tribute berries possessed low sugar and phytonutrient content as well as being one of the lower yielding cultivars. Subsequently, in two eight-month long experiments, it was found that some cultivars fruited more successfully during certain months than others. For example, cultivars of Chandler, Evie-2, Albion, Seascape, Clancy and Darselect plants consistently produced fruit from October to early January while plants from the other cultivars such as Strawberry Festival, AC Wendy and Honeoye mainly produced berries in March and April. Summed over the whole period of experiment 2, Albion, Chandler, Cavendish, Evie-2, Seascape and Portola plants produced the greatest mass of berries. Berries from AC Wendy and Darselect had the highest sugars while berries from Chandler, Strawberry Festival, Seascape and Darselect had the highest phytonutrient values. In the third and final experiment, of the eight selected cultivars, Evie-2, and Portola plants had the highest total yield and average berry mass per plant. Seascape, Chandler and Albion plants were second in total production and had the highest total sugars. Albion also produced the heaviest individual berries. Phytonutrient values varied among cultivars with some having better flavonoids, phenols and/or ant oxidant capacity but no one cultivar had the highest level of all three. Measurement of soluble solid concentration varied by week among the cultivars with Seascape and Albion berries possessing the highest levels. Overall, under these winter greenhouse conditions using capillary mat fertigation and under bench heat delivery system, strawberries were successfully produced for the off-season market.

The experiments involving stolon/runner removal indicated that cultivar type did not influence stolon production. Data were inconclusive as to whether stolon production really affected yield. Thus, data from other experiments is in the process of being reviewed to see if there is a trend.

Goal 3 - Develop a greenhouse crop production plan and guides for use in Nebraska and the Great Plains. Here is the schedule. It and the extension guide can also be found on the website http://agronomy.unl.edu/cea. Videos for construction and other grower-oriented information can also be found on the website.

GREENHOUSE STRAWBERRY
PRODUCTION (WINTER) SCHEDULE*

Month	Activities to Complete
March	Order dormant strawberry crowns (1 per sq. ft) - plan on 10% loss
June	Order pots, soilless mix, fertilizer (1 bag each - 20-10-20; calcium nitrate; 21-7-7), bio fungicide to dip crowns before planting
September (12-20)	Crowns arrive and are potted up; watered in and then placed on wet capillary mat 4 days later start fertilizer – 100 ppm N from 20-10-20 for 4 days then 100 ppm N from calcium nitrate
October 1	Flowering begins Order bumble bees; Temperature 75°F day/65°F night
October 15	First berries are harvested Check pH – if above 7.0 use 21-7-7 at 100 ppm N for 7 days
October 22-December 15	Berry production peaks Stolons removed at least weekly Be sure bumble bees still active; if not reorder Check pH; send leaves for nutrient analysis
December 15	Berry production slows; consider dropping temperature to 70°F day/57°F night Check pH
February 1	Plants starting flower again Bring in bumble bees Check pH
February 15 – April	Peak berry production that should exceed winter production Check pH; send leaves for nutrient analysis
April	High tunnel/greenhouse becoming too warm. Plants can be tossed or moved to the field to produce plantlets for Fall production (note: royalty payments)

*Please see other publications for cultivar performance as not all cultivars work well under winter growing conditions

Beneficiaries

The initial target group was agronomic and produce farmers in Nebraska. This has been expanded to include greenhouse growers, grape growers/wine makers, producers for winter farmer's markets, and nurserymen/plant propagators. Information requests have come from

many parts of the United States (Wisconsin, Colorado, Alabama, Michigan, Iowa, South Dakota and Illinois) and Europe (Great Britain).

Impacts:

1) *The major impact* - based on the research accomplished from this and previously funded strawberry SCBGP grants, the UNL Strawberry Team applied for and received a highly competitive, one-year grant for $110,000 from the National Strawberry Sustainability Initiative. This grant allowed UNL to share their strawberry research with a Nebraska produce grower, Ryan Pekarek, M.S., to determine if winter production of strawberries on a commercial scale was feasible. This was true technology transfer. Monthly postings were made to the website, which included quarterly reports and video clips. Videos for on-site construction and other grower-oriented information all can be found on the website http://agronomy.unl.edu/cea. One research publication for journal publication is currently under review in *HortScience* and one is being revised for *International Journal of Fruit Science* (http://horttech.ashspublications.org/content/23/6/800.abstract).

2) As a result, Dr. Paparozzi received four emails/contacts from Great Plains and Midwest growers who are planning on growing winter strawberries in 2015.

The Project Coordinator presented oral and poster presentations at horticulture and biological systems engineering meetings. Professor Stacy Adams also presented a poster at the annual Great Plains Growers Conference in St. Joseph, Missouri.

A poster was presented at the Great Plains Growers Conference in St. Joseph, Missouri in January 2014 and 2015. It is estimated that 300 people attended the conference each year, which consisted of growers, university personnel, produce companies, and industry-related representatives. The poster was on display for everyone to see. A poster was not presented at the American Society for Horticultural Science (ASHS) meeting because Dr. Paparozzi had the opportunity to publish the project in an international journal.

Hits to UNL's strawberry website well exceeded 1,000. It recorded 1,036 page views, 730 of which were first time visits. The strawberry/cea website logs 150 – 200 hits per month (http://agronomy.unl.edu/cea).

Lessons Learned

Moving a field-grown summer crop into a greenhouse as a winter crop was not the same as moving a winter greenhouse-grown crop outside for the summer. Not only were the plants typically grown in lush field soil, but also the fertilizer recommendations were not directly translatable. The pesticides used were not licensed for greenhouses and of course, there were no clues as to schedules of what to do when. Finally, there were the mystery problems that occurred. As a result the Project Coordinator wrote an article in the *HortTechnology* publication (Paparozzi, Ellen T. "The Challenges of Growing Strawberries in the Greenhouse." HortTechnology Dec. 2013, 23:800-802.)

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Additional Information

Table 1. Mean number of stolons produced by 13 different cultivars or sources in Experiment 1.*These results are from a previous experiment (funded by NDA) which indicated a cultivar difference that needed to be explored.*

Cultivar (source)	Photoperiodic response	Mean number of stolons[z]
AC Wendy	Short day	10.2 ± .49 a
Honeoye	Day neutral	7.8 ± .49 b
Clancy	Short day	7.3 ± .54 bc
Evie	Day neutral	6.7 ± .62 cbd
Cavendish	Short day	6.0 ± .49 cde
Darselect	Short day	5.7 ± .49 de
Seascape (N)	Day neutral	5.0 ± .49 e
Strawberry Festival	Short day	4.3 ± .72 ef
Albion (B)	Day neutral	3.6 ± .49 f
Portola	Day neutral	2.8 ± .76 fg
Albion (A)	Day neutral	1.6 ± .49 gh
Chandler	Short day	0.4 ± .49 hi
Seascape(F)	Day neutral	0.2 ± .49 i

[z]LSMeans with the same letter are not significantly different at P<0.05

Table 2. Mean number of stolons produced on Week 13 of Experiment 2. *These are the cultivars that after 3 years of research consistently gave the biggest and highest number of berries. There was a difference in the average number of stolons produced by 'Chandler' and 'Seascape'. 'Chandler' was eliminated from our recommended cultivar list.*

Cultivar	Stolon number[z]
Chandler	2.2 a
Evie-2	2.0 ab
Albion	1.9 ab
Evie-2+	1.8 bc
Seascape	1.7 bc
Seascape +	1.2 c

[z]LSMeans with the same letter are not significantly different at P<0.05

Table 3. Interaction among cultivars ignoring the presence or absence of stolons on berry weight at Week 13 of Experiment 2. *As indicated above, 'Chandler' produced more stolons and less fruit that the other cultivars.*

	Weight[z] (g)

Cultivar	
Seascape	28.06 ± 4.19 a
Evie-2+	25.26 ± 6.29 ab
Seascape +	16.81 ± 5.74 abc
Evie-2	14.36 ± 4.06 bc
Chandler	3.00 ± 7.03 c

[z]LSMeans with the same letter are not significantly different at P<0.05

Table 4. The effect of presence or absence of stolons by cultivar on berry weight at Week 13 of Experiment 2. *These results were confusing as for the Evie cultivars (Evie-2 and Evie-2+) one did better with the stolons on and one with them removed. We are removing stolons in this year's experiment and will use that information to clarify (we hope) the ambiguity.*

Cultivar	Presence/absence Stolons	Berry weight[z] (g)
Evie-2	Stolons off	22.91 ± 5.74 a
	Stolons on	5.81 ± 5.74 b
Seascape +	Stolons off	17.75 ± 8.12 a
	Stolons on	15.85 ± 8.12 a
Seascape	Stolons off	35.35 ± 6.63 a
	Stolons on	20.78 ± 5.14 a
Evie-2+	Stolons off	11.03 ± 5.14 a
	Stolons on	39.48 ± 11.48 b
Chandler	Stolons off	0.43 ± 11.48 a
	Stolons on	5.57 ± 8.12 a

[z] Tested within CV, LSMeans with the same letter are not significantly different at P<0.05

Table 5. Mean berry weight, total number of berries produced for each cultivar over the entire 10-week harvest period and the total number of flowers removed during the first 5 weeks of Experiment 2. *We tried to delay fruit production by removing flowers. This just did not work and so for this year's experiment we are not removing any flowers and already have marketable fruit (Oct. 21).*

Cultivar	Weight [z] (g)	Number of berries	Number of flowers removed
Seascape	89.53 ± 20.24 a	114	106
Seascape +	50.85 ± 30.02 ab	30	33
Evie- 2	33.22 ± 22.39 ab	31	32
Evie-2+	49.48 ± 21.23 ab	50	140
Chandler	7.33 ± 33.57 bc	8	82

[z]LSMeans with the same letter are not significantly different at P<0.05

Table 6. The total number of stolon meristem tips propagated each week and the rooting rate at end of Experiment 2. *Tip propagation is being used by growers in North Carolina, but not from this system nor in the winter. Still these results, 33% success or less were disappointing. We are considering inviting Dr. Barclay Poling, from NC State to discuss tip propagation from our system.*

Growth week	Number propagated	Number rooted	% rooted
6	11	0	0

7	27	1	3.7
8	75	7	9.3
9	93	29	31.2
10	101	14	13.9
11	111	13	11.7
12	73	17	23.3
13	39	8	20.5
14	19	4	21.1
15	18	2	11.1
16	3	1	33.3
17	1	0	0
18	6	0	0
19	5	0	0
Total	582	96	

Table 7 The total number of stolon meristem tips propagated for each cultivar and rooting percentage at the end of Experiment 2. *Again, this is not a high enough percentage to make it feasible. The bench space is better used for growing fruiting plants.*

Cultivar	Number propagated	Number rooted	% rooted
Evie-2	86	25	29.1
Seascape +	30	4	13.3
Seascape	99	9	9.1
Albion	118	7	5.9
Evie-2+	95	27	28.4
Chandler	154	24	15.6

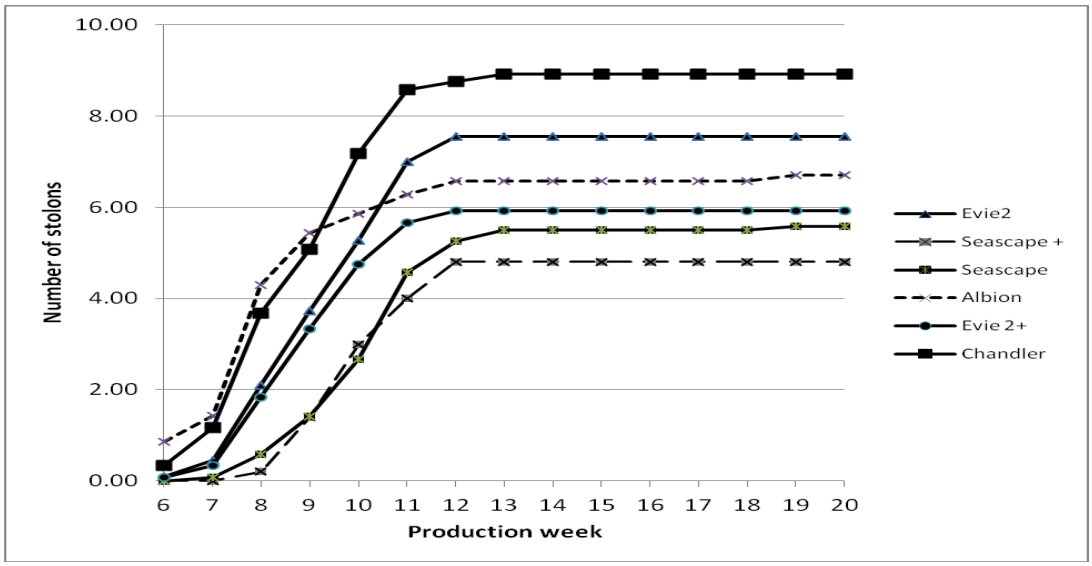

Figure 1. Weekly cumulative number of stolons (average) present per cultivar from Week 6 to Week 20 for Experiment 2. *Dormant crowns are expected to produce some stolons. However, it*

appears that the day neutral cultivars (all except Chandler) are better for winter production as fewer stolons mean less labor needed to remove them.

Project Title

Accelerating Hybrid Hazelnut Commercialization via Mass Production of Seedlings Through Tissue Culture

Project Summary

This project capitalizes and leverages several decades and millions of dollars of research efforts by multiple institutions to develop superior selections of hybrid hazelnuts. Extensive and strong markets for hazelnut products, and powerful environmental and economic benefits would be generated by large-scale production of hybrid hazelnuts. This project worked with three superior selections recently released by the national Hybrid Hazelnut Research Consortium, composed of Oregon State University, Rutgers University, University of Nebraska and the Arbor Day Foundation. To enable large scale, region-wide testing, we worked with Oregon State University to put these three selections into tissue culture and clonally produce 600 plantlets from each selection for distribution to collaborators for widespread field testing under a range of conditions in Nebraska and elsewhere. This accomplishment is a major step forward and a powerful indicator that we are now in the extension and scaling-up phase of hybrid hazelnut commercialization. This investment by the SCBGP has helped set the stage for the full-scale commercialization of hybrid hazelnuts.

Hazelnuts (*Corylus* spp.), also known as filberts, are an important commercial and subsistence crop in many countries. In the USA, 99% of commercial hazelnut production is in the Willamette Valley in Oregon, which produces three percent of the world's hazelnuts. Currently, all commercial hazelnut cultivars come from selections of the European hazel (*Corylus avellana*). However, even though they produce nuts of high quality, large size, and thin shells, this hazelnut species cannot tolerate the climatic conditions of the Midwest or Eastern US, nor is it resistant to Eastern filbert blight (a native disease of hazelnuts common to Eastern and Central US, uniformly fatal to the European hazelnut). On the other hand, American native hazelnut species are cold-tolerant and disease resistant, but nuts produced are small with thick shells, and have little commercial value. In recent years, much interest has been generated for the use of the commercial-quality hybrid hazelnut cultivars, which combine the superior qualities of the European hazel with disease resistance and cold hardiness of the American species. Markets for hybrid hazelnuts include human foods (whole, crushed kernels, high end cooking oils, confections and other value-added products), animal food (high protein mash after oil is pressed out of the kernel), biofuels (hazelnut oil can be produced at twice the volume/acre than can soybean oil, and hazelnut nut oil is chemically superior to soy oil for biodiesel applications) and other uses.

Hazelnuts also are ideal species to integrate into profitable, sustainable, perennial-based woody agricultural or agroforestry production systems, and could become a “third crop” in Midwestern and Great Plains agriculture. As such, it would enhance the competitiveness of individual producers by diversifying their crop and income base and reduce negative environmental impacts. Creating climatically adapted superior hybrids would dramatically enlarge the geographic area where hazelnuts could be produced commercially (from one valley in Oregon to the central and eastern US) and subsequently create new opportunities for thousands of producers in the US

Project Approach

As a result of the individual and combined intense research efforts of several institutions over many decades, three hybrid hazelnut selections (out of tens of thousands of plants) were identified in late 2011 as showing great potential for Midwestern and Great Plains applications. These selections have been proven in Nebraska and New Jersey to be disease-resistant, cold-hardy and heat-tolerant, and produce excellent yields of high quality nuts for multiple markets.

Funds were requested to place these three selections into tissue culture, which requires crafting individual "recipes" to culture each individual genotype of hybrid hazelnut. After considerable investigations and discussions with several universities and private sector companies, it was decided that Dr. Barbara Reed from the National Clonol Germplasm Repository with Oregon State University would implement this component. Oregon State University has experience in this area, specifically with hazelnut tissue culture. They developed the tissue culture protocols for three superior hybrid hazelnut selectin, which included:

1. 'Grand Traverse' (USDA hazelnut collection # COR559.001);
2. OSU 541.147 (The Beast); and
3. NAFD 10-50.

They were also tasked with producing 600 plantlets for each selection, which we will distribute for field testing. We also agreed to establish planting protocols, statistically valid experimental designs and evaluative criteria. Once large enough, we will provide plants to multiple institutions and individuals across the Midwest.

Goals and Outcomes Achieved

The goals for this project were as follows:

1. Successfully establish tissue cultures of three superior hybrid hazelnut selections;
2. Expand the number of clonally produced seedlings of superior selections;
3. Test selections under variable conditions; and
4. Monitor, document and analyze selection performance.

Goal #1: Successfully establish tissue cultures of three superior hybrid hazelnut selections. A contract was signed with Dr. Reed develop the tissue culture protocols for the three superior hybrid hazelnut selections. UNL/NFS, the National Germplasm Repository, and Rutgers University all provided germplasm that eventually enabled placing these genotypes into culture. Tissue culture was successful with all three selections. UNL has taken possession of the tissue cultures and 400 plants from Grand Traverse and OSU 541.147. The remaining plants for these selections are being multiplied and will be sent later this fall or next spring. Culturing NADF 10-50 [a hybrid of multiple species of hazelnut, with issues related to intracellular microorganism contamination] was much more difficult and time consuming to culture, but OSU was eventually successful and multiplication of plantlets is now underway.

They have promised to send both the plantlets and cultures to UNL/NFS next spring (2016). Completion of these deliverables is a tremendous technical accomplishment that sets the stage for widespread regional field testing. The OSU contribution far exceeded the funding supplied, an unexpected contribution by this valuable partner.

Goal #2: Expand the number of clonally produced seedlings of superior selections. OSU has clonally produced 600 seedlings of each selection. Tissue culture was successful with all three selections. UNL has taken possession of the tissue cultures and 400 plants from Grand Traverse and OSU 541.147. The remaining plants for these selections are being multiplied and will be sent later this fall or next spring.

Goal #3: Test selections under variable conditions. Distribute seedlings and planting protocols to willing participants drawn from well-established grower networks was the third goal of this project. Plantlets already received or to be received from OSU must first be grown to adequate size for outplanting, which will take about one year. UNL/NFS has arranged for adequate greenhouse and shade house space to conduct this phase, at no cost to this project. Over this period, we will work with other partners to identify willing collaborators who will outplant and track performance of these clonally produced selections. UNL/NFS will work with these collaborators to ensure plantings are structured properly for statistical analysis.

Goal #4: Monitor, document and analyze selection performance. Once plants are planted by collaborators, we will track performance (with participation by collaborators) and disseminate these results via various NFS publications, electronic media, and via presentations at nut grower and other end user meetings.

Beneficiaries

Beneficiaries of this project include agricultural producers who could diversify their farm enterprises and income sources; rural communities through the addition of increased and diversified farm income and investments in new crops, products and equipment; and nursery companies that would produce large numbers of seedlings of superior selections of hybrid hazelnuts. The positive on and off-site environmental impacts from growing a perennial woody crop include reduced runoff and soil erosion, enhanced water quality, fewer inputs of fertilizers and pesticides, enhanced wildlife habitat (and potential fee hunting income) and increased carbon sequestration. These impacts benefit farm families and residents of rural and urban communities.

Lessons Learned

An important lesson learned is seek out and contract with experts to assist with or complete highly technical, demanding project components those components. This project also ably demonstrates the value in identifying key areas for intervention that, when positively impacted, will substantially accelerate the development of a new crop or product. In this case, providing clonally produced high quality hybrid hazelnut cultivars will, for the first time, provide potential large-scale growers with tested, disease-resistant, highly productive, genetically superior hazelnut plants upon which successful on-farm enterprises can be based.

Several unexpected developments slowed the initial implementation of this project.

1. The severe, unprecedented drought in the Great Plains in 2012 dramatically affected the vigor of hybrid hazelnut selections being grown in Nebraska as stool beds, preventing the collection of germplasm for tissue culture or scionwood of these cultivars.

2. The technician employed by Oregon State Unviersity who was to implement the tissue culture activities moved on to other employment. Given the highly specialized nature of hazelnut tissue culture, it took a while to locate a partner with adequate technical expertise.

3. Hazelnut import quarantines existing in the Pacific Northwest potentially prevents the exchange of materials from the Great Plains to Oregon due Oregon's hazelnut quarantine. Fortunately, by working with the National Clonal Germplasm Repository (NCGR), we had access to their large hybrid hazelnut plant collection, which included Grand Traverse. OSU 541.147, originally developed in New Jersey at Rutgers University, was grown at Oregon State University. OSU established a layer bed in Oregon which provided germplasm for tissue culture, thus avoiding the quarantine issues.

4. NADF 10-50 is a hybrid of multiple species of hazelnut (American, Beaked and European) with more American genetics than the other hybrids being cultured. These hybrids have been difficult to tissue culture (with the few attempts done to date) in the past due to intracellular microorganisms. Explants also grow more slowly and less vigorously. We experienced the same issues in this project, but the expertise at OSU overcame these issues. Future tissue culture of similar hybrids will likely proceed much more easily now that the complex procedures that led to success have been worked out.

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Project Title

Increasing Consumption of Produce among Low-Income Young Adults

Project Summary

Despite two decades of public health initiatives, stricter government dietary guidelines, record growth of farmers' markets and the ease of products like salad in a bag, Americans still aren't eating the recommended number of servings of fruits and vegetables. Children eat fewer servings than adults. Only 26% of the nation's adults eat vegetables three or more times a day. It's less than half of what public health officials had hoped for a decade ago. Worse, it has barely budged since 2000. In Nebraska alone, a study indicated that only 11.48% of adults in southeast Nebraska purchased three cups of vegetables per week. Poor diets and physical inactivity are contributing to the growing obesity epidemic, and these unhealthy eating patterns are transcending down from parents to children. Incorporating fruits and vegetables into consumer diets is the first step in reversing these trends and building healthier, longer lives. It is obvious that simply telling people to eat more fruits and vegetables isn't working. Part of the problem stems from the fact that consumers lack the knowledge as how to properly prepare, cook, and use locally grown produce. This is especially true for low-income WIC participants even when they are provided with the financial benefits to purchase such products. Cooking is often times perceived as some mysterious alchemy with its own brand of spell books. In an effort to address this problem, this pilot project was designed to teach WIC participants how to incorporate local produce into their daily diets.

Project Approach

To accomplish this project, educational cooking demonstrations using locally grown produce were performed at Omaha WIC agencies from 2013 – 2015. WIC participants who attended the demonstrations received a cookbook, tote bag, and a listing of Nebraska farmers' markets. The cookbook contained over 80 recipes using fruits and vegetables commonly found for sale at local Nebraska produce stands. The directory lists over 80 Nebraska farmers' markets, 9 of which are located in Omaha. Over the course of this three-year project, it is believed that WIC participants will increase the use of their federal food dollars at local produce stands, which will benefit growers and the local economy. This project provides locally grown produce to nutritionally at risk, low-income women and children and stimulates the demand for specialty crops. Below are the specific activities performed, goals and outcomes achieved, and lessons learned from this project.

Goals and Outcomes Achieved

The goal of this project was to increase the consumption of locally grown produce among Nebraska WIC participants. Over the course of this three year project, it was anticipated that 90 Charles Drew WIC clients would participate in this project. They would learn how to cook simple meals using locally grown produce. Below were the expected measurable outcomes for this project.

Expected Measurable Outcome #1: Increase the purchases of locally grown specialty crops.

The first goal was to increase the purchases of locally grown fruits and vegetables among Nebraska's WIC population. In 2011, 52% (or $32,913) of all WIC Farmers' Market Nutrition

Program coupons were specifically used by WIC participants to purchase locally grown produce from NDA certified produce stands in the Omaha metropolitan area (benchmark). The target was to increase the use of these coupons to 54% in 2013, 58% in 2014, and 62% in 2015. On a yearly basis, the success of this project would be measured by determining the disposition of all WIC FMNP benefits validly redeemed by authorized farmers (performance measure). Below are the results.

Year 1

The Nebraska Department of Agriculture (NDA) worked with the Douglas County Health Department (DCHD) and the Omaha WIC clinics to distribute WIC FMNP benefits. It was decided early in the year to distribute coupons from the Charles Drew Health Center, Midtown WIC clinic, and the 120th and Dodge clinic in Omaha, Nebraska. This enabled several WIC participants the opportunity to receive WIC FMNP benefits. Each WIC participant was eligible to receive $30 worth of WIC FMNP coupons. The coupons were strictly limited to the purchase of locally grown fresh fruits and vegetables from NDA authorized farm stands. In 2013, 464 vendors were authorized to accept coupons. The Charles Drew Health Center operated a market on Wednesday afternoons in their parking lot from July – September. The intent of the market was to increase the ease of access of local produce to WIC participants and increase coupon use. Every vendor at the market was authorized to accept coupons.

Coupons were disbursed at each clinic beginning July 17, 2013. Nebraska received a federal food allotment of $62,250. However, due to the low redemption numbers from the previous two years, the amount of money released into circulation increased to $99,000.

NDA worked with a clearing bank in Minnesota to handle coupon deposits. At the conclusion of the 2013 season, the coupon redemption rate hit 77% (or $48,234), which was a 25% increase from 2011's rate of 52% and a 32% increase from 2012 redemption levels. Year 1 of this project (2013) was a historic high for Nebraska; it far surpassed its first goal.

Year 2

NDA again worked with DCHD and the Omaha WIC clinics to distribute WIC FMNP benefits. Coupons were distributed at Charles Drew, Midtown, and the 120th and Dodge locations. Each participant was eligible to receive $30 worth of WIC FMNP coupons. Similar to 2013, the coupons were strictly targeted towards the purchase of locally grown fresh fruits and vegetables from NDA authorized farm stands. In 2014, 477 vendors were authorized to accept coupons. A market was again held at the Charles Drew parking lot on Wednesday afternoons, but it was only in operation during the month of July. The intent of the market was to again increase the ease of access of local produce to WIC participants and increase coupon use. Some, if not all, vendors at the market were authorized to accept coupons.

Coupons were disbursed at each clinic beginning June 16, 2014. Nebraska received a federal food allotment of $62,250. The 2013 coupon redemption rate was a great milestone achievement for the program. However, NDA decided to scale back its allotment of coupons in 2014 to prevent a redemption rate exceeding 100%. NDA over issues several coupons every year to account for coupons not used. Unfortunately, this increases NDA's chances of hitting redemption rates exceeding their grant allotment. Consequently, the amount of coupons released into circulation in 2014 amounted to $75,000.

NDA again worked with a clearing bank in Minnesota to handle coupon deposits. At the conclusion of 2014 season, the coupon usage or redemption rate hit a 58.5% redemption rate (or $36,513). This percentage was lower than 2013 numbers, but it did meet the initial goal of a 58% redemption rate for the second year of the project.

Year 3

In 2015, NDA again worked with DCHD and the Omaha WIC clinics to distribute WIC FMNP benefits. Coupons were distributed at Charles Drew, Midtown, and the 120th and Dodge locations. Each participant was eligible to receive only $18 worth of WIC FMNP coupons. The idea was to lower the amount of coupons to each participant so that more could receive benefits. Similar to the previous 2 years, the coupons were strictly targeted towards the purchase of locally grown fresh fruits and vegetables from NDA authorized farm stands. In 2015, 434 vendors were authorized to accept coupons. A market was again held at the Charles Drew parking lot on Wednesday afternoons, from July 22 – August 26. The intent of the market was to again increase the ease of access of local produce to WIC participants and increase coupon use. Some, if not all, vendors at the market were authorized to accept coupons.

Coupons were disbursed at each clinic beginning in June 2015. Nebraska received a federal food allotment of $62,250. The 2013 coupon redemption rate was a great milestone achievement for the program. However, similar to 2014, NDA scaled back its allotment of coupons in 2015 to prevent a redemption rate exceeding 100%. NDA over issues several coupons every year to account for coupons not used. Unfortunately, this increases NDA's chances of hitting redemption rates exceeding their grant allotment. Consequently, the amount of coupons released into circulation in 2015 amounted to $75,000.

NDA again worked with a clearing bank in Minnesota to handle coupon deposits. At the conclusion of 2015 season, the coupon usage or redemption rate was XXXX% (or $XXXX). This percentage was among the lowest in Nebraska's program history. Therefore, it did not meet the initial goal of a 62% redemption rate for the third year of the project.

Expected Measurable Outcome #2: Conduct six educational cooking demonstrations at the Charles Drew Health Center.

The second goal was to set up, coordinate and host educational cooking demonstrations at the Charles Drew Health Center. No benchmark existed. The target was set that 30 WIC participants would attend the cooking demonstrations each year. NDA would hire a local chef to perform the cooking demonstrations using seasonal produce purchased from a local vendor. Produce used in the cooking demonstrations were to be purchased at fair market value from a local farmer. The demonstrations were to be held during the months of July and August. On a yearly basis, the success of this project was measured by determining how many participants attended the cooking demonstrations (performance measure). Below are the results from Year 1.

Year 1

Initially, the plan was to conduct only two, 20 – 30-minute cooking demonstrations at the Charles Drew Health Center during the months of July and August in 2013, 2014, and 2015. Produce used for each demonstration would equate to approximately $30 and would be purchased at fair market value from a local farmer. NDA would hire an individual to translate

the educational material and provide translation services during the demonstration to accommodate the Spanish speaking population. However, after further discussions with DCHD and the Charles Drew Health Center, it was discovered that translation mileage and services were not needed in 2013 since all WIC clients at Charles Drew spoke English. Consequently, NDA redirected as to how some of the project funds were utilized.

In an effort to teach more nutritionally at-risk, low-income young adults how to incorporate specialty crops into their daily diets, the following changes were made to the project.

1. Three demonstrations were held each day instead of one. They began at 1:00, 2:00, and 3:00 p.m. and lasted approximately 30 minutes.

2. In order to increase the attendance at the demonstrations and encourage more clients to patronize local farmers' markets, participants who attended received tote bags containing the *Nebraska Our Best to You* logo. Printed on the bags was the slogan, "Supporting Nebraska's Specialty Crop Industry" and "Funds for this project were provided by the USDA Specialty Crop Block Grant Program through the Nebraska Department of Agriculture."

3. Flyers inviting WIC participants to attend the demonstration were disbursed to WIC participants at all 3 WIC clinics.

4. The translation mileage and services were removed and the chef's flat rate fee was reduced to help accommodate budget modifications. With the decision to conduct more demonstrations over the next two years, the funds were redirected to pay for the tote bags, additional produce, food ingredients, cooking supplies, and utensils potentially needed for the demonstrations. Additional funds were also added to the Indirect Charges cost category to help offset the expenses associated with this project's related activities.

Finding a local chef was a key part of this project's success. An inexperienced chef would have resulted in a poorly executed project. Thankfully, NDA found an experienced, qualified local chef who was very willing to serve as a project partner on a part-time contractual basis. The chef is a culinary professor at Southeast Community College where he teaches numerous culinary, baking, pastry, and management classes. He is a former business owner and a member of the American Culinary Federation. The chef provided his own cooking supplies and ingredients. NDA purchased a wide array of produce from a local vendor at fair market value, all of which were used during the demonstrations. The chef created easy-to-make recipes using local produce. The demos were held on July 17th and August 7th. (August 7th was during National Farmers' Market Week). Listed below are the attendance numbers at each demo with regards to their respective time slots. The number in parentheses indicate the number of WIC participants who attended each session.

July 17th	# of Attendees	August 7th	# of Attendees
1:00 p.m.	8 (5 WIC)	1:00 p.m.	5 (3 WIC)
2:00 p.m.	5 (3 WIC)	2:00 p.m.	0 (0)
3:00 p.m.	7 (4 WIC)	3:00 p.m.	5 (2 WIC)

In an effort to better publicize the results of this project, one of the demonstrations held on July 17th were recorded and posted to the *Nebraska Our Best to You* YouTube Channel at http://www.youtube.com/channel/UCUfhUcNUldN4_hf6attsvww. Additionally, the *Omaha World Herald* published an article following the August 7th demonstration. The article promoted the importance of this project, provided several cooking tips and featured a few recipes from the cookbook. The article can be found at http://www.omaha.com/article/20130814/LIVING/130819631/1696.

Despite the parties who partnered with NDA on this project during Year 1 and the promotion of the demonstrations, the classes were poorly attended. Cumulatively, 30 people attended the cooking demonstrations in Year 1, but only 17 were WIC participants.

Year 2

NDA submitted a letter to USDA to request a budget modification to redirect how some of the grant funds were utilized with regards to this project. NDA modified this budget in June 2013. However, after a lackluster attendance at the cooking demonstrations in 2013, NDA again adjusted its budget to make better use of the grant funds and to reach a larger WIC audience.

As stated above, the chef performed cooking demonstrations at the Charles Drew Health Center on two (2) afternoons in 2013. After further discussions with the Douglas County Health Department earlier in the year, it was suggested that this project be expanded to the Charles Drew Health Center, Midtown WIC clinic, and One World WIC clinic to teach more nutritionally at-risk, low-income young adults how to incorporate specialty crops into their daily diets. As a result, demonstrations were held at each of the three locations in 2014, which increased WIC participation, especially at the One World WIC clinic. As a result of this success, three afternoons of demos were again needed in 2015. Therefore, funds were redirected to support the chef's services and mileage for these days and to pay for additional produce supplies. Funds were also redirected to the Other cost category to accommodate costs associated with printing and copying of promotional materials and use of the Midtown WIC clinic's conference room.

It was suggested that NDA revert back to its original plan to provide translation services, which were needed during the One World WIC clinic cooking demonstrations to accommodate the Spanish speaking population. Funds were needed to pay for translation services and the translator's mileage expenses. NDA's cost categories were adjusted accordingly to accommodate these changes.

Similar to 2013, participants who attended the 2014 demos received tote bags containing the *Nebraska Our Best to You* logo. Printed on the bags was the slogan, "Supporting Nebraska's Specialty Crop Industry" and "Funds for this project were provided by the USDA Specialty Crop Block Grant Program through the Nebraska Department of Agriculture." They also received a list of the farmers' markets located near the Omaha metropolitan area. Flyers inviting WIC

participants to attend the demonstrations were disbursed to WIC participants at all 3 WIC clinics.

NDA worked with the culinary chef they used in 2013 to perform the demonstrations. The chef provided his own cooking supplies and ingredients. NDA purchased a wide array of produce from a local vendor at fair market value, all of which were used during the demonstrations. The chef created easy-to-make recipes using local produce. The demos were held on August 6th, 7th, and September 9th. (The demos in August were performed during National Farmers' Market Week). Three demonstrations were held each day, and they lasted approximately 30 minutes in length. Listed below are the attendance numbers at each demo with regards to their respective time slots. The number in parentheses indicates the number of WIC participants who attended and completed the surveys.

Midtown WIC clinic		One World WIC clinic		Charles Drew Health Center	
August 6th	# of Attendees	August 7th	# of Attendees	Sept. 9th	# of Attendees
12:00 p.m.	6 (6)	2:00 p.m.	32 (12)[1]	1:00 p.m.	4 (4)
1:00 p.m.	2 (2)	3:00 p.m.	5 (4)	2:00 p.m.	0 (0)
2:00 p.m.	5 (4)	4:00 p.m.	6 (6)	3:00 p.m.	7 (6)

Despite the parties who partnered with NDA on this project in 2014 and the promotion of the demonstrations, the classes were poorly attended. The exception was the 2:00 p.m. cooking demonstration held at One World on August 7th. Cumulatively, 67 people attended the 2014 cooking demonstrations, and 44 were WIC participants. NDA had hoped for better attendance, but the project achieved its second goal in 2014.

In an effort to better publicize the results of this project, one of the demonstrations held in August 2014 were recorded and posted to the *Nebraska Our Best to You* YouTube Channel at https://www.youtube.com/watch?v=7-SUMzS2XHY.

Year 3

The third year of the project (2015) was an exact replica of the second year of the project (2014). The chef performed cooking demonstrations at the Charles Drew Health Center on July 28, Midtown WIC clinic on August 5, and One World WIC clinic on August 6. (The demos performed in August were designed to help celebrate National Farmers' Market Week). As a result, demonstrations were held at each of the three locations in 2015, which increased WIC participation, especially at the One World WIC clinic.

Grant funds were used to pay the Midtown room reservation and translation services at the One World WIC clinic.

Similar to the first two years of the grant, participants who attended the 2015 demos received tote bags containing the *Nebraska Our Best to You* logo. Printed on the bags was the slogan,

[1] A total of 32 WIC participants attended the demo, which consisted of 17 adults and 15 children. Only 12 surveys were completed.

"Supporting Nebraska's Specialty Crop Industry" and "Funds for this project were provided by the USDA Specialty Crop Block Grant Program through the Nebraska Department of Agriculture." They also received a list of the farmers' markets located near the Omaha metropolitan area. Flyers inviting WIC participants to attend the demonstrations were disbursed to WIC participants at all 3 WIC clinics.

NDA again worked with the same culinary chef to perform the demonstrations. He provided his own cooking supplies and ingredients. NDA purchased a wide array of produce from a local vendor at fair market value, all of which were used during the demonstrations. The chef created easy-to-make recipes using local produce. Three demonstrations were held each day, and they lasted approximately 30 minutes in length. Listed below is the number of WIC participants at each demo with regards to the respective time slots.

Charles Drew Health		Midtown WIC clinic		One World WIC clinic	
July 28th	# of Attendees	August 5th	# of Attendees	Aug.6th	# of Attendees
1:00 p.m.	7	1:00 p.m.	2	2:00 p.m.	6
2:00 p.m.	1	2:00 p.m.	3	3:00 p.m.	6
3:00 p.m.	2	3:00 p.m.	3	4:00 p.m.	6

Despite the parties who partnered with NDA on this project in 2015 and the promotion of the demonstrations, the classes were poorly attended. Cumulatively, 36 people attended the 2015 cooking demonstrations, all of whom were WIC participants. NDA had hoped for better attendance.

In an effort to better publicize the results of this project, two of the demonstrations held in 2015 were recorded and posted to the *Nebraska Our Best to You* YouTube Channel at https://www.youtube.com/channel/UCUfhUcNUldN4_hf6attsvww.

Expected Measurable Outcome #3. Provide WIC participants with a compatible resource that will assist in increasing the consumption of locally grown produce into the daily diets of WIC participants.

The third goal was to provide WIC participants with cookbooks that contain over 80 recipes that included fruits and vegetables as essential recipe ingredients. No benchmark existed. The recipes in the cookbook provided an opportunity for WIC participants to prepare meals that contained a medley of flavors and textures all the while promoting good health for family diets. The recipes were designed to be both tasty and healthy when eaten with the recommended serving sizes. The target was to provide this resource to approximately 90 participants who attended the cooking demonstrations. At each demonstration, pre- and post-surveys were to be provided to attendees. Surveys were to be used to determine if the cookbooks and demonstrations would increase the incorporation of fruits and vegetables into their daily diets. The success of this goal would be measured by the results of the surveys. It was anticipated that the post surveys would show that 30% of the participants will pledge to increase their intake of fruits and/or vegetables by 2 servings per month, which is equivalent to approximately 2 cups of raw vegetables (performance measure). It was believed that the cooking demonstrations and cookbooks would increase the purchases and consumption of locally grown specialty crops. Poor diets contribute to the growing obesity epidemic and increasing the consumption of fresh fruits and vegetables is a key strategy in reversing these trends. Below are the results from the project.

Year 1

NDA met with DCHD and the Charles Drew Health Center on August 20, 2013, to discuss ways to increase attendance in 2014 and 2015. NDA laid out the goals of this project and the resources WIC participants would receive for attending the cooking demonstrations. During these discussions, it was recommended that NDA alter their budget and provide tote bags to WIC participants to accompany their cookbooks. Adjustments were made to the budget and 500 blue tote bags were ordered sporting the *Nebraska Our Best to You* logo with the slogan, "Supporting Nebraska's Specialty Crop Industry" and "Funds for this project were provided by the USDA Specialty Crop Block Grant Program through the Nebraska Department of Agriculture."

Each WIC participant received a copy of the *2013 Nebraska Farmers' Market Directory*, which lists over 80 farmers' markets in Nebraska, 9 of which are located in the Omaha metropolitan area. Immediately following the cooking demonstrations, WIC participants were able to patronize the farmers' market held just outside the WIC unit from where the demonstrations were held. Their tote bags became great carrying cases for the produce they purchased with their WIC FMNP coupons. The cookbooks provided recipes for commonly grown products they now know how to prepare and use. For example, the chef cooked and prepared beets for the participants, and he talked about the different ways beets could be incorporated into a meal. The cookbook included two beet recipes for the participants to prepare at home. Products purchased for the July 17th demonstration included sweet corn, beans, tomatoes, squash, beets, sweet peas, onions, and zucchini. Products purchased for the August 7th demonstration included kale, beets, squash, cabbage, kale, zucchini, oregano, and squash.

It is believed that the cooking demonstrations, tote bags, directories, and cookbooks increased the purchases and consumption of locally grown specialty crops. The results were quantified by scoring the pre-surveys against the post-surveys. The pre-surveys were handed out prior to the start of the demonstrations; the post-surveys were disbursed at the end. The post surveys revealed that 94% of the WIC participants who attended the demonstrations and received the free materials pledged to increase their intake of fruits and/or vegetables by 2 servings per month. It was originally anticipated that only 30% of the WIC participants would increase their intake of produce by 2 servings per month. Therefore, this project far exceeded its goal in the first year.

WIC FMNP coupon redemption rates have been sluggish during the peak harvest seasons since NDA began administering this federally funded program in 2011. During the months of July and August, cumulative levels equaled $12,732 and $14,409 in 2011 and 2012, respectively. However, 2013 levels during this same time period soared to $22,593. That's a $177% increase compared to 2011 levels and 156% increase from 2012. NDA believes this higher-than-normal redemption rate is partially due in part to this project.

Year 2

As stated above, a meeting between NDA and DCHD were held in the spring of 2014. Budget adjustments were made to pay for additional cooking demonstrations, the chef's services and mileage for these days, translation services and mileage, additional produce supplies, promotional flyers, and conference room rental.

Most of the WIC participants at the One World WIC clinic speak Spanish as their primary language. Consequently, NDA ordered 60 cookbooks that were in Spanish. The pre- and post-surveys were also translated into Spanish.

Each WIC participant received a flyer listing 9 farmers' markets in the Omaha metropolitan area. They also received a tote bag and a cookbook identical to those handed out in 2013. During the demos, the chef cooked and prepared meals that are easy to make and primarily consisted of local produce. Products purchased for the August demos included sweet corn, leeks, potatoes, green beans, peppers, tomatoes, onions, cucumbers and zucchini. Items for the September demos consisted of green beans, tomatoes, cantaloupe, cucumbers, zucchini, kohl rabi, squash, cabbage apples, peppers, onions, and potatoes. The produce purchased for the demos in August and September differed slightly since some of the products did not ripen to full maturity until late August/early September. WIC participants at all of the sessions were strongly encouraged and told to complete the pre- and post-surveys. However, some were reluctant to do so despite our requests. WIC staff members asked if they could attend the demonstrations. They were allowed to do so long as space was available.

It is believed that the cooking demonstrations, tote bags, locations of Omaha farmers' markets, and cookbooks increased the purchases and consumption of locally grown specialty crops. The results were quantified by scoring the pre-surveys against the post-surveys. The pre-surveys were handed out prior to the start of the demonstrations; the post-surveys were disbursed at the end. The post surveys revealed that 95% of the WIC participants who attended the demonstrations and received the free materials pledged to increase their intake of fruits and/or vegetables by 2 servings per month. It was originally anticipated that only 30% of the WIC participants would increase their intake of produce by 2 servings per month. Therefore, this project far exceeded its second goal in 2014.

In terms of WIC FMNP redemption rates during the time the demonstrations were held, the numbers remained lower compared to 2011 and 2013, but higher than the 2012 levels. The WIC FMNP redemption cumulative levels at the end of September equaled $21,567 and $9,318 in 2011 and 2012, respectively. The levels rebounded to $19,179 in 2013, but then relapsed to $15,693 in 2014.

Year 3

As in 2014, each WIC participant received a flyer listing 9 farmers' markets in the Omaha metropolitan area. They also received a tote bag and a cookbook. The chef cooked and prepared meals that are easy to make and primarily consisted of local produce. Products purchased for the demonstrations in 2015 included sweet corn, bell peppers, cucumbers, green beans, potatoes, onions, cabbage, zucchini, tomatoes, jalepeno peppers, beets, leeks, yellow squash, peaches, and sweet potatoes.

It is believed that the cooking demonstrations, tote bags, locations of Omaha farmers' markets, and cookbooks increased the purchases and consumption of locally grown specialty crops. The results were quantified by scoring the pre-surveys against the post-surveys. The pre-surveys were handed out prior to the start of the demonstrations; the post-surveys were disbursed at the end. The post surveys revealed that 88% of the WIC participants who attended the demonstrations and received the free materials pledged to increase their intake of fruits and/or vegetables by 2 servings per month. It was originally anticipated that only 30% of the WIC

participants would increase their intake of produce by 2 servings per month. Therefore, this project far exceeded its second goal in 2015.

In terms of WIC FMNP redemption rates during the time the demonstrations were held, the numbers remained very low compared to previous program years. The WIC FMNP redemption cumulative levels at the end of July and August equaled $2,265 and $6,525, respectively. With the exception of July 2011, these numbers were the lowest monthly coupon redemption totals Nebraska has ever experienced. .

By the time the project concluded, tote bags, cookbooks, and farmers' market locations had been disbursed to 97 WIC participants. The target was to provide these resources to approximately 90 WIC participants, 30% of whom would pledge to increase their intake of fruits and vegetables by 2 servings per month. Based upon the attendance numbers, coupon redemption levels, and survey results over the three years of this project, this project ultimately accomplished its goal.

Beneficiaries

This project had an impact on Nebraska's fruit and vegetable industry and the low-income population who currently receive assistance under the Special Supplemental Nutrition Program for the Women, Infants, and Children Program. A large number of Nebraska's produce operations are located in the eastern portion of the state, many of whom sell in or near the metropolitan cities. This provided consumers with easy access to fresh, nutritious locally grown produce while allowing produce farmers the ability to establish a large customer base to increase profit margins. Higher profit margins and increased profitability results in sustainable farms. There are 9 farmers' markets and 23 growers located in Omaha who are vendors certified to accept WIC FMNP benefits. During the market season, growers travel from several miles away to sell in Omaha. For example, on Wednesdays afternoons. the Charles Drew Health Center hosts a farmers' market in their parking lot. This provides WIC participants with easy access to specialty crops.

Omaha has the heaviest concentration of WIC participants in Nebraska. Therefore, the cooking demonstrations were strongly promoted at the Omaha WIC clinics. WIC participants who attended the demos were exposed to several, easy to prepare, recipes using locally grown produce, thus increasing the consumption of produce in their daily diets. The cooking demonstrations at the One World WIC clinic included a Spanish interpreter and cookbooks (in Spanish) in order to cater to clientele of different nationalities. The demonstrations, tote bags, cookbooks, and *Farmers' Market Directories* were designed to increase the purchases and consumption of locally grown specialty crops.

Lessons Learned

Expanding the demonstrations into two additional WIC clinics did increase the overall attendance at the demos and allowed the project to reach more WIC participants. However, despite the promotional efforts by the Omaha WIC clinics and the Douglas County Health Department, attendance at each session was still lower than NDA had hoped. However, despite the poor attendance, NDA still believes that the project was a success.

Contact Information

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Project Title

Japanese Beetle Survey

Project Summary

The goal of this project is 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.

As of September 30, 2014, Nebraska Department of Agriculture (NDA) Entomology staff had recorded over 731 hours and has driven over 14,281 miles to meet the goals of this project.

Project Approach

2013

Soil sampling was conducted in March 2013, 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 which included: level of infestation, nursery production methods, and the potential to ship nursery stock out of Nebraska. A total five firms with fields in five counties were surveyed. No Japanese beetle grubs were found.

In 2013, a total of 183 JB traps were set in 34 non-infested counties catching over 295 beetles. Forty-seven traps were set in five of the known infested counties, catching 21,837 beetles. Traps were located at airports, state parks, special quarantine compliance areas, and nursery dealers and growers. 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, Box Butte, Burt, Cheyenne, Custer, Dawson, Dodge, Gage, Holt, Lancaster, Lincoln, Madison, Merrick, Platte, Phelps, Polk, Sarpy, Saunders, Seward, Scotts Bluff, Thayer, Wayne, and York counties.

After the 2013 trapping season, NDA declared seven more counties as being infested with JB, Adams, Gage, Dawson, Lincoln, Seward, Thayer, and York. Prior to 2013, Buffalo, Cass, Dakota, Dodge, Douglas, Hall, Hamilton, Lancaster, Saline, Sarpy, Saunders, and Washington were already listed as infested.

Firms in known infested areas that wished to ship interstate or internationally may request to have their nursery stock certified, based on the application of specific chemicals, trapping data, or bareroot material. Prior to the phyto being issued, NDA inspectors are required verify the method of certification. NDA has issued seven state and federal phytos to facilitate the movement of nursery stock interstate and internationally, certifying 8,196 individual plants as meeting the Japanese Beetle requirements of the receiving state or country.

In 2013 NDA entered into eight compliance agreements at five different 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, monitor treatments, and oversee the firms, and will terminate the agreements if used improperly. In 2013 compliance agreements allowed 747 shipments with over 69,917 plants to be shipped interstate.

2014

Beginning in May, 2014, Nebraska Department of Agriculture (NDA) field staff were assigned to set, monitor and retrieve 247 traps in 47 counties at nurseries focusing on high-volume importers, as well as firms shipping interstate and internationally. Traps were required to remain in place until at least October 1, 2014. NDA field staff is finishing the collection of these traps now, and will begin compiling results as soon as all traps are down.
Soil sampling was conducted in May, 2014, 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 155 soil samples were collected over 40 acres, for 2 firms in three counties. No Japanese beetle grubs were found.

In 2014 NDA entered into eight compliance agreements at five different 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 monitor treatments. NDA also oversees the firms and will terminate the agreements if used improperly.
Firms in known infested areas that wished to ship interstate or internationally may request to have their nursery stock certified based on the application of specific chemicals, trapping data, or bareroot material. Prior to the phyto being issued, NDA inspectors are required verify the method of certification. NDA has issued seven state and federal phytos to facilitate the movement of nursery stock interstate and internationally, certifying 2,406 individual plants as meeting the Japanese Beetle requirements of the receiving state or country.

Goals and Outcomes Achieved

Measurable outcomes for this project include: 1) disseminating survey information in the Nebraska Department of Agriculture (NDA) Entomology Program Annual Report; 2) incorporating project results on the NDA website; 3) inclusion of survey results on the NDA Entomology Program display booth at Nebraska Great Plains Conference; and 4) submission of relevant articles to the Nebraska Nursery and Landscape Association (NNLA) newsletter. Each of these objectives either has been met, or is on track to be met.

Information on NDA Japanese Beetle Survey activities was disseminated at the Nebraska Great Plains Conference in Lincoln, February 2013. This included information on the 2012 survey

results, historical finds, and updates on new infested counties. Information on how to request a site to be surveyed was available at this event, along with information on interstate and international shipping and receiving requirements. This event had 800 registered attendees from the nursery, landscape and forestry industries.

Project results were updated on the NDA website at the conclusion of the 2012 trapping season. An article was also submitted to the NNLA newsletter for Spring 2013. Additional outreach was conducted at: the Governor's Ag Conference, held February 2013, with 200 attendees; the Great Plains NNLA/NAA Summer Field Day, August 2013, with approximate attendance of 75 individuals from the nursery and arborist industries; and the Nebraska State Fair, August, 2013, with attendance of 335,000 individuals.

The State Fair 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.
We also printed 1,500 copies of Japanese beetle outreach materials and disseminated them to extension offices in infested counties. These items were to be shared with concerned individuals in their county.

Beneficiaries

All of the nursery stock distributors in our state benefit from this survey. It helps Nebraska maintain its category two status under the Japanese Beetle Harmonization plan, which requires nursery stock being brought into the state to be free of Japanese beetle. It also assists with the tracking of this pest across the state. Early detection of Japanese beetle populations will allow Nebraska nurseries, sod farms, and other plant producers to implement best management practices, to mitigate the damage caused by this plant pest and reduce disruptions in their ability to market their product.

Six firms in Nebraska have either used trapping or another certification method to ship nursery stock out of the state during this time frame. Five firms used compliance agreements to ship products on a regular basis. This allowed 747 shipments with over 69,917 plants to be shipped interstate. NDA has also issued seven state and federal phytos where no compliance agreement was in place to facilitate the movement of nursery stock interstate and internationally, certifying 2,406 individual plants as meeting the Japanese Beetle requirements of the receiving state or country. Additionally, all firms in counties determined to be non-infested based on survey are generally able to ship without needing additional certifications, beyond their nursery license.

Lessons Learned

While Japanese beetle has become established in parts of the state, we can still mitigate trade implications for Nebraska producers through the continuation of this project. Communication with industry on the distribution of Japanese beetle in the state, and how that may impact shipping requirements is vital, to ensure the ability of industry to move product. Educating industry on these requirements and the various means of meeting them, is ongoing.

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Project Title

Sunflower Rust: A Rapidly Emerging Threat to Confection Sunflower Producers in Nebraska

Project Summary

Sunflowers are a well-adapted crop for Nebraska and other areas of the Central High Plains. They also fit well in many production systems as an alternative crop in dryland wheat rotations. Sunflowers are also being increasingly used to lengthen the traditional irrigated rotations of dry beans, corn and sugar beets. Sunflower acreage for Nebraska has been on a roller-coaster ride over the last decade. About 5 years ago, acreage had expanded to 100,000 but had dropped to approximately one-half of that by 2009. During 2010 and 2011 acreage was up to 65,000, a 25% increase over 2009. Production has remained at approximately 50,000 acres over the last two years.

Based on these general trends for increased production in the state, a comprehensive three-year disease survey was conducted between 2009-2011 to determine the most commonly occurring pathogens of sunflower along with their distribution and incidence. More than 100 fields from all production regions of Nebraska were monitored, and it was determined that rust, caused by the fungus, *Puccinia helianthi*, was the most prevalent disease observed (present in more than 90 of surveyed fields). Similar observations have recently been noted from North Dakota suggesting that rust is dramatically increasing in both severity and incidence, but we are unsure why these trends are being observed.

Due to the apparent increase in rust incidence, the severity within Nebraska production, and the lack of resistance in any commercial confectionary hybrids, fungicide treatments are virtually the only option for producers. Prior studies in Scottsbluff, Nebraska over the last three years have brought to light the most effective crop growth stage for treating with fungicides, R5 – reproductive stage 5. Unfortunately, very few products are currently labeled and registered for rust management in sunflowers. Therefore, the overall goal of this study was to test and identify the most effective registered fungicides and compare with them several others that have not been registered or evaluated.

Project Approach

In 2013, the plots were initially planted on May 18. However, we had numerous emergence problems due to cool wet soils, and the plots were not replanted until June 27. Plots in 2014 were planted on June 4. For both planting years, practices were the same. They consisted of Sonalan applications at 6.5 lb/a as a pre-plant, and incorporated as a herbicide. Plots consisted of 4 rows, 25 ft in length on 30 inch row spacing. Furthermore, the study in both planting years employed one variety (Dahlgren 9592CL) and 8 treatments (7 fungicides and an untreated control) with 4 replications per treatment in a randomized block design. The fungicides that were utilized consisted of commercially available labeled and unlabeled products for comparison of varying modes of action, including strobilurins (Quadris, Headline, Aproach), triazoles (Folicure, Proline), carboxamides (Vertisan), and one with both a carboxamide and a strobilurin (Priaxor).

The plants were inoculated in mid-August in both 2013 and 2014 at the R5 growth stage by spraying all 4 rows with a backpack sprayer. We used a water suspension consisting of 326,000 and 160,000 urediniospores per ml respectively. Immediately afterward, a misting system was

activated that watered heads and upper leaves continuously for 48 hours. Plots were then watered every other day normally with sprinkler irrigation.

The fungicide treatments were then sprayed 7-10 days after inoculation at the labeled rate, August 28, 2013 (see Table 1) and August 20, 2014 (see Table 2). Disease severity was assessed with three separate sampling periods each year in mid- to late-September and early- to mid-October. Ten leaves were collected per plot per sampling date (a total of 30 leaves per plot), and then brought into the lab where they were scored with a 0-8 scale based on the estimated percentage of leaf area that was covered with rust lesions.

Plots were harvested by hand in mid-October, and allowed to completely dry in burlap bags. Heads were then combined individually and data was collected consisting of seed size and density (lbs./bu.) and total seed yields (lbs./acre).

Goals and Outcomes Achieved

Our purpose for conducting this study was to further evaluate the currently labeled fungicides for sunflower rust and their effectiveness in improving yields and reducing disease levels. We have now successfully completed two years of field work using the same set of fungicides in both years for the sake of consistency. We have additionally accumulated some valuable data that should benefit any sunflower grower in Nebraska. This information could also be translated to anywhere in the U.S. where sunflowers are grown.

Although the two years were quite different in regards to environmental and production problems, we observed surprisingly similar trends and results between them (see Tables 1 and 2). Few differences were seen among the different fungicide treatments in terms of the seed size for both years. However Priaxor treatments resulted in slightly higher seed size than Folicur in 2013 and Vertisan in 2014. In terms of seed yields (lbs. per acre), no overall statistical differences among treatments were observed in 2013, but Quadris applications produced the higher yields (300-400 lbs per acre over the other products). In 2014 Quadris, Headline, and Priaxor all produced significantly higher total yields compared to the control and two other fungicide treatments (Folicur and Vertisan).

We saw more definitive results and better mean separation between fungicide treatments with the disease severity ratings. Due to more favorable environmental conditions in 2014, disease was much more severe than in 2013. This is readily seen with the cumulative disease ratings for the control treatment - 5.1 in 2013 and 13.1 in 2014 (see Tables 1 and 2). The inclusion of Quadris, Proline, Priaxor, and Headline all resulted in significantly lower disease levels compared with the untreated control in 2014 with similar trends occurring in 2013. Inexplicably, Folicur applications resulted in very good disease suppression in 2014, but this did not translate to improved yields. This was not the case in 2013, as it was among the poorer treatments in regards to yield.

The lowering of disease levels is an important point to emphasize. With rust diseases, reduction in disease severity can often be a critical component of disease control, even if yield differences are not seen. Reducing overall disease incidence and severity, will also reduce the potential inoculum carryover and pathogen survival. Higher levels of disease tends to increase the potential for greater infection by serving as a new source of infection the following season if sunflowers are planted near the same field. We have previously demonstrated that the sunflower rust pathogen can, and does, overwinter in western Nebraska. This is unlike most other rust diseases that we may encounter (dry bean, wheat), that generally arrive in Nebraska

on southerly winds from Texas or Mexico. Therefore any treatment that reduces disease levels, would be beneficial to growers by also reducing populations of the pathogen that can survive over the winter, which in turn causes earlier infections the following spring.

Table 1: ***Yield and Disease Data Collected from 2013 NDA Sunflower Rust Study***

	Treatment	Disease Severity (Cumulative of 3 Ratings 0-8)	Seed Size (lb/bu)	Seed Yield (lb/a)
1	Control - No spray	5.1 a	17.3 ab	1469.4
2	Folicur - 6 fl oz/A	4.5 ab	17.0 b	1527.5
3	Headline - 12 fl oz/A	3.3 c	17.9 ab	1440.4
4	Vertisan - 30 fl oz/A	4.5 ab	17.4 ab	1585.6
5	Quadris - 15.5 fl oz/A	3.0 c	17.7 ab	1817.9
6	Proline - 5.7 fl oz/A	2.6 c	17.6 ab	1452.0
7	Priaxor - 8.0 fl oz/A	3.6 bc	18.2 a	1411.3
8	Aproach - 12 fl oz/A	4.7 ab	17.5 ab	1759.8
	LSD (0.05)	0.92	0.59	333.2

Means in Columns two and three followed by the same letter are not significantly different.

Table 2: ***Yield and Disease Data Collected from 2014 NDA Sunflower Rust Study***

	Treatment	Disease Severity (Cumulative of 3 Ratings 0-8)	Seed Size (lb/bu)	Seed Yield (lb/a)
1	Control - No spray	13.1 a	38.9 ab	1768.2 b
2	Folicur - 6 fl oz/A	7.6 d	39.1 ab	1790.8 b

3	Headline - 12 fl oz/A	9.9 bc	39.3 ab	2156.2 a
4	Vertisan - 30 fl oz/A	11.3 ab	38.2 b	1793.4 b
5	Quadris - 15.5 fl oz/A	8.0 cd	38.6 ab	2048.4 ab
6	Proline - 5.7 fl oz/A	8.2 cd	39.5 a	1943.5 ab
7	Priaxor - 8.0 fl oz/A	10.8 b	39.5 a	2039.3 ab
8	Aproach - 12 fl oz/A	11.1 ab	39.1 ab	1974.7 ab
	LSD (0.05)	2.3	1.2	324.3

Beneficiaries

As previously stated, our findings are consistent with some preliminary work done 4 to 5 years ago. These similar findings from the last two years lend credence to the fact that these results are accurate due to the repeatability of the data from the studies over several years. This information will be of benefit to any grower in Nebraska, particularly since we have previously determined that rust is the most widespread, commonly occurring disease in the state.

This information will also enhance the results from other sunflower-growing states. We have collaborated with pathologists in North Dakota and South Dakota and have attained very similar results among the three states over the last five years. Thus our findings from this study will impact the more than 2 million acres of sunflowers grown in the U.S., thereby benefiting more than an estimated 1,000 growers in the U.S.

Lessons Learned

The study in 2013 was replanted late, effectively delaying the growth of the crop to the point that weather conditions were not ideal during the infection and disease initiation process. Most years would have seen us inoculating in mid-July, but we were approximately three weeks later in performing this task. The delay in planting also caused lower than expected yields and seed size due to the shortened growing season. We were fortunate to receive an extended fall, allowing the crop to reach full maturity, and obtain some yield results.

Rust diseases require cool and moist conditions for optimal infection and disease development. We had these conditions for much of the 2013 season. However the period of time during and following inoculation was hotter and much drier. This likely influenced (by decreasing) the disease severity. But we still were still able to induce enough disease to observe some treatment differences with the fungicides. This was due to our misting irrigation technique after inoculation. The weather during the 2014 season was more conducive for rust disease development as easily illustrated by the higher disease ratings compared to 2013 (see Tables 1 and 2).

All these factors illustrate the reasons that field research is often so difficult to consistently reproduce results, and why we requested multiple years for conducting this study. Nevertheless, we did still see some very positive results that are consistent among different

growing seasons. Out take-home message is that the fungicides Quadris, Headline, Priaxor, and Proline appear to produce better disease control, with Quadris and Headline inducing higher yields. We have previously determined the best time to make the fungicide applications (R5 growth stage), but were unsure of the most effective fungicides for use. This new study has additionally allowed us to continue to test new and promising products such as Priaxor, which was not available from prior studies.

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Project Title

Establishment of a Nebraska Potato Psyllid Monitoring Network

Project Summary

Potato Psyllids are an insect pest causing psyllid yellows disease, rendering the affected plant and its tubers nonproductive. Psyllids also transmit the plant pathogen Liberibacter, which is consistently associated with the Zebra Chip (ZC) disease. Millions of dollars in damage to the potato crops have been attributed to ZC, and Texas, Nebraska, Colorado, and Wyoming are under scrutiny because of the historical pest pressure in this region. Nebraska may get heightened psyllid pressure in 1 to 3 years. The competitiveness of this crop could be damaged if severely affected fresh or processed potatoes were shipped out. However, the damage can be avoided with intense protection.

Recognizing the value of protecting the Nebraska potato industry from this pest, the Potato Certification Association of Nebraska (PCAN) coordinated a regional network. More tools are being developed to better manage psyllids, with the monitoring network being the most important.

To gain cooperation and have access to the information generated from the trapping network, grower groups were equipped and trained to replace, maintain and improve recent efforts. Tools and control methods needed to be evaluated early to determine their long term usefulness.

Preseason conditions and warning systems were defined, established, and coordinated through grower communication and cooperation. Preseason conditions and warning systems have been considered and gleaned. Some are being used and some still need to be defined or refined as described below.

Project Approach

In order to build useful data/information from the new trapping network, the growers were supplied with disposables and also equipped to replace, maintain and improve recent efforts.

New tool development and new chemistries will need to be evaluated as soon as available for evaluation early on in order to determine long term usefulness and need. Preseason warning systems have been partially defined but need further refinement through grower communication and cooperation. PCAN has been, and will be, testing new methods for detection of the insect and pathogen as they become available.

Growers need chemistries tested on a production scale so that they are best equipped to perform the testing. Through all the collaborative efforts in sample collection and meeting at the identifiers' offices and various other places, communication among growers is rampant. Identifying chemistries on reports has also been useful as well as verbal reporting at grower meetings. Through this cooperation and public promotion, information can best be funneled into a well-thought out IPM program for control of the pest and the diseases it causes. This cooperative effort by very innovative growers in a fairly broad geographical region has stimulated collaborative efforts among growers and others with more specialized areas of expertise.

This clearly will be an ongoing effort for the foreseeable future.

Early exploratory work on monitoring intensity and methods done by PCAN and growers on their own have been adopted and used. All methods and materials continue to undergo refinement as innovation allows and is appropriate. Uniformity in data accumulation and correlation as well as usability and practicality are stressed. Use of logistical and financial information and the experience generated from previous years the adjusted protocols met the grower's needs, while allowing for improvement of methodology as it became available during this project.

An organizational meeting was hosted by PCAN personnel with all involved parties in February 2013. This meeting was used to report findings the year before in Nebraska as well as findings in the expanded region covering north and northeast Colorado, eastern Wyoming, and part of Kansas. Interest was very high. Workload, expectations and information reporting form were discussed and tentatively agreed to. Contact information, needs assessment, and relationship establishment was accomplished here. Growers were especially interested in any kind of method of prediction and exchanges of control strategies were also discussed. Immediately after the organizational meeting, the personnel hiring process and supply purchases commenced. Training began at the beginning of the psyllid monitoring season.

Individual grower meetings were held by visitation at growers' offices field monitoring sites, by phone and in conjunction with other meeting purposes. Monitoring site audits/visits and demonstrations of sampling and trap deployment were done as needed. Weekly target scheduling of sample delivery, retrieval and analysis occurred casually at these meetings or by phone/email. Trapping supplies were distributed when available and as needed.

In general, yellow sticky traps were deployed within three to four weeks after planting. Leaf/petiole sampling started shortly after four fully expanded leaves were formed and before planting insecticide effectiveness is expected to subside. Adults were expected to be found on the yellow sticky traps prior to establishment and damage is done. Eggs may be found on the leaves/petioles prior to or at establishment. The population level of adults found on sticky traps and eggs found on leaf/petiole samples describes the pest pressure. Finding nymphs on the leaf/petiole samples marks insecticide loss of effectiveness and need for application of soft chemistry systemic insecticides directed at the potato psyllids. All adult psyllids will be probed and analyzed for *Ca.* Liberibacter *solanacearum* (syn. *psyllaurus*).

Weekly reporting of sample analysis findings were tabulated and reported in detail with summary, wind / weather and pertinent information available.

End of the season total tabulations, as well as weather event occurrences and events ,that are believed to influence the monitoring season are being summarized. General findings are described below and were reported in greater detail at the annual meeting hosted by PCAN and scheduled by the grower group in February.

Goals and Outcomes Achieved

We had determined, based on some work done in the past 3 years, that about 60 fields spread across the state can be surveyed on a weekly basis without loss of organization or quality of work at the present location. A weekly schedule would be worked out with cooperating growers for acquisition and submission of samples. It turned out that the capacity of this number of

growers to supply samples topped out at about 45 fields fully monitored and a few more partially monitored even with the assistance that we were able to give.

In 2013, all samples were examined and potato psyllid presence and life stages were noted for each sample. Each grower's final weekly results were reported in detail by telephone and/or e-mail at the end of the day or when they were ready. Pesticide application data was shared at the growers' earliest convenience as well.

When all samples were finished at the end of each week, a summary report was distributed electronically to all cooperating growers. A summary of wind/weather data possibly affecting migration of the psyllid was also shared when available. Potato psyllids caught in traps were tested for Lso and results were included in the next generated report.

Beneficiaries

The Project directly benefitted all those participating growers in Nebraska. The total area in the state comprises less than approximately 20,000 acres in 2013. While growers in the eastern part of the state are less often affected by the pest and disease, it has been known to occur in that area. A total of 15 growers participated in the program and benefited from the economic impact of this project. In any given year there are approximately 20 to 25 grower/shipper entities, all potentially benefitting from the project.

Beneficiaries received weekly reports on the mode of establishment in areas in the state. Future benefits to all growers will likely be further developed IPM strategies and a better understanding of the biology of the insect and pathogen and how to handle the information provided by the established network.

The project did benefit all participating growers and shippers in the state, including those producing potatoes for chipping, French fries, tablestock and seed.

Approximations of cost reductions growers saved by not having to apply pesticide are made by cost per acre. It was reported that psyllid control costs have been reduced from a range of $300 to $350 per acre to a range of $200 to $235 per acre.

Lessons Learned

The monthly recap report was determined to be too redundant to use during the growing season. However, noting grower feedback concerning logistics, workability, and usefulness during personal communicationm did help to improve usability. At the end of the season, a final detailed report with analysis will be given back to each grower as well as a summarized report of the state's survey with analysis, noting grower feedback concerning logistics, workability, and usefulness. Recent experience has determined that the grower reports should be made and distributed in late November and early December. The final general meeting will be held in February to summarize the previous season and consider information for the coming season.

Pesticide trial visits were not available to PCAN\. However, a wealth of pesticide control data was acquired at the ZC reporting conference in San Antonio,Texas that was attended by PCAN personnel and some cooperating growers. The state survey will be reported on at the Annual Potato Development Committee meeting, and to a joint High Plains/ Nebraska-Wyoming group

convenient to the cooperating growers. At the end of the season grower group meeting, discussions will generate improvements for the following year.

The project is expected to allow producers to save hundreds of thousands of dollars in combined savings in properly placed expensive pesticides as well as losses due to uncontrolled pest occurrences that lead to badly diseased crops. This year, due to lesser psyllid activity, actually provided the survey the opportunity to allow growers to hold off on pesticide application until needed. Better knowledge of timing and placement of pesticides lent itself to some very elegant control regimes.

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Additional Information

Below is a link that illustrates an example of a weekly report electronically distributed to the growers, reporting numbers, life stages, trending graphs and backward wind trajectories as described.

http://www.nebraskapotatoes.com/html/Psyllid/Example%20Weekly%20Report%20for%20SCBG%20Report.pdf

Project Title

Improving Nutritional Value of Convenient Foods Using Nebraska Dry Edible Beans to Exploit International Marketing Opportunities

Project Summary

Dry edible beans are an important part of the economy in western Nebraska and nearby regions. The objective of this project was to develop ingredients from beans for specific commercial food processing applications. This was accomplished using dry milling, air classification, and wet milling techniques. The development of these ingredients would increase demand for beans and thus improve the economic stability in areas, especially rural areas, which produce dry edible beans.

Project Approach

Properties of pin milled Pinto and Great Northern bean flours were evaluated. The most unique property of the flours was the unique starch pasting profile (Fig. 1). Bean flours exhibited low peak viscosity and a lack of breakdown, which could be desirable in food applications that require low hot paste viscosity and high final viscosity (such as canned soups and pie fillings).

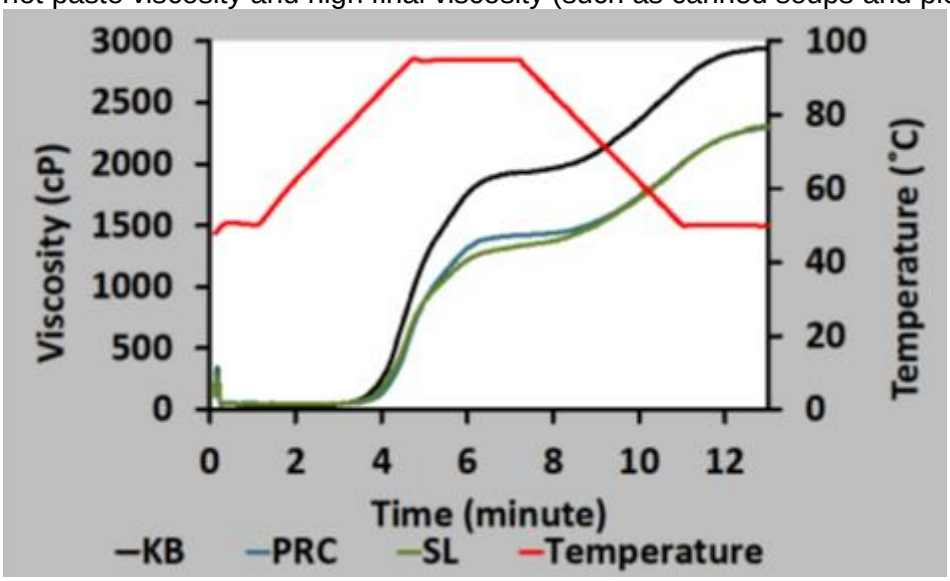

Figure 1. Rapid visco-analyzer curve for selected great northern beans; KB, Kelly Bean Company; PRC, Panhandle Research Center; SL, Stateline Bean Company. Similar shape curves were obtained for pinto bean flours.

Because of the unique nature of the starch, starches were isolated from 5 Great Northern bean cultivars (Beryl-R, Coyne, Gemini, Marquis, and Orion) and examined for physicochemical properties. Properties were similar to other legume starches, except the 5 Great Northern bean cultivars differed in their thermal and rheological properties. Coyne and Gemini had low gelatinization enthalpies, which meant that these starches require the least amount of energy to gelatinize; however, Coyne also had low peak and final viscosities. These data were published in the *Journal of Food Science (*Because of the unique nature of the starch, starches were isolated from 5 Great Northern bean cultivars (Beryl-R, Coyne, Gemini, Marquis, and Orion) and examined for physicochemical properties. Properties were similar to other legume starches,

except the 5 Great Northern bean cultivars differed in their thermal and rheological properties. Coyne and Gemini had low gelatinization enthalpies, which meant that these starches require the least amount of energy to gelatinize; however, Coyne also had low peak and final viscosities. These data were published in the *Journal of Food Science* (Wang, H. and Ratnayake, WS). "Physicochemical and Thermal Properties of Phaseolus Vulgaris L. var. Great Northern Bean Starch." Journal of Food Science. March 2014, Vol. 79:C295-C300. http://www.ncbi.nlm.nih.gov/pubmed/24506235)

Pinto, Black, and Great Northern beans were also wet milled to obtain three fractions that were enriched in protein, starch, or dietary fiber (Table 1). Composition of these fractions was analyzed (Table 2). The protein and starch fractions are of particular interest due to the consumer interest in high protein and dietary fiber food products.

Table 1. Yield of fractions obtained by wet milling of Great Northern (GN), navy, and Pinto beans.

Type	Fiber fraction			Starch fraction			Protein fraction		
GN	34.9	±	1.6	27.3	±	0.6	42.5	±	9.9
Navy	37.8	±	1.9	23.5	±	1.3	37.0	±	1.0
Pinto	40.7	±	1.2	24.4	±	0.4	33.3	±	1.8

Table 2. Composition of starch, protein, and fiber fractions obtained from wet milling of Great Northern (GN), navy, and Pinto bean (%, dry basis except for moisture which is on a wet basis); IDF, insoluble dietary fiber; SDF, soluble dietary fiber; TDF, total dietary fiber.

Bean	Fraction	Moisture	Protein	Starch	Ash	IDF	SDF	TDF
GN	Starch	7.77	1.87	84.0	0.23	1.95	0.66	2.61
Navy	Starch	8.37	1.82	94.0	0.27	1.68	0.30	1.99
Pinto	Starch	7.07	1.76	92.9	0.22	2.83	0.41	3.24
GN	Protein	3.98	52.5	1.89	7.62	15.2	4.44	19.7
Navy	Protein	2.67	57.5	0.39	8.74	19.8	3.50	23.3
Pinto	Protein	3.21	54.9	1.81	7.85	20.0	3.33	23.3
GN	Fiber	5.72	13.2	33.5	3.04	28.2	2.88	31.1
Navy	Fiber	3.96	10.2	30.7	3.14	27.0	3.18	30.2
Pinto	Fiber	7.32	10.8	47.7	2.21	25.8	2.50	28.3

Fiber fraction was measured for its ability to slow starch digestion rate (Fig. 2). The results suggested that the fiber fraction from Great Northern beans was the most effective in reducing the percentage of total digestible starch. This could be important as an ingredient to control blood glucose levels. These results are being prepared for publication in a peer-reviewed journal.

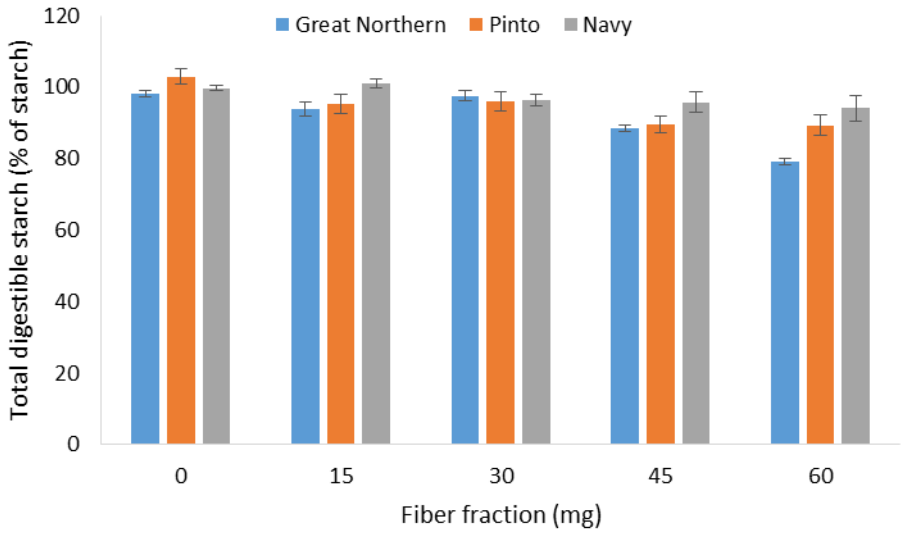

Figure 2. Total digestible starch in the presence of difference concentrations of fiber fractions from selected beans.

Goals or Outcomes Achieved

The overall objective of this project was to develop ingredients from beans for specific commercial food processing applications. To this end, we analyzed the physicochemical properties of starches from Pinto and Great Northern beans. We found that these starches exhibit the unique property of low peak viscosity and no setback, which could be useful in many food processing applications that require a low hot paste viscosity but high final viscosity. We also isolated fractions from beans that were high in starch, protein, or dietary fiber. The protein and dietary fiber fractions could be useful as ingredients in many food products where an increase in protein or dietary fiber would be desirable. Finally, we found that the fiber fraction from Great Northern beans is effective in reducing starch digestion (*in vitro*), which suggests that this fraction could be added to foods for control of blood glucose levels.

The project activities that were proposed for the first year of the submitted project proposal were completed as planned. The accomplishments were as follows:

1. Comprehensively evaluated the compositions of Great Northern and Pinto beans. These experiments were carried out following standard wet-chemistry analytical procedures.

2. Prepared flours of these two market classes, Great Northern and Pinto, using a pin mill (Alpine Model 160z, Aktien-Gesellschaft, Augsburg, Germany) and tested them for functional properties, that were important for food applications.

3. Two research presentations were presented at the 2013 Institute of Food Technologists (IFT) Annual Meeting in Chicago, IL, based on the pin-milled flour properties and functionalities.

a. Mo, L., Wang, H., Burrows, A. S., Ratnayake, W. S. and Flores, R. A. 2013. Physicochemical properties of pin-milled Pinto beans. Pages Poster No. 163-46, Institute of Food Technologists Annual Meeting: Chicago, IL.

b. Wang, H., Burrows, A. S., Ratnayake, W. S. and Flores, R. A. 2013. Properties and functionalities of pin milled Great Northern bean flour. Pages Poster No. 163-126, Institute of Food Technologists Annual Meeting: Chicago, IL.

4. Found that dry fractionation, based on the size distribution of the milled particles, would be suitable for certain functionality traits of the ingredients.

5. Milled samples were tested in food product applications such as instant noodles, muffins, and brownies. All prototype samples were of acceptable quality.

6. Discussed some of these findings with Chinese convenience food manufacturers at the Convenience Food Expo and U.S.-China Food Ingredient workshop, which were held in Beijing September 3-7, 2013.

Two projects were successfully completed during the second year of the project. They were as follows:

1. Great Northern and Pinto beans were evaluated for starch properties and enzyme susceptibility.

   a. Instant noodles, muffins, and brownies, as well as a cooked and freeze dried whole bean snack, were produced from cooked or whole beans.

   b. These products were tested for sensory properties and found to be well liked by panelists.

   c. They were presented at Chinese Reverse Trade Mission visits to Nebraska with about 25 visitors.

   d. The instant noodles were also selected as a finalist in the AACC International Student Product Development Competition and presented at the annual meeting with about 1,000 attendees (about 100 people attended the session).

2. Chemical and physical properties of bean flours and isolated starches were evaluated.

   a. Results were presented in a publication (Journal of Food Science 2014;79:295-300). Readership is not known.

   b. Results were also presented in poster presentations at the Conference on Food Engineering (about 100 attendees), the Institute of Food Technologists (about 20,000 attendees) and AACC International (about 1000 attendees) annual meetings.

Ongoing discussions are underway with food companies regarding the use of these ingredients in their food products. We expect that this will be a long-term effort, but that it will be successful; these ingredients show much promise to increase the nutritional value of many food products.

Beneficiaries

Results from all projects described above have been presented at three meetings of the American Association of Cereal Chemists International, with total attendance of about 1,000 people. Results were also presented at one meeting of the Institute of Food Technologists with a total attendance of about 20,000 people. Some results have been published in peer-reviewed journals. Results have also been presented to a number of food companies. Discussions continue with these companies on the possibility of including these ingredients in commercial food products.

Lessons Learned

This project experienced a number of delays, setbacks, and changes. After year 1 of the project, the Principal Investigator (PI) changed and, thus, the expertise and interest of the lead in the project changed. The overall objective did not change, but some of the specific objectives changed. For instance, particle size analyses were not performed to the extent planned; however, the wet-milled protein and fiber fractions were analyzed to a greater extent than planned and some interesting and unique properties of these fractions were discovered. Another setback occurred when the graduate student on the project abruptly left the program. The workload was transferred to other students, but these students did not have as much time to dedicate to this project as the original student because they also had other projects. This unfortunately impeded our ability to test these ingredients in specific food products. We were left with only being able to hypothesize as to what foods they would be ideal based on their physicochemical properties. Future funding could be used to explore the performance of these ingredients in food products or these evaluations could be performed by companies interested in these ingredients.

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Additional Information

Poster No. 163-46

Physicochemical properties of Pin-Milled Pinto Beans

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Abstract

Pinto bean is an economical source of high-quality protein and fiber, among other nutrients. Its use as a food ingredient, however, is limited in the food industry for various reasons, including lack of understanding on properties and functionalities of processed ingredients. This study investigated the properties and functionalities of pin-milled Pinto bean flour fractions. The properties of the flours from two fractions, large and small particle sizes, after sieving were studied. The results showed that pinto bean had high protein and starch content. Differences in composition could lead to the observed differences in water solubility, water absorption, and RVA peak viscosities,

Introduction

Dry-edible beans have long been considered as an economical commodity with high nutritional value. Pinto bean, a major market class among U.S. dry edible beans, is an excellent source of nutrients including protein, vitamins, antioxidants, minerals, and fiber. The use of Pinto beans, as a food ingredient, is limited in commercial food processing for several reasons; one important reason being the lack of knowledge on advanced processing operations for beans. More value-added applications, other than cleaned whole beans and canned beans, are required to increase the use of U.S. grown dry-beans by the food industry. Pinto bean is a major market class of U.S. produced dry-beans. A better understanding on the composition and properties of Pinto beans is vital to expand the use of Pinto beans in value-added food processing. Separation of bean flour into fractions, with specific compositional and functional properties, is useful for certain product applications. Dry fraction is preferred for commercial ingredient processing due to economic reasons.

Materials & Methods

Selected pinto Beans were obtained from local store (Brown's brand) [B], New Alliance [NA], and Stateline [S] bean companies in Nebraska.

- ~ 2000g of pinto beans were milled by a pin mill (Model 160z, Alpine, Aktien-Gesellschaft, Augsburg, Germany), with a feeding rate at 8kg/h.
- Water absorption index (WAI), water solubility index (WSI) were determined to study the properties of pinto bean flour according to Anderson et al. (1969).
- Pasting properties of flours were evaluated by rapid viscosity analysis (RVA) using standard-1 profile.
- Malvern Mastersizer 3000 particle size analyzer equipped with a Hydro MV wet dispersion unit was used to study the size distribution of bean flour.
- A 106μm sieve was used to separate the flour into two fractions with Hosokawa Air Jet Sieve System. USA standard test sieve No. 140.
- Proximate compositions and moisture contents of pin milled flours were analyzed by standard methods.
- Statistical analysis, mean separations were performed using JMP software (Version 10.0.0, SAS Inc., Cary, NC) on at least three independent replicates (Tukey's HSD test, $p<0.05$).

Results

Table 1. Composition of the small (<106μm) particle fraction

Composition	Sample		
	B	NA	S
Starch %	38.80a	41.30a	40.95a
Crude Protein %	24.05a	22.85b	22.25c
Fat %	1.25a	1.25a	1.35a
Ash %	3.81a	3.75a	3.77a
Fiber %	2.90a	2.50b	2.55b
Moisture %	8.94b	9.11a	9.00ab

Table 2. Composition of the large (>106μm) particle fraction

Composition	Sample		
	B	NA	S
Starch %	28.90a	29.35a	30.10a
Crude Protein %	21.75a	21.35b	19.90c
Fat %	1.10a	1.05a	1.05a
Ash %	4.64a	4.67a	4.79a
Fiber %	9.75a	9.45a	9.75a
Moisture %	8.45a	8.32c	8.35b

Table 3. WAI, WSI of small (<106μm) particle fraction

Property	Sample		
	B	NA	S
WAI	2.38a	2.17b	2.08c
WSI	0.29a	0.27b	0.29a

Table 4. WAI, WSI of large (>106μm) particle fraction

Property	Sample		
	B	NA	S
WAI	2.95a	2.92a	2.87b
WSI	0.25b	0.24b	0.27a

Means followed by the same letter, within the same row, are not significantly different (p>0.05).

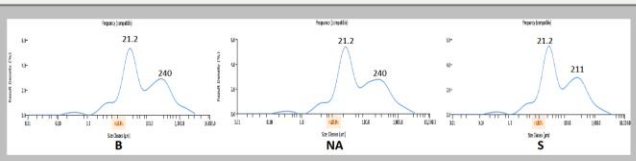

Figure 1. Typical particle size distribution profile for pin milled Pinto bean

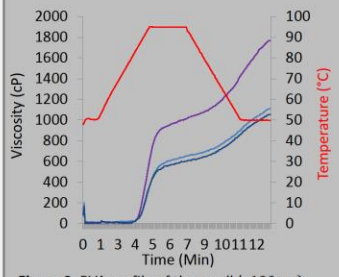

Figure 2. RVA profile of the small (<106μm) particle fraction

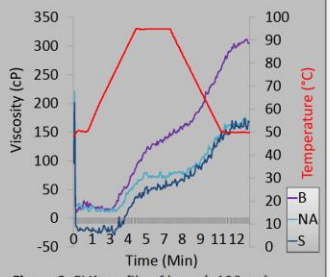

Figure 3. RVA profile of large (>106μm) particle fraction

Conclusions

- The sieve size (106μm) for fraction was selected based on the particle size distribution of pin-milled whole bean flours (Fig.1).
- Large particle fraction of Pinto beans had higher starch and protein contents compared to small particle fraction for all three samples.
- Starch content did not vary based on the source of sample, within each fraction.
- Crude protein content varied based on the source of the sample , within each fraction in the order B > NA > S.
- Fiber content did not vary within the large particle fraction, but varied within the small particle fraction in the order B > NA ~ S.
- Large particle fraction of Pinto bean had higher moisture content compared to small particle fraction for all three samples.
- Sample S showed higher pasting viscosities compared to the other two samples, for both fractions (Figures 2 and 3). This could be attributed to higher WAI of sample S, compared to the other samples within each fraction class (Tables 3 and 4).
- Functionalities of Pinto bean flour fractions, separated based on size, could depend on the source/origin of the sample.

Reference

Anderson, R. A., Conway, H. F., Pfeifer, V. F. and Griffin, E. L. 1969. Gelatinization of corn grits by roll- and extrusion-cooking. Cereal Science Today 14: 4-12.

Acknowledgements

This research was supported, in part, by Nebraska Department of Agricultural of Specialty Crop Block Grant, FB-2012 and Nebraska Dry Bean Commission. New Alliance and Stateline bean companies provided samples for this study.

Nebraska Dry Bean Commission

Applied Research and Engineering

IANR

Project Title

Breeding for Heat Tolerance in Dry Beans in Western Nebraska

Project Summary

Although common bean is relatively sensitive to higher temperatures, the Phaseolus genus is adapted to an extremely wide range of environments, from arid deserts to tropical rainforests, and from sea level to 9,800 feet or more above sea level. Exposure of common bean to day and night temperatures exceeding 86°F and 68°F, respectively, during reproductive development, reduces yield and quality by causing floral abscission, disrupted fertilization and ovule development, and pod deformation. In Nebraska 2011, the dry beans were exposed to 46 days of temperature above 86°F during reproductive development. Nebraska growers complained about flowers and pods abortion. Genetic improvement of common beans for tolerance to high temperatures is a cost effective and practical approach for increasing production and quality in high temperature environments. Breeding for heat tolerance has resulted in the release of heat-tolerant germplasm and varieties. Thus, development of common bean cultivars adapted to higher temperature environments will expand the set of crop choices for famers in warmer areas. It will also enable farmers to moderate effects of, or adapt to, spatial and temporal variability in climatic parameters, such as increase in temperature, that are associated with climate change. Therefore, this project focused on identifying sources of heat tolerance from tropical germplasm and related species, and on the introgression into cultivated U.S. dry bean cultivars. This request assisted our breeding efforts to support the development and release of new Great Northern, Pinto, Light Red Kidney, Cranberry, Black and Small Red Bean cultivar/germplasm with heat tolerance. Identification of sources of heat tolerance was achieved and introgression of those sources into elite Nebraska dry bean germplasm is being done. Segregant generations are advanced to F2:3.

The main goal of the project focused on identifying sources of heat tolerance from tropical germplasm and related species, and on the introgression into cultivated U.S. dry bean cultivars.

Project Approach

In addition to the common bean, there are four other domesticated species of *Phaseolus* harvested for human consumption. These include the scarlet runner bean (*P. coccineus* L.) and the year-long bean (*P. polyanthus* Greenman) from the secondary gene pool of common bean; the tepary bean (*P. acutifolius* A. Gray) from the tertiary gene pool; and the lima bean (*P. lunatus* L.) from the quaternary gene pool.

Although the common bean is relatively sensitive to higher temperatures, the Phaseolus genus is adapted to an extremely wide range of environments, from arid deserts to tropical rainforests, and from sea level to 9,800 feet or more above sea level.

Specifically with regards to high temperatures, the tepary bean expresses excellent adaptation to climates where heat limits the production of common bean. Exposure of common bean to day and night temperatures exceeding 86°F and 68°F respectively during reproductive development, reduces yield and quality by causing floral abscission, disrupted fertilization and ovule development, and pod deformation (Omae et al., 2007; Porch and Jahn, 2001; Rainey and Griffiths, 2005).

Below are the field and greenhouse experiments in 2013:

1. Fifty five entries were grown in the greenhouse at the Scottsbluff, Nebraska location in 2013. Among these entries were: 16 lines from the shuttle breeding between Nebraska and Puerto Rico; 28 from the International Center for Tropical Agriculture (CIAT), Palmira, Colombia; seven reference checks and four tepary beans. The same set of lines, excluding the tepary beans, were grown in Mitchell, Nebraska, in a replicated trial under drought and non-drought conditions. The irrigation was stopped at flowering stage during the growing season.

   Of 516 lines from the shuttle breeding between Nebraska and Puerto Rico, 86 lines were selected with drought/heat tolerance and will be evaluated in 2013-2014 at Juana Diaz, Puerto Rico. There were 167 lines selected from CIAT's breeding program for heat/drought tolerance during a visit to Colombia. A formal seed request has being placed.

   On average, yield was reduced by 41.4% from 3311 to 1938 lbs./acre under non-stress (NS) and drought stress (DS), respectively. Seed size was reduced by 4.9% from 26.1 to 24.8 gr/100 seed weight under non-stress and drought stress, respectively. Days to maturity were delayed by 6 days comparing non-stress vs. drought stress. Several lines performed well under both non-stress and drought stress environments (SB1, SB2, SB8, SB10, SB11, SB13, SB14, BFB611, SCR14, ALB159, and ALB130).

2. Several lines showed heat tolerance (SB-8, TEP 22, TEP 19, Matterhorn, TEP 29, BFB 611, SB-13, TEP 32, SB-16, ALB 130, SER 118, Amadeus, and ALB 159) (Table 1). Matterhorn is a Great Northern with drought tolerance. Teapary lines (TEP) performed well under heat stress.

   Both experiments in field and greenhouse will be repeated in 2014. Those genotypes exhibiting heat tolerance from the trials will be collected and intercrossed in the greenhouse in an effort to pyramid resistant genes into current cultivars with desirable agronomic traits.

The project coordinator traveled to Puerto Rico and selected 516 lines from the shuttle breeding between Puerto Rico and Nebraska with heat/drought tolerance. He also traveled to the International Center for Tropical Agriculture (CIAT) in Columbia and selected 167 lines with heat/drought tolerance.

He assembled a National Drought Bean Trial conducted at Nebraska, Washington, Colorado, California, and Puerto Rico. Two undergraduates and one high school student participated in the field and greenhouse evaluations. He worked with and trained two undergraduates and one high school student in screening for heat tolerance. Leaf temperatures were recorded. In December 2013, a preliminary report was submitted to the *Nebraska Bean Bag.*

Members of the University of Nebraska-Lincoln Dry Bean Breeding program planted, weeded, maintained the plots, harvested, and collected all information.

Below are the field and greenhouse experiments in 2014:

1. Forty-four common bean entries were grown in the greenhouse at the Scottsbluff, NE. Sixteen lines were from the shuttle breeding between Nebraska and Puerto Rico, 11 from the International Center for Tropical Agriculture (CIAT), Palmira, Colombia, 6 reference checks, and 10 tepary beans. The same set of lines but not the tepary beans were grown at Scottsbluff, Nebraska, in a replicated trial under drought and non-drought conditions. The irrigation was stopped at flowering stage during the growing season (terminal drought). Eighty-nine lines from the shuttle breeding between Nebraska and Puerto Rico selected for drought/heat tolerance were evaluated for drought/heat tolerance in Scottsbluff, Nebraska. Additionally, 148 lines were selected/tested from CIAT's (International Center for Tropical Agriculture) bean breeding program for heat/drought tolerance at Scottsbluff, Nebraska.

Below are the field and greenhouse experiments in 2015:

1. Similar experiments planted in 2014 were planted in 2015 in both the greenhouse and the field. The same set of experiments were planted in the greenhouse. Additionally, 200 dry bean lines were selected/requested from CIAT's (International Center for Tropical Agriculture) bean breeding program to be tested in 2016 for heat/drought tolerance at Scottsbluff, Nebraska.

UNL Dry Bean Breeding program planted, weeded, maintained the plots, harvested, collected, analyzed, and summarized all information.

Goals and Outcomes Achieved

The main goal of the project focuses in identifying the sources of heat tolerance from tropical germplasm and related species, and on the introgression into cultivated US dry bean cultivars.

In 2014, on average, yield was reduced by 17.8% from 2,626 to 2,158 pounds/acre under non-stress (NS) and drought stress (DS), respectively. Seed size was reduced by 3.0% from 27.1 to 26.3 gr/100 seed weight under non-stress and drought stress, respectively. Days to maturity was not affected by the drought stress. Several lines performed well under both non-stress and drought stress environments (USPT-ANT //Matterhorn/98078-5-1-5-1, VAX 2, Matterhorn, Marquis and Merlot //Merlot/SER 16). For the 2014 greenhouse experiments, several lines showed heat tolerance. The tepary line PI 319447 had the highest yield followed by the interspecific INB 816 and the shuttle breeding line Merlot//Merlot/SER 16. The interspecific line VAX 2 had the top seven yield. In general, the tepary lines performed well under heat stress.

In 2015, on average, yield was reduced by 42.6% from 2,678 to 1,536 pounds/acre under non-stress (NS) and drought stress (DS), respectively. Seed size was reduced by 2.2% from 27.4 to 26.8 gr/100 seed weight under non-stress and drought stress, respectively. Days to maturity was later by two days for beans grown under normal conditions. USPT-ANT/Matterhorn9878-5-1-5-1, Stampede, and VAX 2 had the highest geometric mean. Additionally, Marquis, Croissant, SMR 109, SMR 126, and SMR 112 had the top yield under both drought and non-drought stress. For the greenhouse experiments on heat, SCR 14, SXB 412 Tacana/VAX 6, SXB 364, and the interspecific line INB 816 had the highest yields per pot. Additionally, SCE 39, SER 336, SER 329, and SEC 34 had the highest yields under heat stress.

Lines with heat/drought tolerance from the USDA-ARS Tropical Agriculture Research Station at Juana Diaz, Puerto Rico and the International Center for Tropical Agriculture (CIAT), Palmira, Colombia were identified.

Several lines showed heat tolerance. The tepary line PI 319447 had the highest yield followed by the interspecific INB 816 and the shuttle breeding line Merlot//Merlot/SER 16. The interspecific line VAX 2 had the top seven yield. In general, the tepary lines performed well under heat stress in 2014.

Several lines performed well under both non-stress and drought stress environments and under heat are being introgressed into elite Nebraska germplasm through hybridization.

A presentation regarding heat/drought experiments was delivered to the Nebraska Bean Growers on August 19, 2014. A total of 150 bean growers attended the field day. The PI also assembled a National Drought Bean Trial conducted at Nebraska, Washington, Colorado, California, and Puerto Rico. Project results were discussed with the Multistate W2150 project on August 20, 2014.

Showed the experiments on heat to the International Bean Trade Mission that visited our station in 2014 and 2015.

Results are being disseminated through the Nebraska Bean Day and Nebraska Field Day held by the Nebraska Dry Bean Growers Association in January and August each year. Each meeting conveys among 150 to 250 dry bean growers. Results are being published in the *Bean Bag* newsletter (it reaches most of the dry bean growers in Nebraska). The identification of sources of heat tolerance in dry beans will directly benefit the dry bean growers in western Nebraska (about 1,700 growers). The USA dry bean community is benefiting indirectly with the identification of such sources of drought tolerance.

Urrea, C.A. 2015. "Breeding for heat tolerance in dry beans in western Nebraska." The Bean Bag. Vol 13 (2): 10.

Beneficiaries

Nebraska is first in Great Northern and second is Light Red Kidney and Pinto bean production in the United States. The development of improved varieties and germplasm with high yield potential, resistance to multiple diseases, greater water use efficiency, heat tolerance and better seed quality are important to Nebraska dry bean growers and industry representatives, particularly those located in western Nebraska. There are approximately 1,700 growers representing 140,000 acres of dry beans. The dry bean industry is a beneficiary of this project with the identification and development of the heat tolerance germplasm cultlivars.

Lessons Learned

Six undergraduate students participated in the greenhouse/field evaluations. Worked with and trained six undergraduate students in screening for heat tolerance.

The main goal of the project focusing in the identification of sources of heat tolerance from tropical germplasm and related species, and on the introgression into cultivated US dry bean cultivars was achieved.

Contact Information

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Additional Information

Graph 1. Evaluation of the DBDN at Mitchell, Nebraska in 2013

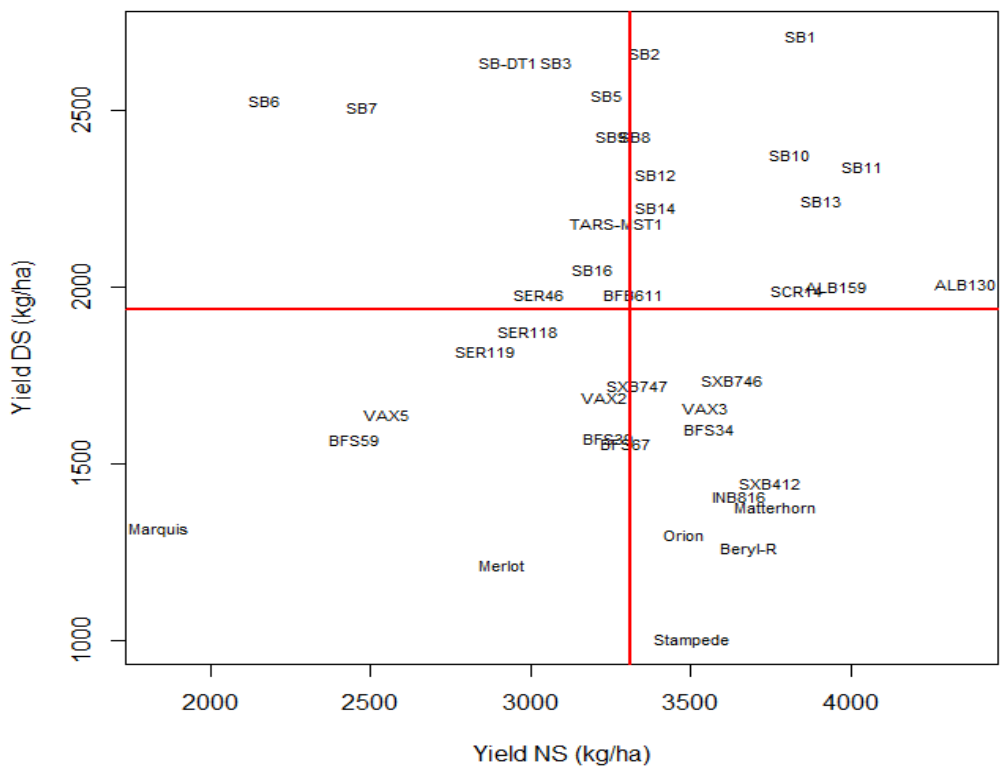

Table 1. Drought Bean Drought Nursery grown in the greenhouse under heat conditions in 2013.

Entry	Pedigree	Yield	100-SeedWeight
		gr/pot	gr
8	SB-8	20.0	19.8

54	TEP 22	19.7	9.1
52	TEP 19	18.2	12.9
45	Matterhorn	17.9	26.0
55	TEP 29	17.7	9.0
25	BFB 611	17.2	20.3
13	SB-13	17.1	18.4
53	TEP 32	17.1	13.0
16	SB-16	16.3	24.1
17	ALB 130	15.6	24.9
27	SER 118	14.6	18.4
49	Amadeus	14.6	18.6
18	ALB 159	14.5	19.8
10	SB-10	14.4	18.8
47	Orion	14.3	27.7
40	BFS 59	13.8	20.5
1	SB-1	13.5	17.5
9	SB-9	13.5	25.1
36	BFS 34	13.4	23.1
6	SB-6	13.3	18.3
15	SB-15	13.3	15.5
5	SB-5	13.1	19.4
11	SB-11	13.1	27.5
2	SB-2	12.8	12.1
4	SB-4	12.6	16.7
30	SXB 746	12.4	21.3
28	SER 119	11.9	18.3
50	Dor 364	11.9	14.0
38	BFS 39	11.4	18.3
48	Beryl-R	11.2	22.8
14	SB-14	10.8	25.2
44	INB 816	10.5	20.5
12	SB-12	10.4	16.2
42	SXB 412	10.4	19.5
7	SB-7	10.2	13.6
41	BFS 67	9.9	24.5
51	Tio Canela	9.8	14.2
34	VAX 3	9.6	23.7
33	VAX 2	9.2	17.6
23	SCR 14	9.2	23.5
35	VAX 5	9.2	21.9
46	Marquis	8.9	16.1
26	SER 46	8.6	21.7

3	SB-3	7.3	9.4
31	SXB 747	7.2	12.5
	GRAND MEAN	12.9	18.9
	LSD 5 %	9.2	6.4
	CV %	35.6	17.0

Experiment on heat tolerance conducted at the dry bean breeding greenhouse in 2014.

Ent. No.	**PEDIGREE**	**Yield**	**100-SeedWeight**
		g/pot	**gr**
53	PI 319447	36.1	36.6
44	INB 816	34.7	30.8
11	Merlotx(MerlotxSER 16)	33.3	41.1
46	Marquis	33.1	32.2
6	(Tacana x VAX6	33.1	24.1
26	SER 46	32.4	33.3
33	VAX 2	31.1	30.4
59	PI 440805	30.9	14.1
30	SXB 746	30.4	35.4
13	Merlotx(98020-3-1-6-2xTacana)	30.4	31.1
49	Merlot	30.3	42.3
31	SXB 747	30.2	22.1
48	Beryl-R	30.2	29.6
58	PI 440799	30.0	14.8
42	SXB 412	29.4	28.6
23	SCR 14	29.4	33.7

51	DOR 364	29.2	23.2
17	ALB 130	28.9	31.1
52	PI 312122	28.7	13.2
1	(Tacana x VAX6	28.2	23.3
4	(Black Rhino)x(SEN 10 (SB-DT1)	27.9	26.4
60	PI 462025	27.8	12.6
2	(MoralesxXAN 176)x('BAT 477xB98311)	27.4	27.7
7	(BelMiDak RMR10xB01741)x('BAT 477xL88-63)	27.4	21.7
16	Merlotx(05F-5055-1x98020-3-1-6-2)	27.2	36.4
5	(MoralesxXAN 176)x('EAP 9503-32A)	26.7	29.2
8	(Matterhorn)x(SER 21	26.5	28.6
45	Matterhorn	26.1	31.7
9	(USPT-ANT)x('Matterhornx98078-5-1-5-1)	25.9	37.9
3	(BAT 477xL88-63)x('BelMiDak RMR10xB01741)	25.7	16.9
15	10486 (TARS-MST1)	25.5	20.5
14	10457	23.9	31.3
57	PI 440798	23.7	10.9
34	VAX 3	23.4	33.2
55	PI 321638	22.9	11.0
54	PI 440802	22.7	14.0
28	SER 119	22.2	24.5
61	PI 477037	21.7	13.9
56	PI 440785	21.1	15.5
35	VAX 5	20.0	29.7

12	Merlotx(98020-3-1-6-2xTacana)	19.5	27.4
50	Stampede	19.2	32.2
10	(ABCP8)x(TARS-PT03-1xVAX 6	17.6	23.2
	GRAND MEAN	27.3	26.2
	LSD 5 %	11.3	5.6
	CV %	20.8	10.7

2014 Drought Bean Drought Nursery grown at Scottsbluff, NE during 2014.

Ent		Non-Stress				Drought Stress						
no	PEDIGREE	Yield	Flowering	Mat	100-seeds	Yield	Flowering	Mat	100-seeds	GM	PR	DII
		lbs/a	days	days	gr	lbs/A	days	days	gr	lbs/a	%	
9	(USPT-ANT)x('Matterhornx98078-5-1-5-1)	3709	44	87	36.0	3629	46	87	36.8	3669	2.2	0.1
33	VAX 2	3394	48	94	26.4	2807	49	94	26.2	3087	17.3	1.0
45	Matterhorn	3392	46	91	35.0	2715	46	91	31.0	3035	20.0	1.1
46	Marquis	3047	45	91	33.2	2929	46	89	34.4	2987	3.9	0.2
11	Merlotx(MerlotxSER16)	2971	46	92	36.0	2931	48	94	37.4	2951	1.3	0.1
48	Beryl-R	2890	44	84	29.4	2792	44	82	28.2	2840	3.4	0.2
50	Stampede	3095	46	92	34.8	2490	47	91	33.6	2776	19.6	1.1
16	Merlotx(05F-5055-1x98020-3-1-6-2)	2857	46	86	31.8	2387	46	89	33.5	2611	16.5	0.9
44	INB 816	2917	47	91	27.8	2286	46	91	27.3	2582	21.6	1.2
14	10457	2802	46	84	31.8	2358	46	86	29.7	2570	15.9	0.9
17	ALB 130	2496	46	86	28.9	2585	46	88	26.5	2540	-3.5	-0.2
10	(ABCP8)x(TARS-PT03-1xVAX 6	2530	46	84	23.2	2368	48	89	22.7	2448	6.4	0.4
49	Merlot	2703	44	82	36.6	2175	44	80	37.7	2425	19.5	1.1

26	SER 46	2608	48	91	25.7	2254	48	91	24.1	2424	13.6	0.8
7	(BelMiDak RMR10xB01741)x('BAT 477xL88-63)	2967	48	94	18.4	1976	49	93	19.3	2422	33.4	1.9
8	(Matterhorn)x(SER 21	2447	47	89	28.9	2304	48	89	25.2	2374	5.8	0.3
5	(MoralesxXAN 176)x('EAP 9503-32A)	2714	47	92	28.8	2073	48	91	25.3	2372	23.6	1.3
28	SER 119	2647	46	92	28.1	2101	48	93	26.5	2358	20.6	1.1
42	SXB 412	2605	48	91	24.9	2049	49	88	24.0	2310	21.4	1.2
6	(Tacana x VAX6	2237	46	85	20.6	2127	47	91	20.7	2181	4.9	0.3
12	Merlotx(98020-3-1-6-2xTacana)	2744	48	93	26.5	1711	48	93	24.8	2167	37.6	2.1
23	SCR 14	2235	46	94	29.0	2010	46	93	29.7	2119	10.0	0.6
30	SXB 746	2348	46	87	30.5	1789	46	92	29.2	2049	23.8	1.3
35	VAX 5	2116	49	92	24.1	1942	49	93	22.8	2027	8.2	0.5
2	(MoralesxXAN 176)x('BAT 477xB98311)	2200	47	93	19.8	1793	48	94	18.5	1986	18.5	1.0
13	Merlotx(98020-3-1-6-2xTacana)	2714	48	91	25.8	1415	49	93	25.1	1960	47.8	2.7
4	(Black Rhino)x(SEN 10 (SB-DT1)	2024	49	92	23.9	1830	49	93	21.4	1925	9.6	0.5
31	SXB 747	2275	49	93	20.3	1532	51	94	18.6	1867	32.7	1.8
3	(BAT 477xL88-63)x('BelMiDak RMR10xB01741)	2407	49	95	16.3	1324	53	95	16.3	1785	45.0	2.5
15	10486 (TARS-MST1)	1824	48	88	18.4	1663	49	90	18.7	1742	8.8	0.5
34	VAX 3	1808	47	93	28.5	1533	49	91	25.9	1665	15.3	0.8
1	(Tacana x VAX6	2326	48	92	20.2	1176	48	92	20.7	1654	49.4	2.7
	GRAND MEAN	2626	47	90	27.1	2158	47	90	26.3	2381	17.8	1.0
	LSD 5 %	949	2	5	3.4	809	2	5	2.5			
	CV %	17.7	2.3	2.8	6.2	18.4	2.2	2.8	4.8			

2015 greenhouse experiments conducted at the PREC-Scottsbluff, NE

Ent no	PEDIGREE	yield g/plot	100-seeds g
18	SCR 14	28.5	14.3
26	SXB 412	28.4	13.1
31	Merlot	28.2	19.2
6	(Tacana x VAX6	28.0	11.2
21	SXB 746	26.8	14.8
33	DOR 364	25.8	11.0
27	INB 816	25.4	13.6
30	Beryl-R	25.3	12.1
22	SXB 747	25.0	8.6
4	(Black Rhino)x(SEN 10 (SB-DT1)	24.7	11.9
1	(Tacana x VAX6	24.5	10.3
25	VAX 5	24.3	14.6
15	10486 (TARS-MST1)	24.3	9.8
16	Merlotx(05F-5055-1x98020-3-1-6-2)	24.1	15.2
9	(USPT-ANT)x('Matterhornx98078-5-1-5-1)	23.8	16.7
8	(Matterhorn)x(SER 21	23.6	12.3
35	PI 319447	23.6	15.5
23	VAX 2	23.4	13.2
29	Marquis	23.0	13.2
38	PI 440785	23.0	7.4

2	(MoralesxXAN 176)x('BAT 477xB98311)	22.7	13.8
24	VAX 3	22.2	11.3
14	10457	22.1	14.5
10	(ABCP8)x(TARS-PT03-1xVAX 6	22.1	11.8
20	SER 119	21.8	12.6
17	ALB 130	21.7	10.8
3	(BAT 477xL88-63)x('BelMiDak RMR10xB01741)	20.3	8.6
12	Merlotx(98020-3-1-6-2xTacana)	20.2	12.5
28	Matterhorn	20.0	14.1
32	Stampede	19.5	18.1
7	(BelMiDak RMR10xB01741)x('BAT 477xL88-63)	18.9	7.0
19	SER 46	18.9	12.7
5	(MoralesxXAN 176)x('EAP 9503-32A)	16.5	10.9
41	PI 440805	14.9	6.7
42	PI 462025	14.9	6.5
11	Merlotx(MerlotxSER 16)	14.5	11.0
40	PI 440799	14.1	7.5
36	PI 440802	14.1	7.6
43	PI 477037	13.0	7.4
39	PI 440798	13.0	5.6
37	PI 321638	11.5	5.2
13	Merlotx(98020-3-1-6-2xTacana)	10.9	5.9
34	PI 312122	9.7	4.8
	GRAND MEAN	21.0	11.3

LSD 5 %	8.4	3.1
CV %	20.3	13.8

2015 greenhouse experiments conducted at the PREC-Scottsbluff, NE			
Ent	**PEDIGREE**	**yield**	**100-seeds**
no		**g/plot**	**g**
23	SCE 39	33.5	14.0
48	SER 336	32.5	14.4
44	SER 329	30.6	15.5
30	SEC 34	30.4	13.8
29	SEC 33	30.3	16.4
71	SMN 38	30.0	14.1
68	SMC 160	30.0	13.1
74	SMR 109	29.8	15.7
3	EAP96-53-16B-1	29.7	10.1
75	SMR 111	29.4	14.6
34	SEC 40	29.1	14.3
89	Merlot	28.8	19.2

64	SMC 154	28.4	11.9
77	SMR 116	28.4	12.6
45	SER 331	28.2	12.5
84	SMR 127	28.2	14.6
1	BFS 29	27.9	12.7
46	SER 332	27.6	14.8
76	SMR 112	27.3	13.9
90	Croissant	27.2	16.3
12	RCB 593	26.7	14.5
25	SCR 51	26.6	10.3
33	SEC 38	26.1	11.8
52	SER 350	25.9	12.6
67	SMC 159	25.8	15.2
70	SMC 164	25.6	13.3
73	SMR 59	25.5	12.2
7	GGR 30	24.9	11.0
26	SCR 53	24.8	11.7
66	SMC 156	24.3	14.9
69	SMC 161	24.1	10.5
35	SEC 43	23.8	14.3
31	SEC 35	23.8	13.5
57	SMC 45	23.5	10.8
36	SEF 40	23.3	13.8
62	SMC 151	23.1	17.4

88	Marquis	23.0	14.7
51	SER 342	23.0	13.1
63	SMC 152	22.9	12.9
32	SEC 37	22.8	15.4
53	SER 351	22.7	12.8
55	SMC 171	22.7	11.3
72	SMN 60	21.9	10.8
65	SMC 155	21.8	10.7
80	SMR 123	21.7	10.8
38	SEF 71	21.6	10.8
21	SAP 1	21.6	24.2
83	SMR 126	21.3	11.8
61	SMC 150	21.3	12.7
28	SCR 9	21.2	11.7
24	SCR 50	21.2	10.2
15	INB 48-1	21.1	8.2
85	SXB 412	21.1	8.6
54	SER 352	21.0	11.5
58	SMC 96	20.8	10.9
79	SMR 122	20.5	10.8
22	SMC 170	20.4	11.3
41	SEN 80	20.2	8.2
18	SEF 60	20.2	10.8
6	GGR 27	19.8	14.7

47	SER 335	19.3	10.1
56	SMC 172	19.2	8.4
78	SMR 117	18.8	10.1
87	Matterhorn	18.7	10.8
59	SMC 142	18.2	9.9
16	SEF 57	18.1	8.2
86	SXB 418	17.8	7.5
82	SMR 125	17.3	8.5
60	SMC 149	17.1	14.1
50	SER 341	17.0	6.5
27	SCR 6	16.5	11.6
42	SEN 81	16.3	8.1
43	SEN 115	15.9	10.4
81	SMR 124	15.5	8.7
39	SEN 53	15.2	5.7
8	Ica Bunsi	14.9	6.0
11	RCB 591	14.8	6.8
37	SEF 44	14.8	8.7
49	SER 339	14.4	7.7
10	NCB 226	14.1	8.5
40	SEN 56	13.9	5.2
5	INB 47	13.4	6.1
4	INB 45	11.7	7.7
9	NAE 80	11.6	4.1

2	INB 40	6.7	3.2
14	SAB 617	5.3	9.1
17	SAB 681	3.5	9.0
13	SAB 259	1.2	4.2
19	SAB 701	0.3	0.6
20	SAB 729	0.1	0.0
	GRAND MEAN	21.1	11.2
	LSD 5 %	16.3	6.8
	CV %	39.1	30.7

2015 Drought Bean Drought Nursery grown at Scottsbluff, NE during 2015.

		Drought Stress				Non-Stress						
Ent no	PEDIGREE	Yield lbs/A	Flowering days	Maturity days	100 Seeds gr	Yield lbs/A	Flowering days	Maturity days	100 seeds gr	GM	PR %	DII
9	(USPT-ANT)x('Matterhornx98078-5-1-5-1)	2388	42	84	37.1	2828	46	92	38.3	2599	15.6	0.4
50	Stampede	1980	48	91	38.3	3330	47	95	37.2	2568	40.5	1.0
33	VAX 2	1880	47	92	29.1	3287	47	95	30.6	2486	42.8	1.0
4	(Black Rhino)x(SEN 10 (SB-DT1)	1925	47	90	23.0	3003	47	85	22.9	2404	35.9	0.8
45	Matterhorn	2178	45	85	33.7	2616	42	89	31.6	2387	16.7	0.4
51	Croissant	1694	47	89	33.9	3258	47	92	34.0	2349	48.0	1.1
46	Marquis	1680	45	86	29.5	3221	45	95	30.9	2326	47.8	1.1
49	Merlot	1870	40	76	37.9	2815	40	76	34.0	2294	33.6	0.8
48	Beryl-R	1742	42	76	26.1	2988	44	82	27.1	2282	41.7	1.0

11	Merlotx(MerlotxSER 16)	1927	46	90	35.2	2684	45	92	38.9	2274	28.2	0.7
1	(Tacana x VAX6	1699	47	93	19.3	2922	47	92	20.0	2228	41.8	1.0
17	ALB 130	1782	45	82	26.8	2782	44	83	27.0	2227	35.9	0.8
8	(Matterhorn)x(SER 21	1569	47	89	27.7	2969	47	90	29.2	2158	47.2	1.1
16	Merlotx(05F-5055-1x98020-3-1-6-2)	1460	46	90	33.8	3043	46	92	33.6	2108	52.0	1.2
42	SXB 412	1471	48	88	25.3	2990	47	90	25.3	2097	50.8	1.2
34	VAX 3	1441	47	88	27.1	2937	46	90	27.7	2057	50.9	1.2
13	Merlotx(98020-3-1-6-2xTacana)	1691	49	93	24.3	2492	49	98	26.8	2052	32.1	0.8
12	Merlotx(98020-3-1-6-2xTacana)	1350	48	95	25.5	3072	48	96	25.4	2037	56.0	1.3
14	10457	1505	45	82	30.5	2620	47	83	31.9	1986	42.5	1.0
6	(Tacana x VAX6	1471	47	91	21.4	2675	47	91	22.0	1984	45.0	1.1
35	VAX 5	1480	47	92	24.1	2447	47	93	24.7	1903	39.5	0.9
31	SXB 747	1487	47	90	19.0	2426	47	92	18.9	1900	38.7	0.9
5	(MoralesxXAN 176)x('EAP 9503-32A)	1429	47	85	25.8	2417	47	90	27.7	1858	40.9	1.0
26	SER 46	1467	48	92	25.9	2168	47	90	25.8	1783	32.3	0.8
2	(MoralesxXAN 176)x('BAT 477xB98311)	1361	48	93	19.1	2217	47	92	20.5	1737	38.6	0.9
28	SER 119	1167	47	89	26.4	2550	47	93	27.2	1725	54.2	1.3
23	SCR 14	1272	45	85	27.8	2297	47	90	28.9	1710	44.6	1.0
44	INB 816	1270	47	91	26.6	2215	47	93	26.9	1677	42.7	1.0
10	(ABCP8)x(TARS-PT03-1xVAX 6	1270	47	88	24.3	2141	47	88	23.6	1649	40.7	1.0
3	(BAT 477xL88-63)x('BelMiDak RMR10xB01741)	1023	48	94	15.6	2138	52	97	16.5	1479	52.1	1.2
30	SXB 746	1058	47	87	29.4	2065	46	92	30.9	1478	48.8	1.1

15	10486 (TARS-MST1)	936	48	85	18.3	2259	47	86	19.1	1454	58.6	1.4
7	(BelMiDak RMR10xB01741)x('BAT 477xL88-63)	777	46	87	17.3	2509	46	92	19.9	1396	69.0	1.6
	GRAND MEAN	1536	46	88	26.8	2678	46	90	27.4	2028	42.6	1.0
	LSD 5 %	500.1	3.2	7.3	1.7	988.5	2.9	5.6	2.9			
	CV %	16.0	3.4	4.1	3.2	18.1	3.1	3.1	5.2			

2015 International Center for Tropical Agriculture (CIAT) lines grown at Mitchell, NE during 2015.

		Drought Stress				Non-Stress						
Ent no	PEDIGREE	Yield lbs/A	Flowering days	Maturity days	100 Seeds gr	Yield lbs/A	Flowering days	Maturity days	100 seeds gr	GM	PR %	DII
88	Marquis	1808	42	85	29.2	2702	42	87	30.9	2210	33.1	0.8
90	Croissant	1682	46	89	33.6	2572	46	84	32.4	2080	34.6	0.8
74	SMR 109	1969	46	93	27.7	1838	48	93	30.2	1902	-7.1	-0.2
83	SMR 126	1555	46	95	30.7	2273	46	95	32.9	1880	31.6	0.7
76	SMR 112	1559	46	90	29.9	2234	46	95	31.4	1866	30.2	0.7
89	Merlot	1522	40	75	35.9	2238	39	76	38.6	1846	32.0	0.8
46	SER 332	1182	47	95	31.3	2125	48	93	28.9	1585	44.4	1.0
87	Matterhorn	1088	44	83	28.8	2275	42	85	32.3	1573	52.2	1.2
48	SER 336	1166	46	83	26.3	2096	48	91	28.3	1563	44.4	1.0
85	SXB 412	1078	46	88	23.5	2250	47	92	24.6	1557	52.1	1.2
25	SCR 51	1282	46	88	28.0	1628	46	84	26.6	1445	21.2	0.5
29	SEC 33	1161	46	88	32.8	1635	47	90	34.1	1378	29.0	0.7
60	SMC 149	1046	46	92	29.8	1803	47	95	31.6	1373	42.0	1.0
61	SMC 150	1068	47	92	31.1	1693	46	95	30.0	1344	36.9	0.9
26	SCR 53	1024	45	84	24.6	1736	46	85	24.5	1334	41.0	1.0
40	SEN 56	1135	46	81	23.9	1438	46	84	25.5	1277	21.1	0.5
62	SMC 151	885	45	87	33.7	1829	46	86	35.9	1273	51.6	1.2
47	SER 335	1168	46	84	26.3	1371	47	87	27.0	1265	14.8	0.3
86	SXB 418	1027	46	83	25.9	1548	46	84	26.4	1261	33.7	0.8
32	SEC 37	884	46	93	31.8	1795	47	95	34.6	1260	50.8	1.2
81	SMR 124	818	47	92	24.2	1896	48	96	27.0	1245	56.9	1.3
34	SEC 40	908	46	84	29.1	1703	46	93	38.7	1244	46.7	1.1
51	SER 342	833	47	88	26.0	1662	47	95	28.7	1176	49.9	1.2
45	SER 331	940	46	85	24.4	1351	47	84	22.8	1127	30.4	0.7
64	SMC 154	576	45	87	23.6	2099	45	87	30.7	1100	72.5	1.7
35	SEC 43	692	46	82	28.8	1084	47	85	27.8	866	36.2	0.8
	GRAND MEAN	1156	45	87	28.5	1880	46	89	30.1			
	LSD 5 %	636	2	7	2.9	1189	2	6	7.0			
	CV %	27	2	4	4.8	31	2	3	11.3			

Project Title

Columbia Root Knot Nematode Survey

Project Summary

The goal of this project is to facilitate the trade of Nebraska-grown potatoes and horticultural nursery stock on the international market by documenting Nebraska's freedom from Columbia root knot nematode (*Meloidogyne chitwoodi*). This will be accomplished through two objectives; 1) conducting soil sampling surveys in 50 percent of seed potato fields and 10 percent of commercial potato production fields, and three percent of horticultural nursery stock fields, by acreage, with a focus on international shippers; and 2) conducting a minimum of 50 inspections of seed potato distribution facilities to ensure compliance with the Nebraska Department of Agriculture's (NDA) Columbia root knot nematode (CRKN) quarantine.

Project Approach

2013

In late winter and early spring of 2013, Nebraska Department of Agronomy entomology staff conducted inspections of seed potato distribution facilities. Ninety two locations in 18 counties were inspected to confirm compliance with the NDA's CRKN quarantine. No violations of the quarantine were found.

In fall of 2013, Nebraska Department of Agronomy entomology staff conducted soil surveys for Columbia root knot nematode (CRKN). Fifty samples were pulled from potato and nursery fields across the state. Negative results from these soil surveys continue to uphold our freedom from CRKN status.

2014

During early spring of 2014, NDA inspectors conducted compliance inspections at 178 seed potato dealer locations in 18 counties. These inspections were to confirm compliance with NDA's CRKN quarantine, and the federal potato cyst nematode quarantine. Thirty-eight violations were found.

Goals and Outcomes Achieved

The measurable outcomes for this project include: 1) documenting the number of certificates issued for potatoes and nursery stock in 2013 and 2014; 2) disseminating survey information in the Nebraska Department of Agriculture (NDA) Entomology Program Annual Report; 3) incorporating project results on the NDA web site; and 4) inclusion of survey results on NDA Entomology Program display booth at the Nebraska Great Plains Conference.

NDA issued four federal phytosanitary certificates for nursery stock shipments to Canada since November 1, 2012. These certificates have facilitated the movement of 6,944 Nebraska grown nursery stock plants to Canada. Additionally, 21 Federal phytosanitary certificates were issued for Nebraska grown seed potatoes to Canada, Brazil, and the Dominican Republic, totaling 772,394 pounds. Each of these shipments were possible because of the soil sampling conducted by NDA.

NDA disseminated information on CRKN activities at the Nebraska Great Plains Conference in Lincoln, January 2013, and 2014. This included information on each year's survey results and violations found. This event had 800 registered attendees from the nursery, landscape and forestry industries. Additional outreach was conducted at the Governor's Ag Conference, held February 2013 and 2014, with 200 attendees; Great Plains Nebraska Nursery and Landscape Association/NAA Summer Field Day, August 2013 and 2014, with approximate attendance of 75 individuals from the nursery and arborist industries; the Nebraska State Fair, August, 2013, with attendance of 335,000 individuals; and Husker Harvest Days, September 2014, with attendance around 300,000. Project results were updated on the NDA website at the conclusion of each trapping season.

Beneficiaries

The results from this survey facilitated product shipments by three potato producers and two nursery producers to out-of-state customers. The potato firms sent 21 shipments totaling 772, 394 pounds to Brazil, Canada, and the Dominican Republic. Two of our nursery growers sent four shipments totaling 7,000 plants to Canada. Exports from our state are required to be free from Columbia root knot nematode, and this survey allows us to maintain that certification. Without this survey our products would not meet the certification requirements of the foreign countries.

Lessons Learned

This survey is vital to the shipment of products from Nebraska on the foreign market and it also allows us to uphold our quarantine for Columbia root knot nematode. Our inspectors check shipments of seed potatoes from other states to make sure they meet our quarantine requirements for entry. In 2014, we found 38 violations of our state quarantine. Each violation may require significant time and resources to document violations, track down paperwork and products, and witness destruction of the product. The inspector might have to make multiple trips to the store to gather paperwork or witness destruction and this can be very time consuming. Our inspectors have become very competent in inspecting these potatoes and have worked hard to keep Nebraska's potato industry safe from foreign nematodes.
The survey has improved communication between the potato industry and this program, which has allowed for us to better understand their needs and concerns, and respond appropriately. Industry is becoming more proactive in requesting survey activity, particularly as new markets appear likely to open.

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Project Title

Utilizing Specialty Crops to Entice and Educate New Farming Entrepreneurs

Project Summary

Historically, the majorities of fruits available to the South Sioux City, Nebraska, area were supplied via the local supermarket and were either imported or shipped from large farming operations outside of the local geographic region. As a result, the availability of healthy, locally grown fresh fruits was often in limited supply. Furthermore, there has been a large influx of immigrants who have moved to South Sioux City, Nebraska, and the vast majorities originate from countries and cultures where fresh produce, specifically fresh fruit, are staples of their diets. As a result, there was a growing need in the community to expand the availability of specialty crops, specifically fresh fruits, available in this area.

In an effort to meet the growing demand among the local immigrant populations for the availability of fresh fruits and to provide the opportunity for those who had expressed an interest in learning to plant, grow, harvest and market fresh fruits, the City of South Sioux City sought to attract and recruit new farming entrepreneurs, specifically targeting individuals from the various immigrant populations, to support them in their request to increase the availability of fresh, locally grown specialty crops such as fruits like cherries, apples, apricots and pears.

To accomplish this goal, the City of South Sioux City partnered with the Center for Rural Affairs, the University of Nebraska – Lincoln Extension, and the Nebraska Forest Service. They also recruited an AmeriCorps*VISTA to develop an outreach educational program, similar to the Community Garden program already established in the community. This team worked to recruit a minimum of ten (10) new farmers and focused on developing an educational tract specific to planting, growing and harvesting fresh produce with an emphasis on fruits native to the region.

The timeline for the project had year one focusing on the recruitment of a minimum of 10 new farmers interested in learning more about specialty crops and starting their own fresh fruit and produce plots. Year two and three were utilized to teach a curriculum that focused on planting, growing, harvesting and marketing specialty crops, with an emphasis on fruits. Years two and three extended upon class work to include hands on experience in planting, growing and management of 203 fruit tress of numerous varieties on a 7 acre area of land, donated by the City, for the project. Ultimately, the goal was to:

1. Provide an educational opportunity to entice and educate new farming entrepreneurs interested in starting their own fresh produce farms;

2. Utilize their hands on learning experiences to develop a Community Orchard to serve as an outdoor classroom; and

3. Provide a readily available source of fresh produce for the residents of the Community.

Following a period of several months during which a marketing campaign was used to attract new farmers to the program, the partners came together to develop a curriculum designed to educate the new farmers recruited on growing, raising, harvesting and marketing the crops they grew.

Project Approach

The team embarked on an aggressive marketing and outreach campaign to promote and garner public interest and support of the program during the first 6 months of the program. A presentation was given at the Nebraska Recreation and Parks Association Conference to an audience of 10 public officials from various Nebraska communities. Three local newspapers ran stories advertising the orchard classes including the *Lincoln Journal Star*, *Omaha World Herald*, *Dakota County Star*, the *Sioux City Journal*, and *Mundo Latino*. Targeted outreach was also conducted to those already participating in the community gardens and local garden groups. As a result of the presentations to local community gardeners, four new Latino community members registered for the classes.

South Sioux City also formed a partnership with the Mary J. Treglia Community House in Sioux City, Iowa, to provide Spanish language interpretation services for those whose primary language was not classes. This was an invaluable asset to improve outreach to the Latino community.

The first orchard class of the series was held on October 5, 2013. Vaughn Hammond, who was a UNL Extension Educator, was the instructor and 14 students attended the class. The average attendance of the classes in the first year was between 11 – 13 people. The topics covered in the classes included orchard establishment, apples, and other tree fruits. All of the class participants in year one pledged their commitment to continuing in the following consecutive years.

During the final two years of the program, the emphasis was on ensuring the curriculum developed was translated and available in both English and Spanish. On May 10, 2014, 16 participants from the class and 32 other community volunteers planted 203 fruit trees in the outdoor experiential classroom area that was also identified as a community orchard. Classes were expanded to include a brief overview on safe food handling practices and were identified as a critical expansion of the overall project. Throughout both years, the average number of class participants averaged between 11 – 16 people. In the final year, the primary objective was to identify key components that would expand the knowledge base, with a specific emphasis on safe food handling practices and how new farmers could contribute to the current food desert that exists within the region.

In 2014 and 2015, several class participants featured the work they were doing at the Siouxland Garden Show and provided presentations to small groups that averaged from 5 – 8 participants.

Overall, the entire success of the project can be contributed to the number of hours and knowledge from the University of Nebraska – Lincoln Extension, key educators, the Nebraska Forest Service, and support services from the Mary J Treglia House. The entire curriculum, class schedule and training for the new specialty crop farmers made this program a success because of their contribution and dedication to this project.

The program more than exceeded the goals set forth in recruiting a minimum of 10 new farmers to grow specialty crops. Over the course of the three years, the average class size was 13 participants. All 13 students reported having demonstrated a consistent level of participation and received a graduation certificate for completing the course. The 13 students represented a variety of ethnicities.

Harvesting and selling of produce hasn't occurred to date as the recommendation from the partners and experts were to use smaller trees in the orchard to establish a better foundation for the future. As a result, the trees will take longer to mature and bear fruit. It was felt that this was the best route to take in order to establish as successful orchard and teach the new farmers the reality of what it takes to start a specialty crop program involving fruit-bearing trees. However, it is important to note, that all class graduates were taught on proper harvesting methods and how to market and sell their produce. They were also given the opportunity to test their new skills in utilizing produce from the local community garden to sell at the local farmers' market.

Goals and Outcomes Achieved

Below are the identified goals, performance measures, baseline data, and corresponding results of the program.

Goal #1: Local marketing campaign to recruit new farming entrepreneurs interested in growing specialty crops in the area.

Performance Measure: A minimum of three (3) local advertising mediums including the city newsletter, variable message sign, local newspaper, presentation at local events, postings at the library and social media were utilized to promote farming (with specific emphasis to target immigrant populations) and encourage those interested to sign-up to take part in the community orchard project.

Target: A minimum of ten (10) new farming entrepreneurs interested in growing specialty crops will sign up for the project as a result of the marketing campaign.

Result: Although the class sizes often varied between 10 to 16 participants, the program graduated 13 new farmers from the program.

Goal #2: A minimum of ten (10) new farming entrepreneurs, who are recruited from the marketing campaign, will have obtained the necessary education and skills to plant, grow, care for, harvest, preserve and market specialty crops.

Performance Measure: The ten (10) new farming entrepreneurs successfully demonstrated that they have gained the necessary skills and education, as evidenced by attending classes taught by the Nebraska Forest Service and University of Nebraska – Lincoln Extension and meeting all the requirements necessary to earn a certification of completion. Requirements included the ability to translate what was learned in coursework into real-world experience as evidenced by their successful demonstration of the skills learned through hands-on exercises designed to measure their understanding of what was taught.

Target: Certificate of Completion received by a minimum of 10 new farming entrepreneurs

Result: 13 new farming entrepreneurs received certificates for completing the educational program.

Goal #3: Increase the number of specialty crops, specific to fruit, available for sale at local markets and consumption by local residents.

Performance Measure: A minimum of four (4) new specialty crops were to be introduced to the new farming entrepreneurs to plant, grow, harvest and sell at local markets. (Cherries, Apricots, plums and pears were provided to the new farming entrepreneurs).

Target: A Minimum of four (4) new specialty fruits will be sold at local markets in the area.

Result: Although more than 10 varieties of specialty fruits have been planted in the orchard, experts recommended that small trees be planted to establish a better foundation for the future. As a result, the trees took take longer to mature and bear fruit. It was felt that this was the best route to take in order to establish as successful orchard and teach the new farmers the reality of what it takes to start a specialty crop program involving fruit-bearing trees. However, the stage is set for this to occur in the next couple of years.

Beneficiaries

Groups that have benefited from this project include the entire South Sioux City, Nebraska community. As a result of this educational program to recruit new farming entrepreneur interested in specialty crops, the community as, a whole, has benefited from their educational and hands on experience. This has enabled the community to be the beneficiary of a new community orchard that will not only continue to provide educational opportunities for new farming entrepreneurs, but will serve as a local fresh food source for those living at poverty level. The City of South Sioux City has a population of 13,353 residents and there are locations in this community in which more than 60% of the residents are living at or below poverty level. The introduction of a community orchard acts as a secondary benefit to the educational training the 13 new graduates of the new farming entrepreneurs program. It will help alleviate the burden placed on local non-profit entities and local charities as they struggle to provide healthy and viable food resources for those in the greatest need. Furthermore, the 13 new farming entrepreneurs of the program have acquired the skills and education necessary for them to develop a viable source of income for themselves and their family. The potential economic impact, although difficult to quantify at this time, is estimated to significantly reduce the fiscal burden on local resources for providing food for those in need, all the while, offering a significant financial opportunity for the graduates to establish their own specialty group business.

Lessons Learned

The most significant lesson learned was that sometimes programs take time to evolve and when experts in the field of specialty crops, specific to fruit, recommend starting with smaller trees and allowing them to mature and establish a solid root system as being critical, it resulted in an unexpected deviation in the program that required good problem solving skills. Although the new farming entrepreneurs were not able to harvest fruit they helped plant, grow and care for, they were still provided education on how to harvest and market specialty crops. In the future, programs that involve planting will require better investigation to ensure that the deliverables can be obtained in a timely manner to meet the performance measurements identified for the program.

One of the greatest unexpected outcomes was the overwhelming recognition that the community orchard and the work the new farming entrepreneurs received as a result of their involvement in the program. The Community Orchard Program has been featured in a number of news articles touting the success of this program.

As a result of the heavy rains in 2014, a large number of trees were oversaturated. With more than 18 inches of rain in the month of June alone, survival was difficult at best. The rains, along with some trees being planted too deep, also caused some to settle. However, this issue was mitigated on October 24, when class participants and volunteers from the community met at the orchard to help raise the trees and fill in the area that had settled around them.

We also had difficulty reaching the Latino community and other minority groups. Attendance by these groups was disproportionately small compared to the overall population of ethnic groups in South Sioux City. Although the Latino community demonstrated a greater interest in the program, reaching other minority groups was difficult. Efforts will continue to attempt to engage them.

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Additional Informaiton

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http://siouxcityjournal.com/special-section/siouxland_business/community-orchard-planned-for-south-sioux-city/article_a9169413-a21f-53ec-b5b5-bdc924da97dc.html

http://siouxcityjournal.com/uploaded_images/south-sioux-city-orchard/image_e4510a17-5c4d-5b74-a4db-d9deffa0e92e.html

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http://www.ktiv.com/story/29828842/2015/08/18/parks-rec-director-hopes-new-south-sioux-city-orchard-inspires-others

http://norfolkdailynews.com/news/orchard-grows-food-sprouts-education-on-raising-fruit-trees/article_eb2c0a04-4f49-11e5-a312-d78cee822e1c.html

Project Title

Growing Potato Starch under Dryland Conditions in Western Nebraska

Project Summary

Due to the high value of fresh and fry markets, growing potatoes specifically for the dehydration market, i.e., starch and dry matter, is not economically feasible under conventional practices. For dry matter-specific production to be feasible, the input costs need to be reduced, meaning no irrigation, no pesticides, etc.

Most of the cost of production is the price of seed potato tubers themselves. By not using pesticides or synthetic fertilizers, i.e., organic production practices, the dry matter and starch produced could be used in organic-based dehydration products as well as conventional products.

Potato tubers grown as raw material for dehydrated products do not need to be, and usually are not, market quality. Therefore, to lower potato seed tuber cost, determining the most economical seed-piece size and spacing of a high-starch cultivar is essential for success.

To date, there has not been any completed study of growing potatoes specifically for starch production using sustainable agricultural practices under semi-arid conditions. Western Nebraska is an ideal location for such a study due to its rich soil, dry climate, and low disease and insect pressures.

The objective of this study is to produce a high-yielding potato crop, with high dry matter, under dryland conditions, utilizing the principles of sustainable agriculture to keep costs to a minimum. The specific objective is to lower production cost by comparing five plant spacings and five seed-piece weights for high-yield and high-dry matter content using the potato cultivar, Atlantic.

In preliminary testing of several varieties, Atlantic was found to be the best under these circumstances. The goal is to be able to economically produce a high-yielding potato crop with high dry matter content under dryland conditions and using organic farming practices. The principle reasons motivating growers and industry in this study are:

1. To establish a consistent source of potato dry matter so that dependency on culls is avoided,
2. To produce raw potatoes without the use of pesticides, and
3. To be able to provide potato dry matter and starch organic products to consumers.

Project Approach

Seed tubers of the potato cultivar Atlantic were cut into five size/weight classes, 1.5, 2, 2.25, 2.5, and 3 ounces. They were allowed to suberize (heal) at 60° to 70°F and acclimate for a few weeks before planting. Planting was in early May according to soil temperature. Seed-pieces were planted 6, 9, 12, 15, and 18 inches apart in 36-inch rows at a 4-inch depth using a horizontal-cup planter for precision planting. No pesticides or fertilizer were added. Mechanical cultivation was used twice for weed control and once at the end of the season to aid harvest. Soil samples were taken at the start and conclusion of the season to determine moisture and

nitrogen contents.

Plants were observed throughout the season for unusual growth patterns. Tubers were harvested in October to achieve maximum yield and tuber maturity. Yields were weighed and specific gravity determined using a hydrometer after harvest. Dry matter and starch contents can be calculated using an established formula. Plots consisted of two rows, 45 feet long and 36 inches apart. Each seed size by seed spacing plot were replicated five times in a factorial design, resulting in: 25 treatments, five seed sizes and five seed spacings, in a total of 125 plots.

Statistical analysis used SAS software. A n economic analysis was conducted at the end of the project, to evaluate the economic feasibility of dry matter production in western Nebraska in 2013.

Goals and Outcomes Achieved

The overall goal of this study was to determine the feasibility of growing potatoes under semi-arid conditions using sustainable, organic farming practices in western Nebraska. The following summarizes the results and conclusions following the format listed under "Expected Measurable Outcomes" in the project proposal.

1. "The immediate expected outcome was to identify the most economical seed-piece size and spacing to lower the cost of seed potatoes while producing the greatest amount of starch. This would make it profitable to grow potatoes specifically for starch."

There was a significant difference in yield between different seed-piece spacing while there was no significant yield differences based seed-piece weight, i.e., size (see Table 1). The highest yields occurred with placing seed-pieces six or nine inches apart. At these spacings, yield was 16% higher than at 12-, 15- or 18-inch spacings. Therefore, if highest yield was the goal, then 2 oz. seed-pieces planted close together would accomplish that goal.

Table 1. Yield in cwt/acre, 2013.

Seed Spacing (in)	Seed Size in Ounces (oz)					
	1.5	2.0	2.25	2.5	3.0	Mean
6	103	107	96	98	108	102 A*
9	106	97	103	114	104	105 A
12	85	92	91	88	84	88 B
15	85	93	92	88	88	89 B

18	88	91	95	92	83	90 B
Mean	93	96	95	96	93	95

* Numbers in column followed by the same capital letter are not significantly different at the 95% confidence level.

Another key tuber characteristic is the amount of dry matter produced. Dry matter content is generally calculated from the tuber specific gravity. Both seed-piece size and spacing affect tuber specific gravity (See Table 2). The highest dry matter content of 22.0% (specific gravity = 1.086), occurred with six-inch spacing of seed-pieces weighing between 2 and 3 oz. The other seed spacings' dry matter content was 21.1% (specific gravity = 1.082). Comparing yield to dry matter content would show that dry matter yield of six-inch spaced, 2 ounce seed-pieces, would be 2,244 lbs./acre as opposed to that of 15-inch spaced, 2 ounce. seed-pieces which would be 1,963 lbs./acre, 13% less in comparison. Is the highest material return per acre the most economical?

Table 2. Specific Gravity (1.0xx), 2013

Seed Spacing (in)	Seed Size in Ounces (oz)					
	1.5	2.0	2.25	2.5	3.0	Mean
6	84	86	87	86	88	86 A*
9	83	81	85	84	84	83 B
12	78	80	86	85	83	82 B
15	81	82	82	80	81	82 B
18	81	82	81	81	84	81 B
Mean	81 B**	82 AB	84 A	83 AB	84 A	83

* Numbers in column followed by the same capital letter are not significantly different at the 95% confidence level. ** Numbers in row followed by the same capital letter are not significantly different at the 95% confidence level.

2. "Since in order to lower input costs, the starch produced requires using organic practices, a potential new market could develop, e.g. organic reconstituted chips."

The field project successfully grew potato tubers without the use of any pesticides. Disease and insect infestations did not occur. Weed pressure was minimal and controlled using two early-

season mechanical cultivation passes. No fertilizer was applied. Potatoes were planted following dry bean harvest and residual nitrogen was 21 lbs./acre in the top 16 inches of soil. Therefore, practices were such that organic raw material was produced which is suitable for the organic dry matter market.

3. “Performance of the potato plants will be measured throughout the season using plant growth determinations, weed competitiveness, and tracking production costs.”

Emergence was normal, occurring at the end of May, 18 days after planting. There was a lower percentage stand of plants with six and nine-inch spacings when compared to larger spacings (66% vs. 96%); and with 1.5 ounce seed-pieces compared to heavier ones (69% vs. 82%).

Flowering was visually estimated bi-weekly from June to August. Significantly earlier flowering occurred with closer spacings than with longer spacings. Seed-piece size had no effect on flowering.

The percent of senescence (vine death) was visually estimated in mid-September. The vines of heavier seed-pieces senesced sooner than lighter ones. Seed-piece spacing had no effect on senescence timing.

4. “The target is to reduce seed tuber cost to an economically optimal level and to reduce operation cost so that the total cost would be marginally above that of the seed cost.”

Careful record-keeping of minimal production inputs, excluding seed tuber costs, were performed. It was estimated that planting cost were $20/acre; four cultivation passes at $5/each were $20/acre; and harvesting cost was $30/acre. The total operating costs were $65-70/acre. Note that there was no irrigation cost.

5. “This could be accomplished by measuring the optimal plant spacings and seed-piece weights using the high-yielding and high-starch, chipping cultivar ‘Atlantic’. The principle measurable outcomes of the field study are tuber and starch yields, and economic return. The economic return will be calculated based on market prices paid by dehydrators such as those making reconstituted potato chips averaging over years at the end of the study with the aid of an economist and the cooperating local potato grower, Western Potato Inc., to identify economic success of project.”

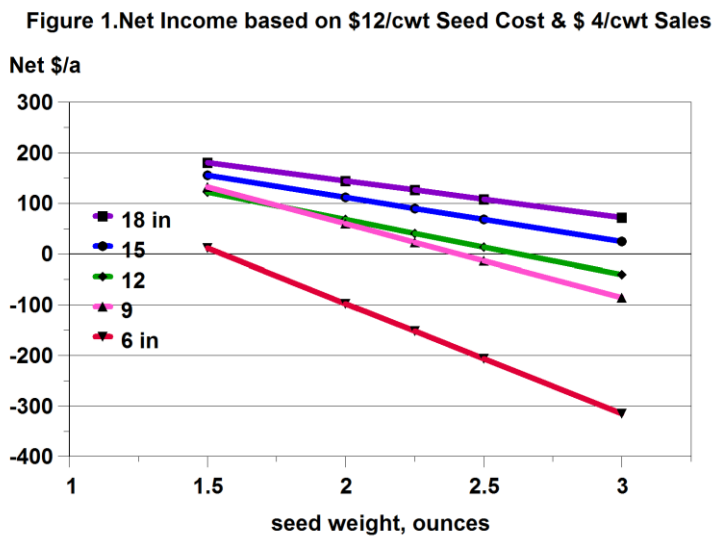
From discussions with potato growers in the Nebraska Panhandle, seed tuber costs were identified to be up to $11/cwt, plus $1/cwt for cutting, or a total of up to $12/cwt (note that this is a high estimate)..

Calculating the amount of potato seed-pieces planted per acre for the various combinations of seed-piece spacing and size, the amount of seed tuber to be purchased ranged from 9.08 cwt/acre (18-inch spacing and 1.5 ounce seed-piece) to 54.45 cwt/acre (6-inch spacing and 3 ounce seed-piece). Therefore, the cost of the seed ranged from $108.96/acre to $653.40/acre. Adding the $70/acre fixed production cost, the production cost ranged from $179 to $723/acre.

Discussing purchasing cost with consulting dehydration companies, the range of purchasing over years was $3.50 to $5.50/cwt yield. This was for conventionally-produced harvest and not for organically-produced tubers as the latter market would be new and relatively unknown.

Using the price of $4.00/cwt, the gross income per acre was calculated based on yield. Then, the production cost, which varied based on seed-piece spacing and size, was subtracted from

sale price to calculate the net return or profit (See Figure 1 showing the return). Note that the spacing by size combinations that yielded the highest were the least profitable. For the highest profit, spacing further apart and using lighter seed-pieces could achieve profits greater than $100/acre (See Figure 1)



6. “The one distinct and measurable outcome external to the project will be the interest and planning of dehydrators such as Proctor and Gamble to contract dryland acreage for potato starch production thereby developing dryland potato acreage.”

The economics of producing potatoes under this scenario was compared to production of dryland millet and wheat for profitability. Table 3 summarizes one comparison based on a low potato yield of 90 cwt/acre, high potato seed price of $12/cwt, and a low sale price of $4/cwt. As can be seen, potatoes, when properly sized and spaced at planting, can result in a higher profit to growers than wheat or millet (See Table 3).

Table 3. Comparison of Potato to Millet and Wheat, 2013.

Expenses	Millet	Winter Wheat	Potato
operation	$ 75	$ 80	$ 70
seed	$ 7	$ 25	$ 145
pesticides	$ 13	$ 30	0
fertilizer	$ 25	$ 60	0

total expenses	$ 120/acre	$ 195/acre	$ 215/acre
yield	40 bu/a	40 bu/a	90 cwt/a
price	$ 4.80/bu	$ 6.80/bu	$ 4.00/cwt
gross	$ 190/a	$ 270/a	$ 360/a
net	$ 80/a	$ 75/a	$ 145/a

7. "For sufficient information to be accumulated to interest a dehydrator and for scientific dissemination, this project would need to be repeated over future grant periods. But, if grant funding concludes after only one period, the one-year data will still be presented to large dehydrators for their consideration and an Extension notice will be released for grower information."

This study has been funded for a second year (see Annual Report on 18-13-236), and funding for the third and final year has been approved. Preliminary information was published (Pavlista, A.D. 2013. Organic dryland potatoes for starch in western Nebraska. Amer. Jour. of Potato Research 90 (2):144). Contact has been on-going with the two dehydration-product companies interested in this study to identify the feasibility of contracting growers for production.

Beneficiaries

The results of this year's project were disseminated to target audiences. The target audiences are potato growers, scientists and industry representatives.

Presentations in the first year (2013-2014) of this study were made to:

1. Nebraska potato growers on a personal informal basis - target audience = 20.
2. The Central Great Plains Working Group in August 2014 in Sidney, NE - target audience = 50; researchers, from the University of Nebraska, Colorado State University, Kansas State University, University of Wyoming, South Dakota State University and USDA-ARS in Colorado at the dryland cropping session.
3. The Potato Association of America in July 2014 in Spokane, WA - target audience = 300, USA and Canadian potato growers, University, USDA-ARS and Ag-Canada researchers.
4. The NCCC215 ("Potato Genetics and Breeding Program") in Dec, 2013 in Chicago IL - target audience = 60, north-central region potato growers, potato scientists and USDA representatives.
5. Preliminary findings were published in *The American Journal of Potato Research*; see reference above.

Plans already set for 2015 include presentations to:

1. The Organic Farmer's Conference in February 2015 in Torrington, Wyoming - target audience = 50.

2. The Nebraska Potato Development Com. in March 2015 in Kearney, Nebraska - target audience = 20.

3. The Central Great Plains Working Group in August 2015 in Akron, Colorado - target audience = 50.

4. The Potato Association of America in July 2015 in Portland, Maine - target audience = 300.

5. The American Association of Horticultural Science in August 2015 in New Orleans, Louisiana - target audience = 500.

Long-term plans for dissemination at the study's conclusion are:

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

2. Scientific Community - target audience = 1,000+, a manuscript for submission to the *American Journal of Potato Research*, the journal of The PAA, will be prepared in 2016.

3. Growers - target audience = 1,000, a University of Nebraska Extension publication is planned in 2016-17 on the cost of growing potatoes for the dehydration industry.

4. Dehydration Industry - target audience = 2-4 corporations, presentations will be made to companies with interest in contracted dry matter / starch production and organic dry matter products for consumers.

Lessons Learned

The two primary unexpected outcomes from this first year are:

1. The seed-piece size and spacing combinations resulting in the highest yield were the least profitable ('less is more' concept).

2. That growing dryland potatoes organically can be at least as profitable as growing winter wheat or millet in western Nebraska.

From this first year's data, a recommendation/hypothesis may be tentatively formulated: For profitability greater than $100/acre, plant the seed-pieces (about 2 oz. in weight), and space them 15 to 18 inches apart. These parameters will result in plantings between 12 and 14½ cwt/acre, and a population density ranging between 9,700 to 11,600 plants/acre.

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Additional Information

Below is a link that illustrates an example of a weekly report electronically distributed to the growers, reporting numbers, life stages, trending graphs and backward wind trajectories as described.
http://www.nebraskapotatoes.com/html/Psyllid/Example%20Weekly%20Report%20for%20SCBG%20Report.pdf

Project Title

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

Project Summary

Fenugreek, an annual legume and known to possess a number 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. 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. This project focused on identifying cultivars with high seed potential and germplasm source for high nutraceutical compound in western Nebraska. This document presents germplasm evaluation results (2013 phenotypic data and medicinal compounds data generated in 2014 using 2013 harvested seed), variety testing results of three site-years data under irrigation (Scottsbluff 2013, Scottsbluff 2014, and Sidney 2014), and three years of extension and outreach activities (2013, 2014, and 2015). A total of 155 PI lines were evaluated in 2013 field trials under irrigation in Scottsbluff. All the lines flowered between 37 to 47 days after planting. Wide variation was found in plant height (30 cm - 69 cm.) and seed size (5 g - 24 g/1000 seeds). Similar variation was also found in medicinal compounds galactomannan (7.45% – 31.30%) and diosgenin (0.53% - 4.46%).
Average seed yield was 1631 kg/ha and it ranged from 1250 kg/ha (PI 251640) to 1944 kg/ha (PI 141725). Four lines (three from Iran and one from Canada) produced seed yield, which was significantly higher than that of 'Tristar', the only two publicly available cultivars of fenugreek in North America. Average values of diosgenin, galactomannan and 4-hydroxyisoleucine were 1.08% (0.49% to 1.72%), 12.26% (8.07% to 14.76%), and 1.8% (1.34% and 2.05%), respectively. The results of this study were disseminated to over 900 people, which consisted of growers, agriculture industry personnel, scientists, and the general public. The 4-hydroxy isoleucine of 2013 germplasm could not be completed.

Project Approach

A total of 155 PI lines were planted as 5 foot x 12.5 foot single plots (132 lines) and 10 foot rows (23 lines) at Scottsbluff, Nebraska (under irrigation) on May 16, 2013. Of 155 PI lines, 143 were tested in 2012 season and 12 were new lines. The trial were harvested on October 1, 2014. Fourteen cultivars were used in 2013 and 2014 for variety testing. This includes the same 8 tested in 2012 and 6 new PI lines; five were from Iran and one from Ethiopia. The trials were planted with 4 replications on April, 16, 2013 at Scottsbluff with irrigation and May 8, 2013, at High Plains Ag. Lab (HPAL, near Sidney) under dryland (rain-fed) and irrigation. The trials were planted as 8-rows plot (5 foot x 25 foot) with 7.5 inch row spacing using seeding rate of 20 kg/ha. The trial at Scottsbluff was harvested on October 1, 2013. The variety trial at Sidney was repeated in 2014 since the 2013 trial at HPAL failed due to weather conditions. The 2014 trial was planted on May 27 and harvested October 7 following same planting parameters mentioned above. Sonolan @4oz./acre was used as pre-plant herbicide and Raptor @ 4 oz./acre was applied as post-emergence herbicide in all trials. Approximately 0.25 inches water was applied within 24 hrs after planting to activate Sonolan and to allow for better emergence. After this initial irrigation, the dryland trial was not irrigated but the irrigated trials were irrigated throughout the season.

Flowering (50% level) and plant height (at maturity) were recorded. Seeds harvested from the trials were used for yield, seed size and medicinal compounds assay.

Goals and Outcomes Achieved

Evaluation of selected fenugreek germplasm based on results of previous project grown under irrigation for nutraceutical compounds - diosgenin, galactomannans and 4-hydroxyl isoleucine; and their production potential

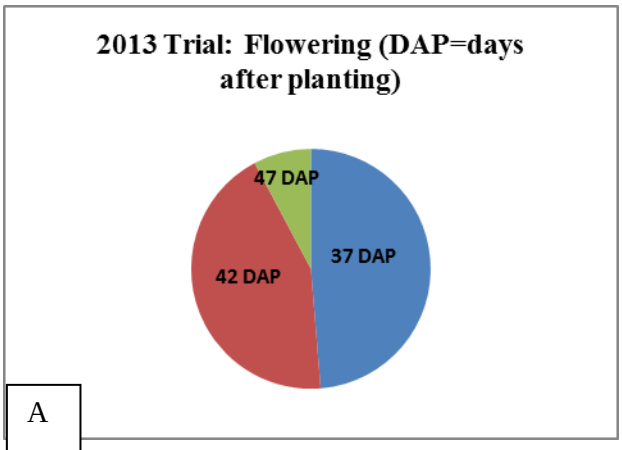
The below table shows a summary of the results of the PI lines tested in 2013 (Table 1). All the 155 PI lines flowered between 37 to 45 days after planting (Figure 1A). Approximately 48% (75 lines), 43% (67 lines) and 8% lines (13 lines) flowered 37, 42 and 47 days after planting, respectively. Plant height ranged from 30 cm to 69 cm (Figure.1B). Majority of the lines (62%) ranged within 41 cm to 55 cm. Seed size also varied significantly from 5g (PI269992, Pakistan) to 24g (PI212922, India) per 1000 seeds (Fig.C). Medicinal compounds diosgenin (Fig.2A) and galactomannan (Fig.2B) ranged from 0.53% to 4.46% and 7.45% to 31.30%, respectively.

Table 1. Country of origin of 155 PI lines and their trait values based on field trials under irrigation in 2013 in Scottsbluff, Nebraska.

Country	Number of lines	Flowering (DAP)*	Plant height (cm)	1000 seed weight (g)	Diosgenin %	Galactomannan %
Afghanistan	12	**37** - **47**	38 - 61	11 - 18	1.55 - 2.94	11 - 19.7
Angola	1	42	43	10	1.57	16.60
Armenia	1	42	56	17	1.45	11.83
Australia	2	**37**	44, 56	15	3.00	14.76, 15.96
Bulgaria	5	**37** - 42	**30** - 66	15 - 18	2.37 - 3.36	16.86 - 18.21
Egypt	6	**37** - **47**	**30** - 64	11 - 18	1.15 - 2.82	10.66 - 19.55
Ethiopia	13	**37** - **47**	33 - 51	11 - 22	**0.53** - 3.23	11.75 - **31.30**
Greece	1	**37**	48	21	1.29	14.93
India	27	**37** - 42	36 - 64	8 - **24**	0.63 - 3.27	**7.41** - 20.11
Iran	27	**37** - **47**	36 - 58	9 - 21	0.76 - **4.46**	13.03 - 19.47
Italy	1	42	51	21	1.26	13.69
Jordon	2	**37**	46, 48	10, 21	1.77, 2.17	14.96, 15.50
Morocco	6	**37** - 42	**30** - 53	7 - 19	0.81 - 3.16	14.03 - 17.22
Nepal	4	**37** - 42	36 - 64	10 - 19	1.50 - 2.68	14.38 - 16.51

Pakistan	22	**37** - **47**	**30** - **69**	**5** - 22	0.71 - 3.12	8.83 - 18.04
Spain	4	42 - **47**	33 - 48	10 - 17	1.12 - 2.30	12.78 -17.16
Syria	2	**37**	38, 51	18, 22	1.81, 2.10	15, 15.63
Turkey	17	**37** - **47**	36 - 58	10 - 21	0.60 - 3.22	10.35 - 19.45
Yemen	1	**37**	46	19	2.40	15.87
Unknown	1	**37**	41	17	1.74	15.34
Total/Av.	155	40	47	15	1.97	15.69
Data ranges	1-27	37-47	30-69	5-24	0.53 – 4.46	7.45 – 31.30
Lowest value		37	30	5	0.53	7.45
	Line	Majority		PI 269992	PI 194022	PI 180351
	Country	Multiple	Several	Pakistan	Ethiopia	India
Highest value		47	69	24	4.46	31.30
	Line	Several	PI532861 & PI426970	PI212922	PI226679	PI195691
	Country	Multiple	Pakistan	India	Iran	Ethiopia

*Days after planting; Lowest and highest values are in **bold**



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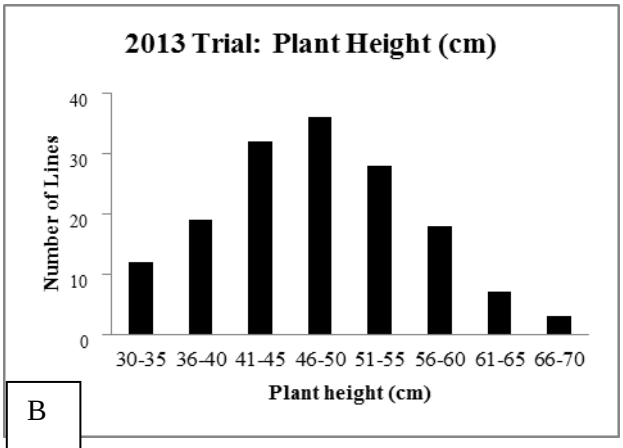

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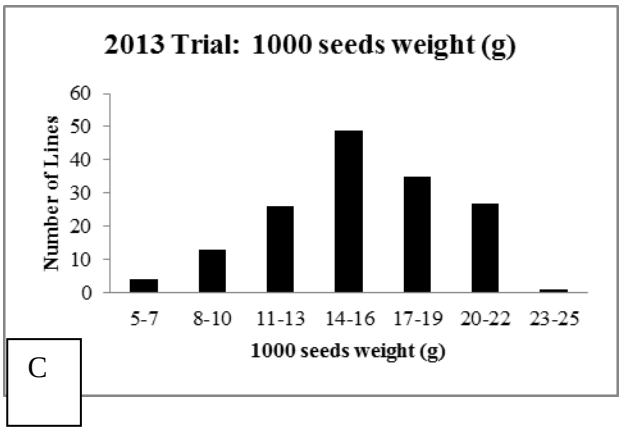

Figure 1: Frequency distribution of flowering time (A) and plant height (B), seed weight (C) of 155 PI lines tested in Scottsbluff, Nebraska under irrigation in 2013.

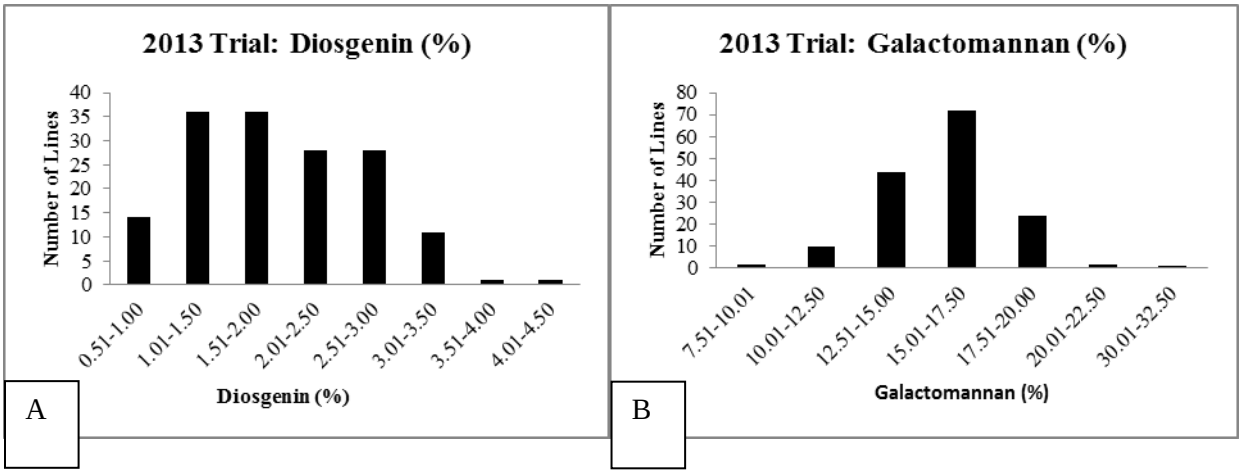

Figure 2: Frequency distribution of diosgenin (A) and galactomannan (B) of 155 PI lines tested in Scottsbluff, Nebraska under irrigation in 2013.

Evaluation of varieties for seed yield potential under dryland and irrigated condition.

Seed yield data from three irrigated trials (Scottsbluff 2013, Scottsbluff 2014, and Sidney 2014) is presented in Table 2. Average seed yield was 1631 kg/ha and it ranged from 1250 kg/ha (PI 251640) to 1944 kg/ha (PI 141725). Four lines (three from Iran and one from Canada) produced seed yield, which was significantly higher than that of 'Tristar', the only two publicly available cultivars of fenugreek in North America. Seed yields of PI41725, PI138954, L3708, and PI141728 were 35% and 29%, 24%, and 23%, higher than the Tristar, respectively. The 1000 seeds weight of the 14 cultivars was 10.31 g and ranged from 6.66 g to 13 g. Similar to the 155 PI lines, the cultivars also varied significantly in galactomannan, diosgenin and 4-hydroxyisoleucine. Average values of diosgenin, galactomannan and 4-hydroxyisoleucine were 1.08% (0.49% to 1.72%), 12.26% (8.07% to 14.76%), and 1.8% (1.34% and 2.05%), respectively. Tristar was similar in diosgenin (1.18%), galactoamannan (9.55%), and 4-hydroxyisoleucine (1.34%).

Table-2. Fenugreek variety trial (irrigated) results across three site-years (Seed yield was based on average of Scottsbluff 2013, 2014 and Sidney 2014. All other data was from Scottsbluff 2013).

Variety	Country	Yield rank	Seed Yield (kg/ha)	1000 seed weight (g)	Diosgenin %	Galactomannan %	4-Hydroxy isoleucine %
PI141725	Iran	1	1944	6.66	0.5	12.34	1.61
PI138954	Iran	2	1856	7	1.16	8.07	2.03
L3708	Canada	3	1788	13	1.35	14.07	1.81
PI141728	Iran	4	1772	7.66	0.91	13.47	1.9
PI141726	Iran	5	1733	8.33	0.49	14.5	1.68
F18	India	6	1711	10.66	1.21	14.76	1.88
PI141724	Iran	7	1699	8.66	0.54	12.64	2.05
F70	India	8	1686	12	0.99	14.49	1.69
L3068	Canada	9	1615	11.33	1.72	12.36	1.94
L3375	Canada	10	1525	11	1.23	9.34	1.88
Tristar*	Canada	11	1440	12.66	1.18	9.55	1.34
L3308	Canada	12	1420	12.33	1.34	13.01	1.67
Amber	Canada	13	1397	12.33	1.18	9.57	1.88
PI251640	Ethiopia	14	1250	10.66	1.26	13.42	1.81
Mean			**1631**	**10.31**	**1.08**	**12.26**	**1.8**
LSD (0.05)			**330**	**1.37**	**0.48**	**3.3**	**0.48**

* North American publicly available non-medicinal cultivar (developed by Agri-Canada)

Beneficiaries

The results and findings of this study were disseminated to the target audiences and it will continue beyond the life of this project. The target audiences to whom this information was presented to included growers, agriculture industry personnel, scientists, and the general public. Project results were presented in a variety of different ways. They included the following:

1. Hosted a Fenugreek Field Day at HPAL in Sidney on August 6, 2013. Approximately 90 people attended this event.

2. Presented information to the HPAL Advisory Committee in February 2014 and January 2015 in Sidney. Approximately 40 people attended this event, which consisted of growers, bankers, and grain handling personnel.

3. Presented information during the UNL Road Scholar Tour in May 2014 in Scottsbluff. Approximately 30 people attended, which included UNL faculty and administration.

4. Hosted a HPAL Field Day in June and August 2014 in Sidney. Approximately 120 and 140 people attended these events, respectively. Attendees consisted of growers, industry and government representatives, UNL faculty and administration.

5. Presented information to the Central Great Plains Working Group in August 2014 in Sidney. Approximately 50 people attended, which consisted of researchers from UNL, Colorado State University, Kansas State University, University of Wyoming, South Dakota State University, and USDA-ARS.

6. Presented information to USDA-Farm Service Agency in September 2014 in Scottsbluff. Approximately 45 government representatives attended this event.

7. "Evaluation of Fenugreek (*Trigonella foenum-graecum* L.) for Agronomic Traits and Medicinal Compounds" was presented at the 26th Annual AAIC Industrial Crops Meeting September 12-19, 2014, in Athens, Greece. Approximately 300 scientists attended this event.

8. Presented information to the New Crops Conference in December 2014 in Sidney. Approximately 50 growers, interested industry representatives, and government personnel attended this event.

9. Hosted a Panhandle Research and Extension Center Field Day on August 18, 2015, in Scottsbluff. Approximately 50; growers, industry and government representatives, and UNL faculty and administration attended this event.

Lessons Learned

There was heavy rain at Scottsbluff in 2013 before harvest, which caused approximately 50% yield loss. Therefore, actual yields could have been approximately twice than that presented in Table 2. Also, there was a delay in determining 4-hydroxyisoleucine in the 155 PI lines due to some problems with the HPLC in the laboratories of Drs. Rose and Schlegel.

Fenugreek seems to have production potential. Developing optimum production practices (planting and harvesting period, and weed management) seems to be important factors for better seed yields. High seed yielding cultivars seems to be negatively associated with lower medicinal compounds. Therefore, conventional breeding, involving crossing followed by selection, would be necessary to develop cultivars with high seed yields and high medicinal compounds.

The 4-hydroxy isoleucine of 2013 germplasm could not be completed. This is because the highly corrosive solvent breakdown of the HPLC in Dr. Schegel's laboratory. The HPLC is currently under repair.

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Project Title

Agronomic Practices for Fenugreek in Western Nebraska

Project Summary

Fenugreek, an annual legume primarily grown in India, is an important medicinal / pharmaceutical crop with properties alleviating many conditions such as Type 2 diabetes and inadequate lactation in nursing mothers.

This crop is not grown in the Western Hemisphere. So, can western Nebraska take the lead and become a source of fenugreek products in North America? There is no information on this possibility. Therefore, the overall objective of this project is to identify several key production parameters for western Nebraska.

The specific objectives of this study are to identify adequate irrigation amounts, the best planting date in the spring, and the timing of harvest for optimal seed yield for pharmaceutical purposes.

Western Nebraska is an ideal location for this study due to its similarities to the fenugreek growing province in India (Rajasthan). One similarity is a dry, well-drained sandy loam soil that is slightly alkaline and highly calcareous. Also similar in western Nebraska when compared to Rajastan, is the annual rainfall and seasonal temperatures.

The benefit of this study is to introduce a new crop and new industry into western Nebraska thus enticing interest from pharmaceutical companies to consider Nebraska as a source of raw product.

Project Approach

Seed of the Canadian cultivars Amber and Tristan were planted alongside each other on May 7, May 17 and May 28, 2013. Preliminary trials conducted in 2012 demonstrated that planting in April was too soon.

Plot sections for each planting date were harvested at three different times, August 20, September 10 and October 2, 2013.

The growing-season variable was irrigation. The following three regimes were instituted: no irrigation; half irrigation or 0.5 inch per week; and full irrigation or 1 inch per week. Total irrigation from early June to early September was 0, 6 and 12 inches. When rainfall was added into the calculation, total water exposure ranged 3 to 13 inches, 3 to 15 inches, and 6 to 18 inches respectively for each harvest.

No nitrogen was added since the 2012 preliminary trial indicated that there was sufficient nitrogen (30-40 lb/a) in the soil and that adding more nitrogen would have no effect.

Plants were sown in 12-inch rows at a seeding rate of 18 lbs./acre resulting in a density of 13,000 plants per acre or 3 to 4 plants per square foot. Plots were placed in a 3x3 Latin square design with irrigation level as the main plot. The plots were split into three planting dates and each of these sub-plots were split between the two cultivars. This allowed all parameters to be statistically comparable when using SAS software.

Goals and Outcomes Achieved

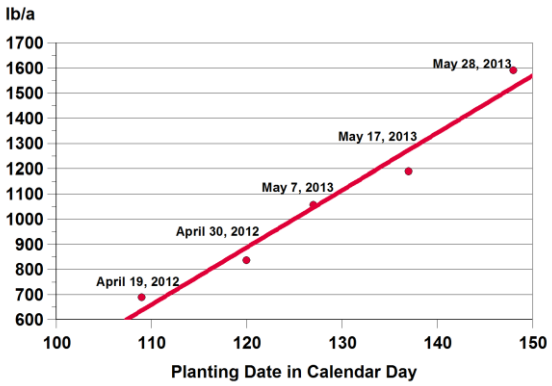
The overall goal of this study is to develop the technology and determine the feasibility of growing fenugreek under the semi-arid conditions of western Nebraska. Three measurable agronomic outcomes for determination are: planting dates, irrigation levels, and harvest dates.

The following summarizes the results and conclusions following the format listed under "Expected Measurable Outcomes" in the project proposal.

1. Appropriate spring planting dates for seed production"

   Combining data from the preliminary 2012 trial and that of 2013 under full irrigation and harvest in mid-September, a linear relationship appears between planting and yield (see Figure 1). The graph suggests that planting on May 28, seed yield still may not have reached its maximum potential. Based on this information, an even later planting date of June 2 was added in 2014.

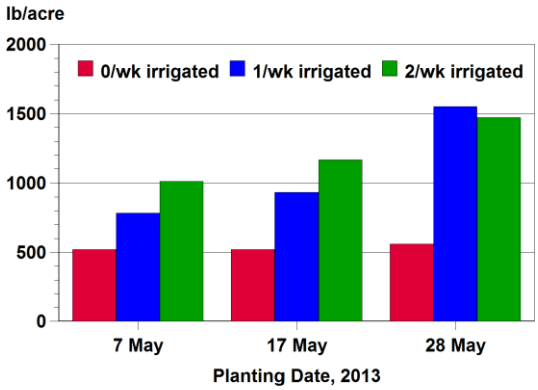
Figure 1. Yields (in Sep) by Planting Date, Full Irrigation



2. Irrigation requirements for optimal fenugreek production

   Yield was affected by the amount of irrigation regardless of planting date (see Figure 2). However, it should also be noted that regardless of irrigation levels, later planting dates resulted in higher yields.

Figure 2. Amber Seed Yield Harvested in early-mid Sep, 2013



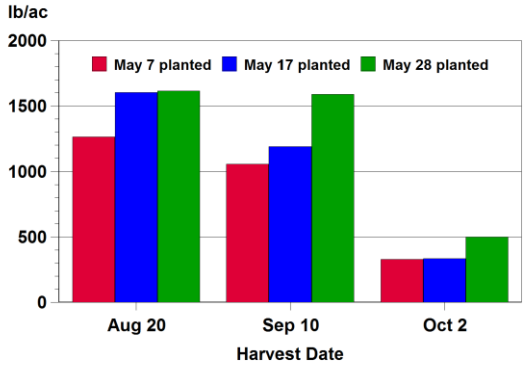
3. Proper nitrogen amounts

After this project's proposal was already submitted, data were tabulated from the 2012 preliminary trial. The results showed that the residual nitrogen in the soil was sufficient for optimal growth of fenugreek in this area. Therefore, this objective of the project was replaced with the following objective:

Optimal harvest dates for seed production

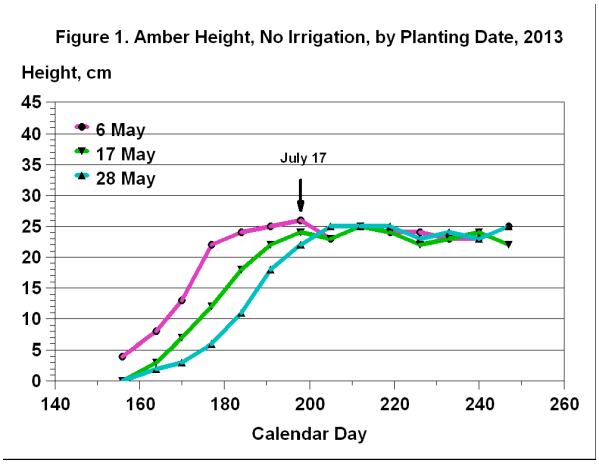
Date of harvesting did show an effect on seed yield with the optimal period being between late August and mid-September (see Figure 3). A planting date versus harvesting date interaction was identified with later planting showing the highest yield at all three harvest dates.

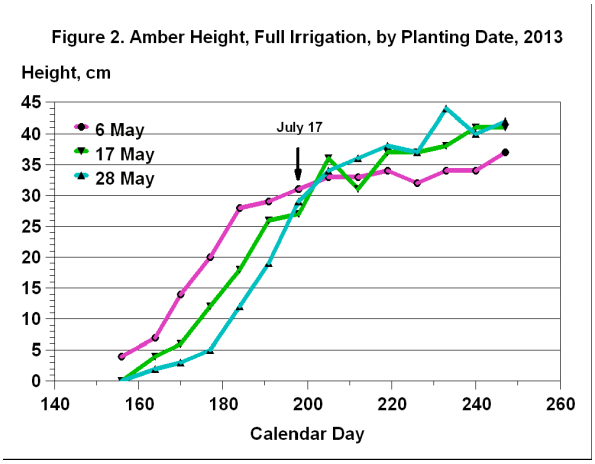
Figure 3. Fenugreek Harvest Yield, full irrigation, 2013



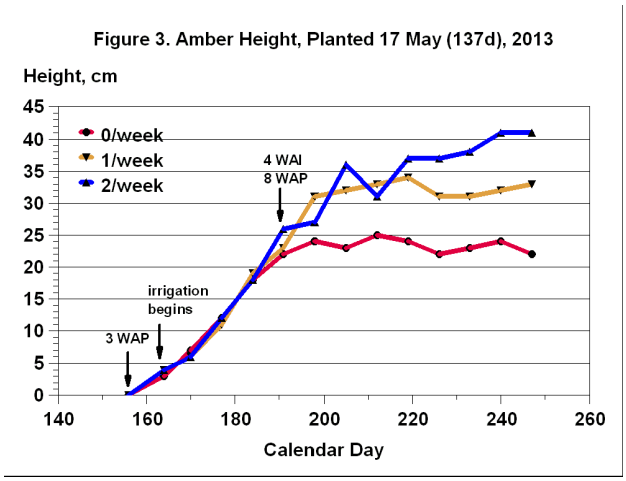
4. Growth patterns will be measured throughout the season as a guide for future growers.

Vegetative Growth – Although planting later in May delayed the onset of growth, the vines of later planting dates grew faster and all plants, regardless of planting date, were the same height by July 17 at all three irrigation levels. At none and half irrigation levels, after that date, height did not change and there was no further height increase (see Figure 1). At full irrigation, height growth rate was reduced but continued to gradually increase; however, the first planting grew at a slower rate than the later two planting dates (see Figure 2).

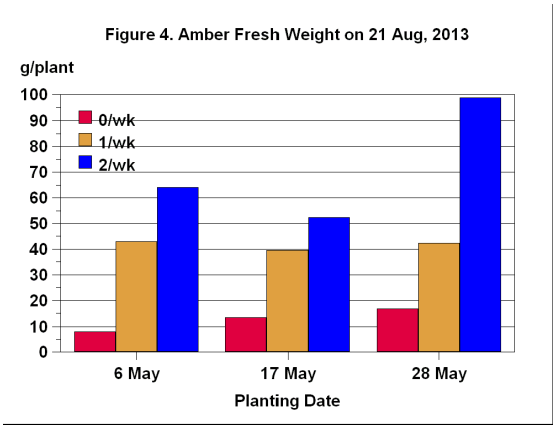


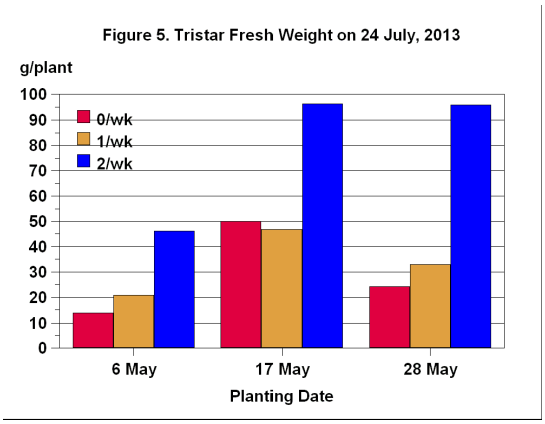


Differential heights due to irrigation occurred three, four and five weeks after the onset of irrigation for May 6, 17, and 28 planting, respectively. The divergence in height growth as affected by irrigation level indicates that it depends more on planting date than on time after the onset of irrigation. However, irrigation levels had a profound effect on continued and final plant height. For instance, with the May 17 planting (middle date), increased irrigation resulted in plants growing longer and taller (Figure 3, WAP = weeks after planting, WAI = weeks after irrigation began. Graphic lines indicate irrigation frequency of 0, 1, 2 per week). This pattern was similar for all three planting dates.



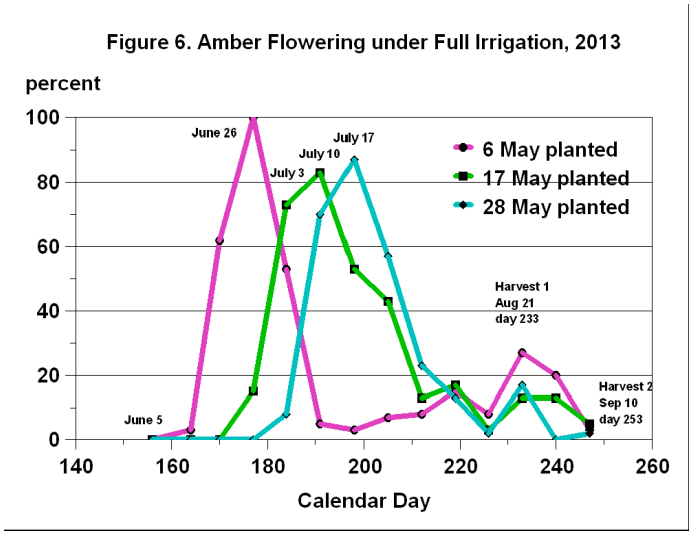
The greatest plant weight was achieved with the third planting for both varieties. Irrigation was required to achieve maximum vine weight. However, the two varieties also differ. Amber does not achieve maximum plant weight at 3½ oz /plant until August 21 at first harvest (see Figure 4). Tristar, on the other hand, achieved maximum plant weight on July 24, a month before Amber (see Figure 5). Furthermore, this weight was achieved with once or twice per week irrigation. Tristar weight on August 2^{t} was less than in July and less than Amber on that date. This suggests that Tristar gains weight faster and needs less water to maximize it.





Reproductive Development -

There was no recorded difference between Amber and Tristar. Flowering dates were delayed by one week for each delay in planting. Full bloom occurred on June 26, July 3, and July 10 for planting on May 6, 17, and May 28, respectively. Pod set peaked about a week after full bloom. Irrigation level had no effect on date of flowering or fruiting. However, there were two noticeable effects in both varieties. The first planting, May 6, developed more flowers and more pods than later planting dates (see Fig. 6). Whether this will translate to differences in yield in the first harvest will be callculated this winter. The second observation was that with irrigation, there was a second flush of flowering and fruiting occurring in late Aug regardless of planting date (see Fig. 6). Whether this resulted in a higher yield at the second harvest also will be calculated this winter.



Note that irrigation had a major effect on promoting growth, and planting date affected reproductive timing.

5. The principle measurable outcome over time will be the adoption of fenugreek into the production system of western Nebraska.

This is a long-term goal. By accumulating good production data and presenting this information to growers and industry, this goal could be fulfilled.

6. The one distinct and measurable outcome external to the project will be the collaboration between the University of Nebraska Medical Center partnering with the Institute of Agriculture and Natural Resources with IANR supporting the agronomic facets and UNMC supporting the pharmaceutical aspects. This collaboration is expected to interest pharmaceutical companies and their agronomic components."

   Contact has been on-going with the University of Nebraska Food Science Department and Food Processing Lab. Contact with the University of Nebraska Medical Center is being explored. These groups are waiting for more information on agronomic practices and genetic lines with a high content of medicinal compounds and adapted to western Nebraska.

7. For sufficient information to be accumulated to interest the pharmaceutical industry and for scientific dissemination, this project would need to be repeated over future grant periods. But, if grant funding concludes after only one period, the one-year data will still be presented to growers and interested medical companies. A University of Nebraska Extension bulletin would still be planned."

This study has received SCBGP funds in fiscal years 2013 and 2014, which should allow for sufficient information to be accumulated to interest the pharmaceutical industry and to be used for scientific dissemination. Preliminary information was published in a Nebraska Panhandle Extension publication for growers (Pavlista, A.D. 2014. Fenugreek yield as affected by planting date and irrigation. HPAL Update of Research. PHREC 14-30:58-59.) Contact with potential interested companies is being explored.

Beneficiaries

The results of this year's project were disseminated to target audiences. The target audiences are growers and scientists.

A list of presentations in the first year (2013-2014) of this study were:to

1. The High Plains Ag Lab Advisory Com. in February 2014 in Sidney, Nebraska target audience = 40; growers.

2. The University of Nebraska-Lincoln Road Scholar Tour in May 2014 in Scottsbluff, Nebraska, target audience = 30; University of Nebraska-Lincoln faculty and administration.

3. The Central Great Plains Working Group in August 2014 in Sidney, Nebraska - target audience = 50; researchers, from University of Nebraska, Colorado State University Kansas State University, University of Wyoming, South Dakota State University, and USDA-ARS in Colorado in the limited irrigation session.

4. The USDA-Farm Services Agency in September 2014 in Scottsbluff, Nebraska - target audience = 45; government representatives.

5. The New Crops Conference in December 2014 in Sidney, Nebraska - target audience = 50; growers and interested industry and government representatives.

Plans already set for 2015 include presentations to:

1. Central Great Plains Working Group in August 2015 in Akron, Colorado - target audience = 50.

2. The American Association. of Horticultural Science. in August 2015 in New Orleans, Louisiana- target audience = 1000.

3. Western Sustainable Ag Crops and Livestock Conference in Ogallala, Nebraska - target audience = 100.

Long-term plans for dissemination at the study's conclusion are:

1. Internet - target audience = 1,000+, growers, researchers and government representatives world-wide. A new website specifically for fenugreek will be inaugurated in 2016-2017.

2. Scientific Community - target audience = 1,000+, a manuscript for submission to the Journal for Medicinal and Aromatic Crops, a world-wide open access journal, will be prepared in 2016.

3. Growers - target audience = 1,000, a Production Guide, as a University of Nebraska Extension publication is planned in 2016-17.

4. Medicinal Industry - target audience = 2-4 corporations, presentations will be made to companies with interest in contracted contracting acres and developing market relations.

Lessons Learned

The most interesting outcome was that there was significant interaction between planting dates, irrigation level and harvest dates. From this data, a set of recommendation or hypothesis may be tentatively formulated. Maximum yields, greater than 1,500 lb/a, were achieved at the August harvest only by fully irrigated (1 inch / week or irrigated twice per week) plots planted May 17 or 28. At the later harvest in September, maximum yields were achieved also by half irrigation (0.5 inch / week or irrigated once per week) plots but only with the third planting, May 28. The resulting tentative recommendations, requiring verification over the next two seasons and be completed by 2017, are:

1. If irrigation is not limiting (1 inch/week) and harvest is planned for mid to late August, then fenugreek may be planted from mid to late May (Figure 4). If harvest is planned for September, then planting should be at the end of May, possibly early June.

2. If irrigation is reduced or limited (0.5 inch/week), then plant at the end of May, possibly early June and harvest in early to mid September (Figure 5).

3. Yields under all conditions were substantially reduced to about 500 lb/a when harvest was delayed until early Oct (e.g., Figure 3).

4. The two varieties did not significantly differ; compare Figures 4 and 5.

Figure 4. Amber Seed Yield, 2013

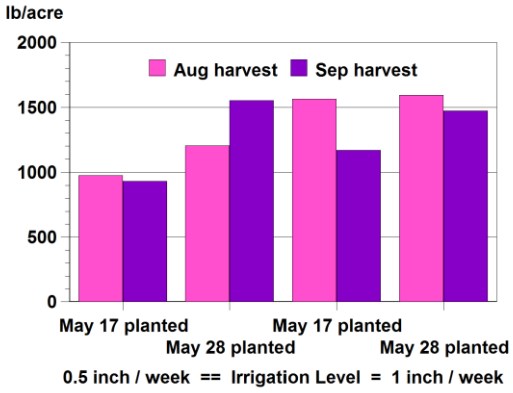
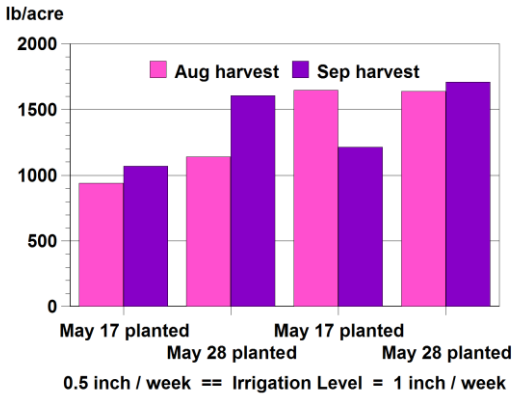


Figure 5. Tristar Seed Yield, 2013



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