Oklahoma Department of Agriculture, Food, and Forestry (ODAFF)

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USDA AMS Agreement: SCBGP-OK-0040

Final Report

December 21, 2017

Research and Grower Education Programs on Scab Disease in Pecans

Project Summary:

Oklahoma ranks second in the nation in pecan acreage with 141,675 acres on 3,589 farms. Pecan production in 2015 for Oklahoma was approximately 13 million pounds. Farm revenue generated in Oklahoma from pecans was approximately $21 million in 2015. The primary disease of pecans in Oklahoma and elsewhere is pecan scab caused by the fungus *Fusicladium effusum*. A few cultivars are resistant to scab, but a majority of the cultivars grown in Oklahoma have some susceptibility to scab. Fungicide sprays may help alleviate the negative impacts of the disease but their effectiveness can be hindered by the large size of the tress, the number of applications needed and the costs associated with spraying. Additionally, in seasons with favorable conditions for scab development and growth, the fungus becomes difficult to control even with numerous fungicide sprays and may result in loss of the entire pecan crop. Pecan scab has been and continues to be a significant threat to the productivity of pecan growers and impacts profitability due to increased costs to manage the disease and the associated decline in nut production. Knowledge of pecan cultivars that are resistant to scab can reduce the costs associated with pecan production in Oklahoma. For producers, strategies to identify and monitor for scab will facilitate the implementation of control strategies (fungicides) early in the season when they can be more effective at keeping the fungus from progressing through the orchards. Research efforts that integrate the latest molecular technologies including the use of DNA markers currently utilized in other high-value crops can contribute to the identification of scab resistant pecan cultivars with excellent commercial quality. These efforts would therefore greatly increase the profitability of pecan cultivation in Oklahoma and result in sought-after scab resistant pecan cultivars. Therefore, the objectives of this project are to:

- Objective 1: Gain knowledge about the response of pecan cultivars to pecan scab in Oklahoma
- Objective 2: Increase awareness of pecan scab and develop education programs for pecan growers
- Objective 3: Research the genetic basis for resistance to pecan scab using molecular DNA technologies

All funds requested were used to advance the goals of the project aimed towards understanding pecan scab, educating growers, and developing DNA technologies for pecan to enhance the competitiveness of pecan cultivars grown in Oklahoma. The maintenance of healthy pecan trees promotes continued productivity as a result of effective management of pecan scab and can increase the market for Oklahoma-grown pecans due to uncompromised nut quality and size. Long-term, understanding the genetic basis of pecan can lead to better orchard management strategies and the development and implementation of molecular breeding strategies to integrate scab resistance in pecan production in Oklahoma. These approaches would reduce the need for agricultural inputs including fungicides and ultimately increasing the profitability of pecan growers in this region.

Project Approach:

The approaches and activities completed during this research are organized based on the three proposed objectives.

Objective 1: Gain knowledge about the response of pecan cultivars to pecan scab in Oklahoma

Goal: Develop and standardize a phenotyping assay to assess scab severity or susceptibility in pecan trees.

Activities completed in support of this goal include:

1. Isolate and propagate the scab fungus from different pecan trees grown in Oklahoma using a variety of growth mediums to culture and grow the scab fungus.
2. Standardize the growing and spore-promoting conditions (growth media, photoperiod and temperature) for pecan scab to use as source of inoculum for rating the pecan trees.
3. Obtain pecan scab response ratings for pecan trees in the field from a provenance collection that includes pecans from a wide range of geographical regions (See Obj. 3). These pecan scab ratings were used to identify trees within each provenance location for genome-wide characterization at the DNA level to identify candidate scab resistance genes in pecan.

Objective 2: Increase awareness of pecan scab and develop education programs for pecan growers

Goal: Disseminate information and knowledge related to pecan scab to promote management of the disease.

Activities completed in support of this goal include:

1. Pecan workshops organized and hosted by the Noble Foundation.
2. Invited oral presentations from project Principal Investigators at Pecan Growers meetings in Oklahoma and other States.
3. Poster presentations of research findings at professional meetings.
4. Team member participation during pecan meetings.

Objective 3: Research the genetic basis for resistance to pecan scab using molecular DNA technologies

Goal: Develop DNA marker technologies for pecan and identify potential genetic determinants underlying resistance to pecan scab.

Activities completed in support of this goal include:

1. Collect samples from the pecan cultivars 'Kanza' (scab resistant cultivar, 3 trees) and 'Pawnee' (scab susceptible cultivar, 3 trees) at the McMillan orchard in Oklahoma and from twenty-two different grafted cultivars (5 trees each for a total of over 100 trees) grown in the greenhouse at the Noble Foundation.
2. Complete RNA sequencing and bioinformatics processing of the sequence data to identify genome-wide single nucleotide polymorphisms (SNPs) between pecan cultivars contrasting for pecan scab responses.
3. Obtain a pecan mapping population generated from a cross between Pawnee (susceptible) and Kanza (resistant) that would be segregating for pecan scab response.
4. Identify a set of pecan trees from the provenance collection representing broad genetic diversity of the *Carya* genus that differs in pecan scab response. For example, identify both resistant and susceptible trees within the same provenance.
5. Implement genotyping-by-sequencing (GBS) technologies to identify differences in the DNA sequence of multiple pecan trees.
6. Collect tissue samples from the 'Gold standards of pecan cultivars' referred to as ORTET pecan trees from the USDA Germplasm collection in College Station, TX (L.J. Grauke – pecan germplasm curator) and characterize their genetic differences to generate a 'DNA fingerprint' for pecan.
7. Characterize pecan cultivars contrasting for pecan scab response at the DNA level using high-resolution melting analysis to identify genetic differences in key genes.

Goals & Outcomes Achieved:

Objective 1: Gain knowledge about the response of pecan cultivars to pecan scab in Oklahoma

1. Collected pecan scab isolates from pecan orchards in Oklahoma and isolates obtained through an appropriate APHIS permit with members of the USDA-ARS station in Byron, GA (Clive Bock and Bruce Wood).
2. Propagated pecan isolates in Petri dishes with silica at -20°C to enable the long-term growth and conservation of the scab isolates without contamination from other organisms.
3. Initiated spore cultures of pecan scab in different media (potato-dextrose agar and oatmeal-agar media) and grown in different photo period conditions (Fig. 1), working closely with the Noble Foundation's fungal genomics laboratory (Carolyn Young's team). Results: Oatmeal-agar media (OAM), 15 h photoperiod and 24°C of temperature are the optimal growth conditions to promote pecan scab sporulation. Pecan scab spores (Fig. 2) are needed to inoculate the vegetative tissue of pecan trees and document their response to different isolates.
4. Isolated pecan scab spores from the OAM. Spores were isolated from mycelia scrubbing the surface of the OAM with Tween 80 0.1% and then filtering with cheesecloth. Spore

dilutions were made with water once the spore number was determined using a hemocytometer under the microscope.

5. Completed assays of the pecan scab isolates from the cultivars Pawnee and Desirable (obtained from Clive Bock from USDA-ARS Byron, GA) grown in OAM. These isolates were used to inoculate leaves from the three pecan cultivars Pawnee, Kanza and Desirable using a detached leaf assay. The scab inoculations were performed with a piece of agar sliced from the OAM plate and drop inoculation of a standardized number of spores suspended in water. Mycelia and some spores were observed in the pecan leaves five days post-inoculation (Fig. 3).
6. Collected single spores from pecan scab samples from Oklahoma at the McMillan orchard, NF. Isolations were made from improved cultivars (Pawnee, Maramec, Choctaw and Cheyenne) and native pecan trees leaves and stems.
7. Isolated single scab spores using a developed protocol. Briefly, cultures were initially grown in 2% water agar media with antibiotics (streptomycin, chloramphenicol and tetracycline, 50 μg/ml each) for 2 to 3 weeks at 24°C. A single spore was then transferred with a micro-needle to an OAM and grown for 4 weeks.
8. Obtained field-based pecan ratings for a pecan provenance core collection that includes pecans from a wide range of geographical regions (See Obj. 3).

In summary, multiple approaches were used to establish a pecan scab phenotyping protocol. Optimizing experimental conditions enabled the development of protocols for quantitatively screening level of disease in pecan samples. Ongoing activities include evaluating the response to pecan scab of multiple pecan cultivars in controlled environments implemented in walk-in grow chambers at NF. Hoop houses will be used to infect different trees with scabs isolated in Oklahoma as previously described and used to identify quantitative trait loci (QTL, genomic regions associated to scab resistance) in a mapping population resulted from the cross between Pawnee and Kanza.

Objective 2: Increase awareness of pecan scab and develop education programs for pecan growers

1) Pecan workshops organized by Noble Foundation include:
   - Pecan Pruning Workshop held at Bynum Farms, Springer, OK. February 3rd, 2015.

   -Pecan Grafting Workshop held at the Noble Foundation, Ardmore, OK. April 28th, 2015.

   -Pecan Grafting Workshop held at the Noble Foundation, Ardmore, OK. April 26th, 2016.

   -Pecan Pest Management Workshop held at the Southern Oklahoma Technology Center, Ardmore, OK. May 17th, 2016. Project participants received the educational materials entitled ‘Pecan 101’ and ‘Pecan pocket guide for insects and diseases’.

   -Pecan 101 Workshop held at the Southern Oklahoma Technology Center, Ardmore, OK. September 29th, 2016. Project participants received the educational materials entitled ‘Pecan 101’.

2) Invited oral presentations from project Principal Investigators at Pecan Growers meetings in Oklahoma and other States.

-Co-PI Rohla gave a talk entitled: 'Pecan Cultivars for Oklahoma' at the Oklahoma Pecan Growers Association Annual Conference in Ardmore, OK. June 13th, 2015.

-Co-PI Rohla gave a talk entitled: 'Pecan 101' at the Wise Country Pecan Workshop in Decatur, TX. Dec. 3rd, 2015.

-Co-PI Rohla gave a talk entitled: 'Pecan Research at the Noble Foundation' at the Southern Region American Society of Horticulture Scientist – Pecan Workshop in San Antonio, TX. Feb 2nd, 2016.

-Co-PI Monteros gave a talk entitled 'Decoding pecan genetics and the potential impacts for pecan growers' at the Southeastern Pecan Growers in Destin, FL. Feb 17th, 2016. ODAFF funding was acknowledged.

-Co-PI Rohla gave a talk entitled: 'Center for Pecan and Specialty Agriculture and Pecan Research at the Noble Foundation' at the Southeastern Pecan Growers in Destin, FL. Feb 17th, 2016.

-Co-PI Rohla gave a talk entitled: 'Center for Pecan and Specialty Agriculture and Pecan Research at the Noble Foundation' at the Georgia Pecan Growers in Perry, GA. March 30th, 2016.

-Co-PI Rohla gave a talk entitled: 'Improving Soil Health in Pecan Orchards and Pecan Research at the Noble Foundation' at the Comanche County Pecan Growers Annual meeting, Comanche, TX. April 14th, 2016.

-Co-PI Rohla gave a talk entitled: 'Pecan Research at the Noble Foundation' at the Clay County Pecan Growers Annual meeting in Clay, TX. May 12th, 2016.

-Co-PI Monteros gave a talk entitled: 'Decoding pecan genetics and the potential impacts for pecan growers' at the Annual Conference of Oklahoma Pecan Growers Association in Tulsa, OK. June 2nd to 4th, 2016. ODAFF funding was acknowledged.

-Co-PI Rohla gave a talk entitled: 'Center for Pecan and Specialty Agriculture and Pecan Research at the Noble Foundation' at the Annual Conference of Oklahoma Pecan Growers Association in Tulsa, OK. June 2nd -4th, 2016. WC also attended the conference.

-Co-PI Rohla gave a talk entitled: 'Center for Pecan and Specialty Agriculture and Pecan Research at the Noble Foundation' at the Annual Conference of the Northern Nut Growers Association in Nebraska City, NE. August 3rd- 4th, 2016. W. Chaney also attended the conference.

-Co-PI Rohla gave a talk entitled: 'Center for Pecan and Specialty Agriculture and Pecan Research at the Noble Foundation' at the Annual Conference of the Alabama Pecan Growers Association in Fairhope, AL. September 15, 2016.

3) Poster presentations

-Y. Alarcon presented a poster entitled 'Developing genomic resources for pecan improvement' at the 2015 National Association for Plant Breeders (NAPB) meeting in Pullman, WA. July 27th-30th, 2015. ODAFF funding was acknowledged in the poster.

4) Team member participation in pecan meetings

-Members of the research team (CR) attended the annual conference of Western Pecan Growers Association in Las Cruces, NM. March 2rd-4th, 2015.

-Members of the research team (YA, MJM, WC and CR) attended the annual conference of Texas Pecan Growers Association in Frisco, TX. July 13th-14th, 2015.

-Members of the research team (CR, WC and YA) attended the annual conference of Texas Pecan Growers Association in San Marcos, TX. July 10th-13th, 2016.

5) Engaged with student outreach and training: Denis Jaquez and Morgan Phillips were involved in research and/or training as part of the project. Both girls came to our lab through the Southern Oklahoma Technology Center mentoring program.

6) Publications: YA and MM wrote the article 'Scientific advancements provide pecan cultivar identification tools'. Ag News and Views, Vol 34, N°6, June 2016. Other publications for peer reviewed scientific journals are currently in preparation.

7) The data generated from this grant was leveraged to obtain a $4.4 million grant focused on 'Coordinated development of genetic tools for pecan' with multiple collaborators in OK and the United States.

Objective 3: Research the genetic basis for resistance to pecan scab using molecular DNA technologies

A. <u>Developing DNA resources in pecan (genome-wide SNP discovery)</u>

1. Harvested pecan leaf tissue, completed RNA extraction and transcriptome sequencing (RNA-Seq) using TruSeq RNA Library Preparation Kit v2 and Illumina HiSeq 2000 platform of three Pawnee and three Kanza trees from the McMillan orchard, OK.

2. Completed RNA-sequencing, curation and analysis of data obtained and used it to identify 43,417 genome-wide single nucleotide polymorphism (SNP) between Pawnee (scab susceptible) and Kanza (scab resistant) (Fig. 4). SNP are molecular markers (differences of one base in the DNA sequence) that could be associated with scab resistance and may be used for marker-assisted selection in the future.

3. Designed 96 molecular markers targeting random SNPs from the RNA-Seq data and used them for PCR amplification of Pawnee and Kanza trees from both the orchard and the greenhouse. Validation of the predicted SNP from the RNA-Seq data was performed with the high resolution melting (HRM) technology implemented using the LightScanner® equipment (BioFire, Salt Lake City, Utah). The melting data was analyzed and visualized using the LightScanner Software with CALLIT 2.0 (Idaho Technologies) and the small amplicon module.

4. Assessed the rate of SNP validation from the SNPs found in the five trees per cultivar) and used to successfully identify genetic differences between Pawnee and

Kanza represented by melting profiles or curves with different colors (Fig. 5). The SNPs were grouped in categories based on the sequence composition of the different pecan trees.

5. Five trees per cultivar of at least twenty pecan cultivars (total trees sampled = 110 trees), planted in Oklahoma and currently growing in Noble Foundation's greenhouse facility, were genotyped using the validated SNPs. Genetic differences based on HRM profiles within Pawnee and Kanza trees were identified both in the greenhouse and in the orchard trees. Essentially, trees from the same cultivar were not genetically identical. Thus, standards from the labeled pecan cultivars were sampled from the ORTET (original 'Mother' trees) located in USDA College Station, TX to get the 'gold standard' for each named cultivar.

In summary, 43,417 SNPs or genetic differences were detected from the RNA-Seqquencing data of the pecan cultivars Pawnee (scab susceptible) and Kanza (scab resistant). High resolution melting analysis (HRM) was used to validate the predicted SNPs. Genetic differences between trees of the same cultivar thus providing an opportunity for developing a DNA fingerprinting assay for the named pecan cultivars.

B. <u>Identification of genetic determinants of pecan scab resistance</u>

1. Designed molecular primers (oligos) to validate the *in silico* SNP discovery and to target disease resistance genes from pecan and other species (apple scab is caused by *Venturia inaequalis*, highly similar to *Fusicladium effusum*) and using the black walnut genome for gene annotations. A total of twenty SNP targeting primers were designed using apple scab resistance genes (*HcrVf2* and *HcrVf4*, and three different alleles of the scab resistance gene *Rvi1*).

2. Identified genetic differences between Pawnee (scab susceptible) and Kanza (scab resistant) based on primers designed to target apple scab resistance genes (Fig. 6).

3. Mined the gene annotations from the transcriptome sequences corresponding to genes that are expressed to identify candidate disease resistance genes including pathogenesis related proteins, membrane interaction proteins, and response to fungi proteins among others. These SNP primers are in the pipeline for genotyping the mapping population segregating for pecan scab and could be used in future gene expression analysis that could be used to identify genes differentially expressed in response to exposure to the pecan scab pathogen.

4. Obtained a mapping population consisting of 189 F1 pecan seedlings generated from a cross between Pawnee (scab susceptible) x Kanza (scab resistant). The seedlings were planted in the greenhouse at the Noble Foundation and 145 of those were used for DNA extraction, quantification with Nanodrop and PicoGreen and DNA quality control in agarose gels before genotyping-by-sequencing (GBS) at the Genomic Diversity Facility at Cornell University. The outcome included over 37,000 SNPs after filtering for alternate allele reads and greater than 50 samples with SNP called. The parents of this mapping population and seventeen F1 seedlings from the mapping population were characterized with fourteen SNPs primers (Fig. 7) designed from apple scab resistance genes and the pecan RNA-Seqquencing data. All the SNP data

will be combined with scab susceptibility ratings and used to generate linkage maps and identify genomic regions associated with scab resistance genes.

5. Characterized resistant and susceptible bulked samples from six provenances at the DNA levels. Specifically, the pecan provenance collection includes trees from the natural range of pecan growth and includes over nine hundred trees from nineteen different locations in the USA and Mexico. These trees were planted in Byron, GA and rated for scab susceptibility in the field by USDA-ARS scientists. Twelve DNA bulks were created with equal amounts of DNA from three trees per bulk belonging to six provenance locations: Kansas (KS), MS (Mississippi), MO (Missouri), Mexico (MX), TX-V (Texas-Val Verde), and TX-Z (Texas-Zavala). Within each location, a resistant bulk and a susceptible bulk were generated as part of a bulked-segregant analysis (BSA).
6. Identified over 57,000 SNPs from the GBS data of the twelve bulks (6 resistant and 6 susceptible bulks, each of which consisted of 3 trees). Of those, 3,603 SNPs were polymorphic between resistant and susceptible bulks (Table 1). A total of 989 SNPs were identified in the resistant bulks across the six provenances. These SNPs and the genes in which they are located are being further evaluated for their role as genetic determinants for pecan scab resistance. Also, 101 of those SNPs located in candidate scab resistance genes such as leucine-rich repeat receptor like protein kinases, chitinases, cysteine-rich receptor-like protein kinases, MATE efflux family proteins, peroxidases, among other disease resistance proteins were identified.

In summary, multiple candidate scab resistance genes were identified using a range of approaches including RNA Sequencing, genome wide SNP discovery with GBS and high resolution melting of multiple pecan samples. Twenty SNP primers targeting apple scab resistance genes were developed and tested in pecan samples showing a differential HRM profile between scab susceptible and resistant trees. SNPs were identified in pecan scab resistant pecan trees and some of those are located in key genes known to play a role in fungal defense responses including chitinases, leucine and cytosine rich repeat receptors proteins, and peroxidases, among others. A mapping population segregating for scab resistance was used to identify genome-wide SNPs in over 140 pecan trees with GBS to identify genomic regions associated with scab resistance genes.

C. <u>Developed DNA fingerprinting assays for named pecan cultivars</u>

Due to the identification of differences at the DNA level within pecan trees from the same cultivar (not previously reported) using the developed methods, it was necessary to develop standard DNA fingerprinting profiles for each of the named pecan cultivars. We engaged with the pecan germplasm curator L.J. Grauke at the Pecan Germplasm facility, USDA-ARS Research Station in College Station, TX to obtain leaf materials from the 'Gold standards' referred to as ORTETs of named pecan cultivars. Specific activities include:

1. Completed leaf sampling on-site in TX using GPS technologies to tag each sampled tree and DNA extraction of 63 pecan ORTET trees. Sampled trees were genotyped with the 96 validated SNP primers previously described.
2. Identified eighteen SNP primers to characterize fifty-eight named pecan cultivars with a single SNP (Fig. 8) or a combination of SNPs. We filed a patent application

describing the use of DNA technologies in pecan: Monteros, M.J., Y. Alarcon, C. Rohla. 2016. Methods for identifying pecan tree cultivars. NBLE: 092USP1. US Patent Serial No. 62/311,201.

In summary, genetic tools for DNA fingerprinting to identify pecan cultivars represent a resource for growers to better understand and manage their orchards for pecan scab and other diseases. Also, the DNA fingerprinting methodology can be used as a tool by growers to make decisions when replacing old or diseased trees with new trees that are resistant to pecan scab as part of the orchard-renovation efforts. The markers developed could also be used as a quality assurance metric for growers to buy 'DNA-certified' trees from nurseries and help reduce the number of pecan scab susceptible trees being planted in Oklahoma and surrounding States to help reduce the inoculum load of pecan scab spores.

Beneficiaries:

- The specialty crop beneficiaries of the project include pecan growers in Oklahoma, the southeastern US and other pecan-growing areas that are susceptible to pecan scab. The project will specifically benefit pecan growers in Oklahoma (roughly 3,500 pecan farms) and surrounding states by providing knowledge and expertise (grower-education programs) on how to identify, monitor and control the pecan scab fungus to minimize losses in pecan nut production. Also, the genetic resources developed for 'DNA fingerprinting' in pecan can be used by growers and/or nurseries to develop, market, and buy DNA-certified trees that will have the desired disease resistance traits of a particular pecan cultivar.
- Pecan breeders, students, professors and scientific staff from research agencies working in pecan related research projects who attended the conferences, meetings and workshops where the team presented the research accomplishments and new knowledge generated during this grant period. Also, the two high school and college students who contributed to this project obtained hands-on training on techniques utilized in molecular laboratories.
- Pecan community and other researchers working on pecan and related species who can utilize the developed molecular and DNA resources in pecan.
- Cost savings of pecan growers by reducing the number of fungicide applications per growing season as trees that are susceptible to pecan scab are replaced by pecan trees resistant to pecan scab infections.

Lessons Learned:

- Standardizing phenotyping methods to develop a quick and reliable pecan scab assay to quantify the response of the tree to the pathogen is key to understand the genetics underlying pecan scab disease resistance. Pecan scab isolates from the cultivars Pawnee and Desirable grow best in oatmeal-agar media (OAM). The detached leaf assay enables tracking of the fungal infection in a controlled environment using the same number of spores for inoculation. Current efforts are focused on optimizing a spray vs. agar-based inoculation methods using spore suspensions in attached leaves to quantitatively assess disease responses on each sampled tree.

- The identification of genetic differences between Pawnee and Kanza trees from multiple sources presented an opportunity to generate a DNA fingerprinting assay for pecan as a resource for growers. The ORTET pecan trees from the Pecan Germplasm facility (USDA-ARS Research Station in College Station, TX) are considered the 'gold standard' or ORTETs for named cultivars and these were used to identify a set of SNPs to characterize these pecan cultivars. These findings were utilized in a patent application submitted describing "Methods for identifying pecan tree cultivars" (NBLE: 092USP1. US Patent Serial No. 62/311,201). The developed DNA fingerprinting methods could serve as a resource for pecan growers to manage their orchards in response to pecan scab responses and to guide orchard-renovation strategies.
- The bulked segregant analysis approach of diverse pecan germplasm from the provenance collection rated in the field resulted in the identification of sequence differences in key genes detected using genotyping-by-sequencing. A similar approach could be used to identify genetic variation in the entire provenance collection for pecan scab and other traits of agronomic importance including flowering and/or alternate bearing.
- Evaluating variation at the DNA level in candidate resistance genes between susceptible vs. resistant trees was used to identify key genomic regions relevant to scab resistance. Further evidence of the role of these genes in pecan scab resistance can be obtained by evaluating the relative levels of gene expression in scab resistant vs. susceptible pecan genotypes during scab inoculation. These activities are beyond the original scope of this proposal and will be pursued as part of a continuing project using both quantitative real-time PCR and RNA-Sequencing of mock-inoculated vs. scab-inoculated pecan scab resistant and susceptible pecan cultivars.

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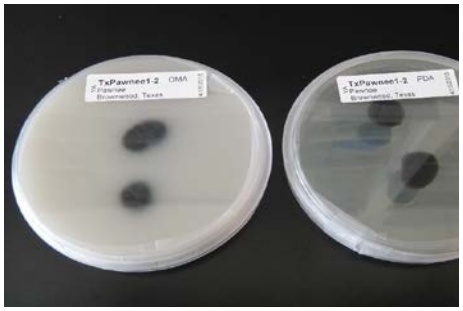

Figure 1. *Fusicladium effusum* cultures (two weeks old) from Pawnee isolates grown in oatmeal-agar media (OAM) (left) and potato-dextrose agar media (PDA).

Figure 2. *Fusicladium effusum* spores from desirable scab isolates in oatmeal agar media (OAM) after 4 weeks of growth at 24°C in a 15 h photoperiod.

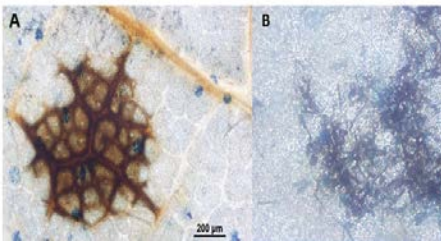

Figure 3. *Fusicladium effusum* lesions in Desirable pecan leaves five days after scab inoculation, dyed with lacto-phenol cotton blue after boiling treatment of the leaf in ethanol 70%. A) Scab lesion in Desirable leaves (200 µm). B) Scab lesion in Desirable

SNP Category		# of SNPs
• Category 1	Kanza AA vs. Pawnee CC	11,910
• Category 2	Kanza AC vs. Pawnee AA	14,277
• Category 3	Kanza AA vs. Pawnee AC	8,832
• Category 4	Kanza AC vs. Pawnee AC	8,398
• All SNP Categories		43,417

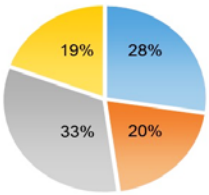

Figure 4. Single nucleotide polymorphisms (SNP) identified between Pawnee and Kanza pecan trees from the McMillan orchard using RNA-Seq data.

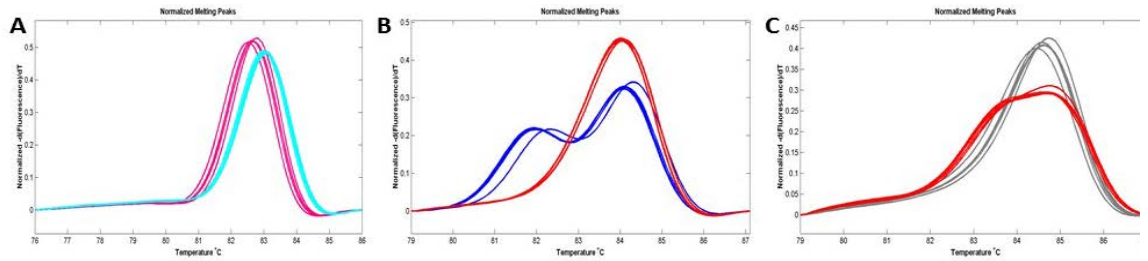

Figure 5. High resolution melting (HRM) profiles of multiple Pawnee (P) and Kanza (K) trees. SNPs from different categories are shown. A. Category 1 SNP (P = aqua, K = pink). B. Category 2 SNP (P = red, K = blue). C. Category 3 SNP (P = red, K = grey).

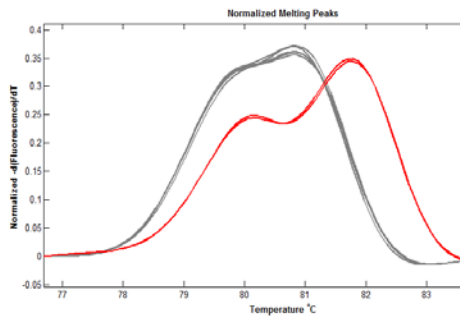

Figure 6. HRM profile of Pawnee (red) and Kanza (grey) with SNP CI0203 targeting a disease resistance protein.

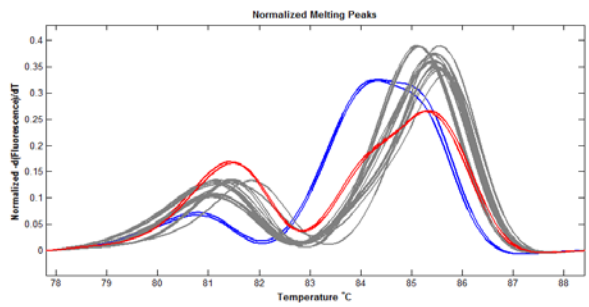

Figure 7. HRM profile of Pawnee and Kanza parental genotypes and seventeen F1 progenies with SNP CI0196. Kanza pollen donors and 14 F1 lines (grey), Pawnee and one F1 progeny (red), two F1 progenies (blue).

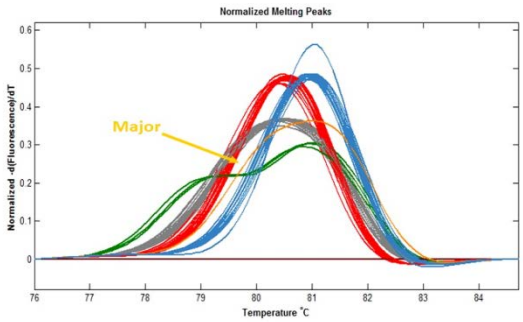

Figure 8. HRM profile of fifty-eight pecan cultivar samples with SNP primer CI0058. Pecan cultivar Major is clearly identified.

Provenance	Number of SNPs
KS	698
MS	357
MO	974
MX	296
TX-V	682
TX-Z	596
Total	**3,603**

Table 1. Number of SNPs between scab resistant and susceptible bulks on each provenance. KS = Kansas, MO = Missouri, MS = Mississippi, MX = Mexico, TX-V = Texas-Val Verde, TX-Z = Texas- Zavala.

Quantifying the Agronomic and Economic Impact of Shade on Tomato Production in Oklahoma

Project Summary:

Both fruit quality and amount produced are negatively impacted by high temperature and larger amounts of direct solar radiation. Using shade to decrease ambient temperature under the shade area has been shown to decrease the proportion of the tomato crop that is damaged and to decrease temperature under the shaded areas. In addition to improved fruit quality, the amount of nutrients and water inputs were decreased as well as labor cost per pound of saleable fruit. How much shade is needed and the trade-offs between fruit quality and the amount of fruit produced, cost of shade and savings in lower water and nutrient cost must be determined on a state by state basis. This project added data to the national data base on using shade to improve crop production quality, decrease cost and improve nation food security.

Redlands Community College utilized the grant money for various operating expenses dealing with the project outcome. This project played a very important role in conducting research that was vital to the project being successful. Although the unpredictable Oklahoma weather slowed down some of our progress at times, we were able to complete the project and expense the grant funds in just over two years.

Project Approach:

Four rows 60 feet long were established, oriented in a north-south direction. Super Fantastic was planted in one row and Better Boy in the next row. Both are indeterminate type. Within a row plants were planted at 3 foot intervals and rows were 5 feet wide and 14 feet on center. Each set of two rows were a replication of eight treatments (two varieties and four levels of shade). Each row was divided into quarters (subplot) with five plants per subplot. The quarter on the south end of each row served as a control (0% shade) for each row and was not covered with any shade cloth (full sun). Three levels of shade (30, 40 and 50%) were randomly assigned within row to the other three quarters. Shade cloth was supported by a metal frame at approximately 6.5 feet above row by steel post. Frames were braced with tie downs at the corners and wrapped around the frame. Tomatoes were planted on May 4th, 2015 and shade cloth was applied on June 12. Plastic was used as the mulch in the row and straw was used to mulch the aisles between rows. When the plastic mulch was laid down using a single pass machine that mounded the soil, laid a drip line along the side of the row, and covered the mound with plastic in one pass. Soil moisture was determined weekly with a hand meter to determine when and how long irrigation was needed. Amount and number of fruit produced was determined twice weekly. High-low thermometers were installed in each quarter in Rows 2 and 3. Rain gauges (manually read) were also installed with the high-low thermometers to measure rainfall. Data was analyzed as a two factor with replication experiment using Excel software and Analysis of Variance Procedures.

On July 20, 2015, a ceptometer was used to determine how much each level of shade cloth decreased PAR (photosynthetically active radiation). Two readings were taken below and above the shade cloth at 11:00 A.M. The PAR was reduced by 34.8% under the 30% shade cloth, 45.8% under the 40% shade cloth, and 57.2% under the 50% shade cloth. Because the shade

cloth was 5 feet wide and suspended above the canopy, plants were in full sun for a portion of the day as the sun drew higher and lower in the sky.

Harvest was twice weekly (weather permitting) and divide into two periods. Harvesting started on June 22 and peaked on July 27. This denoted as period 1. Harvesting continued until September 17. This period was denoted as period 2. Neither amount of shade or variety had a significant ($P < 0.10$) effect on the amount fruit or the number of fruit produced. In period 1, five plants produced 8.0 kg of fruit and in period 2, 9.5 kg of fruit for a total of 17.5 kg of fruit from five plants. The number of fruit pieces harvested from 5 plants in periods 1 and 2 was 40 and 108, respectively. The weight of each piece decreased from 200 g in period 1 to 88 g in period 2.

During early 2016 the remaining grant funds were used to repeat the study as stated above, however we reduced the nitrogen levels, thus giving us a better handle on plant growth, we also limited the amount of water to the tomatoes since our water testing showed significant nitrogen levels. We were able to acquire additional student workers to do additional research on the tomatoes. The outcome was still the same as stated below under goals and outcomes.

Goals & Outcomes Achieved:

The goals of this research project were 1) to define the relationship between the amounts of shade provided during the hot summer month, the amount of nutrients used and the quality and quantity of fruit produced and 2) to provide a learning laboratory for Redlands' students and staff, Master Gardeners, and OSU Extension Educators.

We were able to meet goal number 1. Shade had no significant effect on the amount of nutrients used, the quality of the fruit or the amount of fruit produced. The micro-environment created by providing shade was different from anticipated.

With regards to the second goal, Redland's students associated with the project activity participated in the collection of data and data entry. They were given the opportunity to learn about plant physiology and experimental design. This goal was partially completed. We were unable to incorporate the Master Gardeners and OSU Extension at this time.

Beneficiaries:

It is hard to determine the exact number of beneficiaries of this project as the tomato is a staple in every backyard and market garden in our state. Through outreach and dissemination of these results growers will be able to make a more informed management decision on whether they utilize shade in their production.

Lessons Learned:

1) Physical layout required some problem solving, but Technician Neil Fobes designed and constructed a metal framing system to hold the shade cloth in place. Weather delayed planting, but the length of the growing season was adequate.

2) Recruiting labor to collect data was a problem, however, by extending the grant deadline, we were able to hire additional student workers and complete additional research with the valuable dollars that we received.

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N/A

Effect of LED Lighting and Silica Supplementation on Growth and Flowering on Common Cut Flower and Nursery Produced Ornamentals

Project 1: Effect of LED Lighting on Growth and Flowering of Greenhouse Produced Cut Flowers

Project Summary:

Part 1 (LED): Growers are looking to reduce input costs to remain competitive. Energy inputs range from 10 to 30% of total production costs for the greenhouse industry, thus any new lighting technology that significantly reduces consumption of electricity for crop lighting while maintaining or improving crop value is of great interest to growers with small operations that sell to farmers markets and larger operations that use light to extend production or control flowering. Light sources such as fluorescent, metal halide, high pressure sodium, and incandescent lamps are generally used for plant growth under greenhouse conditions and have been around for half a century. However, these sources have disadvantages of having less suitable wavelength spectra for plant growth, limited lifetime of operation, require high amounts of electricity, and produce heat that can burn plant foliage. In 1990, light-emitting diodes (LEDs) were investigated for the first time for plant growth, and were found to be efficient alternatives to traditional lamps used in lighting systems, but have only been evaluated on a few crops thus growers continue to use traditional incandescent/halogen lighting.

Our study used and evaluated LEDs (GreenPower LED Flowering 120 V, E26; Philips, Amsterdam, The Netherlands) and gibberellic acid (GA) for growth and flowering of cut flowers. Experiments were conducted at the Department of Horticulture and L.A. research greenhouses in Stillwater, OK and ran from late fall to early spring. Results varied between species and cultivars in response to light and GA. In addition, light and GA have a synergistic relationship with each other in regards to plant and flower development. For all species, GA appeared to have more of an effect on growth rather than flowering characteristics. Flowering

occurred early in liatris under sole LED lighting by about 2 weeks compared to those under other lighting treatments and no lighting. Although flowering occurred earliest in both cultivars of dahlias under no lighting, those under lighting treatments had better development and had better support of flowers. This project was not built on a previously funded project with SCBGP.

Part 2 (Silica): Plant quality is what consumers expect when they shop for plants, yet a number of abiotic and biotic factors often influence plant quality so growers are looking for ways to cheaply and easily improve plant quality. Silicon is the earth's second most abundant element in the earth's crust after oxygen and has shown to benefits plants, yet and is not considered an essential element and is often lacking in potted production where soilless media is used. Its water-soluble form is silica, a naturally-occurring element. The occurrence of Si within a plant is a result of its uptake, in the form of soluble $Si(OH)_4$ or $Si(OH)_3O^-$, from the soil. The ability of a plant to accumulate Si varies greatly between species (0·1–10 % of shoot dry weight). Plants deprived of Si are often weaker structurally and more prone to abnormalities of growth, development, and reproduction. The latest research shows that plants benefit in many important ways from supplemental soluble silicon. These benefits include greater tolerance of environmental stresses, such as cold, heat, drought, salinity, mineral toxicity or deficiency, improved growth rates and resistance to insects and fungi. Plants with silicon added to the nutrient formula also show a decrease in leaf and flower senescence. The shelf life of cut flowers, specialty pot crops and plugs is also extended. Leaves are thicker and darker green compared to those grown without soluble silicon. Research into potential benefits of adding silica is fairly new, and has only been evaluated on a select number of plants.

Optimum Si supplementation was found to vary, depending on species, application method and rate, and irrigation treatment. Top-dress treatment at 60 and 80 g/pot Si were the most effective in well-watered rudbeckia for width, shoot weight, and mean flower number in which all increased. Rudbeckia that were water-stressed had greater height, width, and flower diameter when supplemented with 100 g/pot Si (incorporated), 40 and 80 g/pot Si (top-dress), and Metro-Mix with Si, respectively. Metro-Mix with Si did better for width, flower diameter, and calcium content when compared to Si supplementation in rudbeckia. This project was not built on a previously funded project with SCBGP.

Project Approach:

Part 1 (LED)

In September, the following bulbs were received:
- *Lilium asiatic* (L.) ‘Montreux’ and ‘Yellow Cocotte’

In October, the following plugs were received:
- *Dahlia* spp. (Cav.) ‘Karma Serena’ and ‘Maarten de Zwaan’

In November, the following corms were received:
- *Liatris spicata* (Gaertn. ex Schreb) ‘Kobold’

Bulbs were placed in a cooler upon arrival for one month. Liatris corms were not placed in the cooler and were immediately treated. Bulbs and corms were soaked in different rates of gibberellic acid (GA_3) solution for 30 minutes (min). Dahlia leaves were sprayed once with

different rates of GA_3 solution. See table below to see dates of material received, GA_3 treatments, transplanting, and light treatments.

Plant material was transplanted/potted into standard 15-centimeter pots filled with Metro-Mix 360 media (one plant per pot). The light treatments included Philips LED Flowering Lamps (deep red/far-red/white), LED Flowering Lamps (deep red/white) with halogen bulbs, sole halogen bulbs, and no artificial lighting. Pots filled with plants were randomly distributed under these light treatments which were set up in the research greenhouses.

Plant Material	**Received**	**GA_3 Treatment**	**Potted/Transplanted**	**Light Treatment**
Lilium asiatic (L.) 'Montreux'	09/15/2015	10/17/2015	10/17/2015	10/17/2015
Lilium Asiatic (L.) 'Yellow Cocotte'	09/15/2015	10/24/2015	10/24/2015	10/24/2015
Dahlia spp. (Cav.) 'Karma Serena'	10/14/2015	10/31/2015	10/16/2015	10/16/2015
Dahlia spp. (Cav) 'Maarten de Zwaan'	10/14/2015	10/31/2015	10/18/2015	10/19/2015
Liatris spicata (Gaertn. ex Schreb) 'Kobold'	11/12/15	11/13/15	11/13/15	11/13/15

Lilium asiatic (L.) 'Montreux' bulbs were soaked in the following GA_3 rates: 0, 20, 50, 70, 100, 120, 150, 170, 200, and 250 ppm. Five single pots per rate, replicated four times.

Lilium asiatic (L.) 'Yellow Cocotte' bulbs were soaked in the following GA_3 rates: 0, 40, 140, and 340 ppm. Twelve single pots per rate, replicated four times.

Dahlia spp. (Cav.) 'Karma Serena' leaves were sprayed once with the following GA_3 rates: 0, 50, 100, and 150 ppm. Ten single pots per rate, replicated four times.

Dahlia spp. (Cav.) 'Maarten de Zwaan' leaves were sprayed once with the following GA_3 rates: 0 and 150 ppm. Seven single pots per rate, replicated four times.

Liatris spicata (Gaertn. ex Schreb) 'Kobold' corms were soaked in the following GA_3 rates: 0, 50, 170, 250 ppm. Twelve single pots per rate, replicated four times.

Plants were supplemented 7 hours of light after sunrise. Before daylight savings time (08 November 2015), lighting was delivered above the bench areas from 1900 to 0200 HR. After daylight savings time, lighting was delivered between 1700 to 2400 HR—lights were on during this time frame up until the end of the study. Standard timers were used to switch the lights on and off and standard light strings were used in which bulbs were installed.

Data collected from plants included date of first flower (anthesis), flower diameter (in mm), number of flowers, plant height (in cm from media surface to tallest flower or bud), width (in cm averaging two perpendicular measurements), and shoot dry weight (in g). The date of first flower was only recorded when petals fully opened. A digital caliper (Tresna Instrument., LTD, Guangxi Province, China) was used to measure flower diameter. Shoot weight was determined by cutting the stems at media level and then dried for 3 d at 54.4 °C. Data was analyzed with SAS version 9.4 software (SAS Institute, Cary, NC). Analysis of variance methods (PROC MIXED) were used with a two-factor factorial arrangement with GA_3 and lighting as the factors of interest. Separate analyses were conducted for each plant species. When interactions of GA_3 and lighting were significant, simple effects were reported. Mean separations were determined using a DIFF option in an LSMEANS statement and a SLICE option (when appropriate) and with a 0.05 level of significance. Means and standard errors were reported.

A quantum sensor (LI-250A; LI-COR Biosciences, Lincoln, NE) was used to measure PPF of the LED lamps and halogen bulbs. Relative spectral distribution (wavelength) of light from the halogen and LED lamps were determined using methods by Sager et al (1988).

Part 2 (Silica)

On 8 May 2015, the following rooted cuttings and plugs were received:
- *Rudbeckia hirta* (L.) 'Denver Daisy'
- *Dahlia* spp. (Cav.) 'Dahlinova Montana'
- *Gerbera jamesonii* (L.) 'Festival Light Eye White Shades'

Species	Received	Potted/Transplanted	Data Collected
Rudbeckia hirta (L.) 'Denver Daisy'	05/08/2015	05/28/2015	06/17/2015
Dahlia spp. (Cav.) 'Dahlinova Montana'	05/08/2015	05/28/2015	06/17/2015
Gerbera jamesonii (L.) 'Festival Light Eye White Shades'	05/08/2015	05/28/2015	06/17/2015

Plant material was obtained from Park Seed (Greenwood, SC). Cuttings and plugs were transplanted into standard 15-centimeter pots filled with Metro-Mix 360 media (Sun Gro Horticulture, Bellevue, WA) that did not contain silicon and a single treatment of Metro-Mix 360 media (Sun Gro Horticulture, Bellevue, WA) that did contain silicon (RESiLIENCE™). A single

plant was placed in each pot and plants were grown at the Department of Horticulture and L.A. research greenhouses in Stillwater, OK under natural photoperiods. Eight silica treatments were established as well as two water treatments. Plants were either well-watered at 10 psi or water-stressed at 20 psi using tensiometers to control the irrigation. Silica treatments included applications of diatomaceous earth across the top of the pots (top-dressed) at 20, 40, 60, and 80 grams (g) or incorporated at 50, 100, 150, and 200 g with 12 pots per treatment per irrigation treatment along with both Metro-Mix 360 media. Plant species and silica rates were randomized within irrigation treatment (block).

When plants reached harvesting stage, the experiment ended. Data collected on plants included height in cm from media surface to tallest flower, width (in cm averaging two perpendicular measurements), shoot dry weight (in g), number of flowers, and flower diameter (in cm). Shoot weight was determined by cutting the stems at media level then dried for 2 d at 52.2°C. For elemental analyses, leaves were collected from five plants per silica and irrigation treatment of each species. Silica solubility of DE and leaf samples were analyzed for total-N content ($g \cdot kg^{-1}$ DM), macronutrients, and micronutrients by the Soil, Water and Forage Analytical Laboratory (SWFAL) at Oklahoma State University, using a LECO TruSpec Carbon and Nitrogen Analyzer (LECO Corporation, St. Joseph, MI). Soil silica analyses performed using five pots per silica and water treatment of each species by SWFAL at Oklahoma State University, using the 0.5 M ammonium acetate method (Wang et al. 2004). Transpiration and resistance were recorded weekly and soil moisture values were collected daily between 13 May 2015 and 20 May 2015 using the FieldScout TDR 200 meter (Plainfield, IL) from one pot per treatment. Soil silica values were collected from a nine-pot composite per irrigation treatment. Analysis of variance methods (PROC MIXED) were used with a two-factor factorial arrangement with irrigation and silica treatment as the factors of interest. Separate analyses were conducted for each plant species. When interactions of irrigation and silica treatment were significant, simple effects were reported. Mean separations were determined using a DIFF option in an LSMEANS statement and a SLICE option (when appropriate) and with a 0.05 level of significance. Means and standard errors were reported.

This project was achieved with the help of a graduate student under mentorship and guidance from Dr. Dunn. Dr. Dunn ordered supplies, arranged for greenhouse space, and established the experimental treatments. The student was responsible for setting up and running experiments, collecting data, and writing-up the results for dissemination to the public.

Goals & Outcomes Achieved:

Goals: The goal of the research was to provide growers with knowledge on LED technology as well as plant hormone usage in relation to growth and flowering of cut-flowers.

Project Activity:	**Timeline**
Recruit student/order supplies	January-April--2015
Run first silica expt.	April-June--2015

Run first LED expt.	August-November (2015)
Analyze data/write thesis	January-December--2016
Write factsheet	March-August (2016)

Comparison of Actual Accomplishments: When comparing goals and accomplishments, the goal of communicating to greenhouse growers about LED technology and silica has been achieved based on having completed research and using the information gained to inform growers of the advantages and disadvantages of using this technology or nutrient that was not previously available. Accomplishments include development of an Oklahoma State University Cooperative Extension fact sheet, which can be viewed at http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-10413/HLA-6450web.pdf . This factsheet has received a total of 1,423 views as of 9 April 2018 based on online downloads alone, which is significantly greater than the targeted amount of 100 visits. Partial results were presented at the 81st Annual Meeting of the Southern Region American for Horticultural Science in the Norman F. Childers M.S. Graduate Student Paper Competition. In addition, Results from the experiments have been communicated with growers in conversations during site visits as well as a thesis listed in additional information.

Beneficiaries:

There are over 150 Oklahoma nursery and greenhouse operations and just as many smaller growers that sell directly through farmers markets and hundreds of thousands of households that use supplemental lighting to start transplants that can benefit from this research. The factsheet alone gets over 200 reads a month and two growers have talked to me about switching from conventional lighting to LED lighting to save on energy costs as well as improve production. Students are exposed to research finds in class, so information will relayed to industry when they enter after graduation. Last week, I received a call from a grower asking about the benefit of silica, so both projects provided short term information for those growers asking now, but will also serve new growers looking at new ways to improve their production as well. For growers that switch to LED lighting costs upfront are higher, but a 20% reduction in energy costs would translate into hundreds if not thousands of dollars per year depending on the size of the operations. Use of silica in some species would reduce inputs like water and pesticides which could also account for hundreds if not thousands of dollars in savings as well for growers or homeowners depending on the size of the operation or amount of plant material.

Lessons Learned:

Part 1 (LED)

LED lamps are equally effective as incandescent/halogen lamps at regulating flowering. Both light fixtures had similar light intensity. However, the Philips GreenPower Flowering lamps consumed about 14 to 15 watts per bulb whereas incandescent/halogen lamps used about 75 watts per bulb, showing a 46 to 50 percent decrease in energy consumption which is ideal for growers concerned with energy costs.

Red (R) is the most effective light color to inhibit flowering in short-day plants (SDP). This was true for both cultivars of dahlias (considered SDPs) that were under the lighting treatment consisting of LED (deep red/white) with halogen lamps. This lighting treatment was also most effective in promoting taller liatris plants and yellow Asiatic lilies. Extension growth is typically promoted under R light.

Far-red (FR) and R are the most effective light colors to promote flowering in long-day plants (LDP). This was true for liatris (considered LDPs) that were under the lighting treatment consisting of sole LED (deep red/far-red/white) lighting fixtures.

For all species, GA appeared to have more of an effect on growth rather than flowering characteristics. However, for liatris, GA did influence greater flower number but decreased width and shoot weight. Height is promoted by GA for dahlia 'Karma Serena' but for yellow Asiatic lilies this characteristic seemed to fluctuate.

Results varied between species and cultivars in response to light and GA. Light seemed to be the most dominating effect on growth and flowering characteristics especially in liatris and both cultivars of dahlia. Flowering occurred early in liatris under sole LED lighting by about 2 weeks compared to those under other lighting treatments and no lighting. Although flowering occurred earliest in both cultivars of dahlias under no lighting, those under lighting treatments had better development and had better support of flowers. The significant effects of GA on some flowering characteristics in certain species was surprising. This plant hormone was often denounced as a flowering stimulus, which proves that more research needs to be conducted to further assess in other plant species the regulation of flowering by light and GA. The significant interaction between light and GA influenced mean flower number, height, and days to anthesis for dahlia 'Karma Serena' and Asiatic lily 'Montreux', dahlia 'Maarten de Zwaan', and yellow Asiatic lilies, respectively. Interaction between light and GA need to be furthered assessed.

Part 2 (Silica)

Top-dress treatment at 60 and 80 g/pot Si were the most effective in well-watered rudbeckia for width, shoot weight, and mean flower number in which all increased. Rudbeckia that were water-stressed had greater height, width, and flower diameter when supplemented with 100 g/pot Si (incorporated), 40 and 80 g/pot Si (top-dress), and Metro-Mix with Si, respectively.

Shoot weight increased for well-watered dahlia when supplemented 20 g/pot Si (top-dress) while 40 g/pot Si (top-dress) promoted more total nitrogen in the leaves.

A trend was seen in all the plant species under both irrigation treatments and within varying Si treatments in which manganese content increased. However, no report of toxicity by the element was observed nor reported. Silicon is known for alleviating metal toxicities.

As for the effect of irrigation, well-watered rudbeckia, dahlia, and gerbera within certain silica treatments showed greater height, width, and shoot weight. Within most silica treatments for water-stressed rudbeckia and gerbera, favorable effects were seen such as an increase in leaf resistance which relates to evapotranspiration. Although, irrigation appeared to be the most

significant factor on this physiological characteristic, the idea that supplementary Si can act as an antitranspirant film is encouraged which is the case for agronomic crops rice and corn.

Significant effects of both silica treatment and irrigation influenced stem diameter, leaf resistance, Si leaf content and soil Si which were seen in rudbeckia, dahlia, and gerbera. Interaction between both factors need to be furthered assessed.

When subjected to the water-stress condition, rudbeckia benefitted the most from DE as a Si supplementation compared to Metro-Mix with Si regarding height, leaf resistance, and leaf magnesium content. Metro-Mix with Si did better for width, flower diameter, and calcium content when compared to Si supplementation in rudbeckia.

Even plants not subjected to stress benefitted more from Si supplementation regarding shoot weight, leaf total nitrogen and potassium content compared to the control and Metro-Mix with Si. For width and mean number of flowers, Metro-Mix with Si was more beneficial than the control. Dahlia only benefited from Si supplementation for leaf total nitrogen when not under the stress condition. As for gerbera, leaf resistance was increased by Si supplementation under the stress and non-stress condition.

Although a grower could use the commercialized Metro-Mix media containing Si, they could benefit more by adding diatomaceous earth as a Si supplement to the substrate. Application of a Si supplement can aid in the enhancement of plant quality when not subjected to stress conditions or can help alleviate the negative effects of water-related stress.

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Additional Information:

Mills, T.S. 2017. Effect of LED lighting and silicon supplementation on growth and flowering of cut flowers. MS Thesis. Oklahoma State University

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Canna GermPlasm Screening Program and Field Testing

Project Summary:

Ornamental plants are the fourth largest agricultural industry in Oklahoma, and over 80% of domestic canna production occurred here in Oklahoma. Problems with not being able to provide virus free plant material after it was noted that 90% of cannas have a virus, the market, industry, and consumer confidence in this easy to grow, drought tolerant plant has declined and decimated the industry. There is need to improve diagnostic testing to reduce the costs for an expanding germplasm screening program to provide virus free stock plants to the ornamental industry. In

addition, growers also need to know more about how the virus is transmitted in the field and garden, so that we can inform growers about how to maintain clean stocks and reduce the incidence of disease in their production. It is not enough to provide growers or consumers with clean seed stocks if we cannot assure them that the seed stocks will stay clean. For an industry valued in the millions, without establishing an efficient way to screen plants for viruses and provide recommendation to reduce the spread the industry will continue to decline.

Multiplex reverse transcriptase – polymerase chain reaction (RT-PCR; C1000 Touch Thermal Cycler) for three different primers were carried out to test three mixed *Canna* viruses. Multiplex RT-PCR can be used for rapid and reliable detection of *Canna* viruses, including those which are of concerns to farmers, such as; *Canna Yellow Mottle Virus* (CaYMV), *Canna Yellow Streak Virus* (CaYSV) and *Bean Yellow Mosaic Virus* (BYMV). To manage a large population of samples, nucleic acid isolation, PCR components including primers concentration and PCR regiments used were optimized to assure sensitivity and reliability of the assay. As farmers use vegetative propagation methods for *Cannas*, we tried to find out various modes of transmission of viruses. During storage of materials such as rhizome, they come in contact with each other very often so we wanted to know if *Canna* viruses can be transmitted to healthy cannova from infected ones. For this we conducted 3 experiments, soil-based transmission, plant to plant transmission and insect transmission, to evaluate modes of transmission of viruses. Greenhouse growers, farmers and nursery operators are constantly in search of easy and cost effective technology to enhance the productivity and maintain sustainability, and the project is targeted to achieve the same.

Project Approach:

Listed below are the activities and tasks performed during the grant period.

Project Activity:	**Time Frame**
Planting of rhizomes for screening	February 2015-Jan. 2017
Optimizing multiplex RT-PCR test	Feb-March, 2015
Field and greenhouse experiment to determine virus transmission	Apr.-Aug. 2015, 2016
Greenhouse sampling, scoring and RT-PCR tests to validate assay in objective 1	March-June 2015
Giving virus free plant material out	May-2016, 2017
Collect rhizomes, leaves for PCR analysis	Sept. 2015, 2016
PCR analysis of rhizomes and leaves	Oct. 2015-March2017
Obj. 2 monthly and testing and replanting	Feb.2015-Jan. 2017

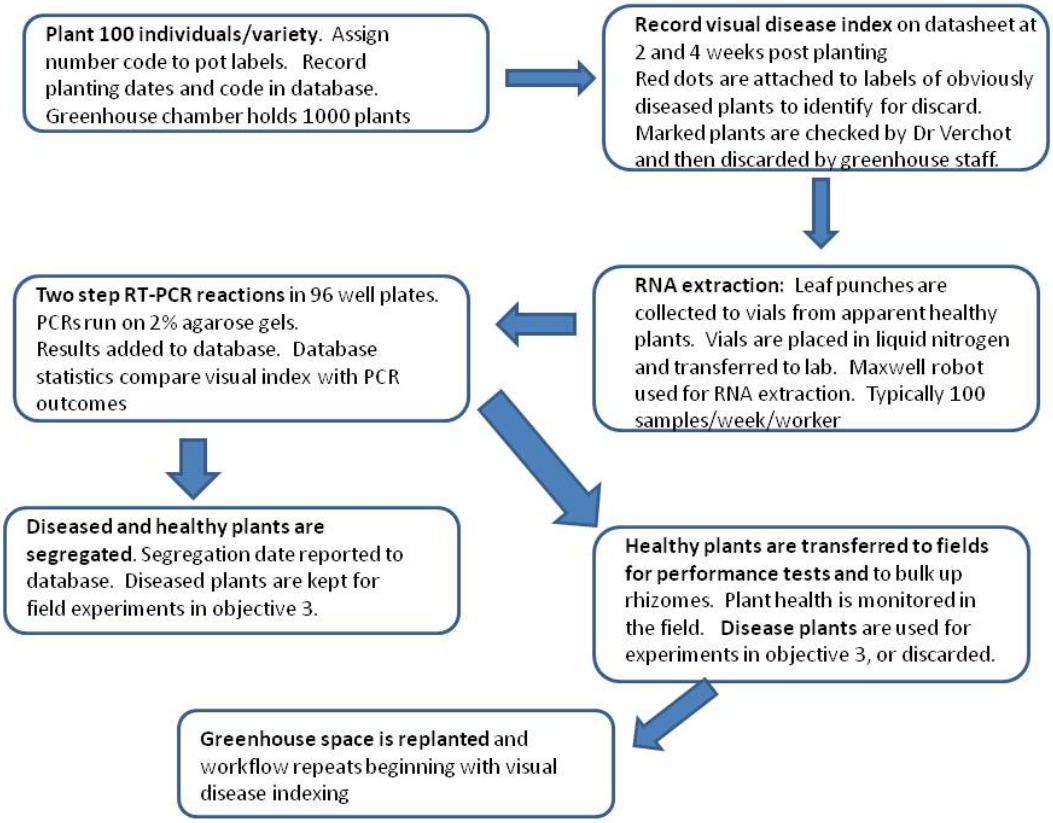
Objective 1 (Developing a multiplex RT-PCR protocol)

We have identified and conducted preliminary diagnostic tests using genus specific primers for detecting 4 of the 5 viruses. Potyvirus primers detect CaYSV and BYMV, Cucumovirus primers

detect CMV and TAV. These four viruses have RNA genomes and require RT-PCR for detection. We have species specific primers for detecting CaYMV (genus Badnavirus). Importantly, CaYMV is a pararetrovirus and its replication cycle has both a DNA and RNA phase. We have learned that CaYMV produces sufficient transcripts that we can employ RT-PCR or PCR for diagnostic detection. Total nucleic acid extracts are prepared from 100 mg of leaf tissue using a Maxwell Robot (Promega) and are useful for RT-PCR diagnostic detection of all viruses as seen in the ethidium bromide stained 2% agarose gels in Figure 1. Cucumovirus PCR products are 938-966 bp; Potyvirus PCR products are 350 bp; and CaYMV product is 691 bp. Because these PCR products differ in size, the next step toward optimization is to combine two or three primer sets into a single assay to detect multiple viruses. To determine sensitivitiy, 'virus-specific plasmids' that will be used as controls for these experiments are pGEMT plasmids containing cloned genomes segments of BYMV, CaYMV, CaYSV and TAV. Healthy canna leaves were used as negative controls. For multiplex, the selected primers have similar melting temperatures (40-45ºC) and flank genome regions of different sizes (Fig 1 legend). For optimization, 1.0 ng virus-specific plasmids will be mixed and used as templates for singleplex and multiplex PCR using 2 and 3 primer sets. Products were visualized on a gel to determine if primers are incompatible for multiplexing. Success in multiplexing is when two or three sets can be combined. Different methods were tried for isolation of RNA and TNA, out of which, Maxwell 16 instrument was considered the best. The average yield (Thermo Fisher Scientific NanoDrop ND-1000) from this process was comparatively higher than others when plants with different colored leaves were tested. Accomplishments include developing a multiplex to screen for four different viruses at one time, which saves on time and costs associated with screening plants.

Objective 2 (Providing virus free material to the industry)

This proposed research focused on screening six varieties that are highly marketable: Australia, Cleopatra, Pretoria, Red Futurity, Tangelo and Striped Beauty. A database was used to track planting and discard populations, diagnostic, discard, and replanting. The database is elaborate and tracks each individual plant that shows symptoms, the visual disease rating, the diagnostic results, and the percentage of infected and healthy plants per variety. The database also enables us to identify the most successful varieties that pass diagnostic inspection and can be recommended for field production. Visual inspections and disease ratings were made between 2-4 weeks after planting and are entered these into a database. Visual rating of disease is as follows: 1=healthy, 2= mild mottling/discoloration, 3= yellow mosaic, 4= necrosis and severe mosaic. We were able to screen about 250 plants each month. RNA extractions ad diagnostics can take one to two weeks to complete on the large sample populations. This is often done to confirm the plants that are identified as candidate healthy plants, are in fact virus free. Often a second round of segregating healthy and infected stocks is needed at this point. In the end, over 500 clean plants were obtained and given out. A flow chart is given below for these objective.



Objective 3 (Transmission)

For transmission research, three experiments were carried out. 1) Plant to plant transmission, where healthy plants and infected were grown in the same pot. For this very reason, various combinations of virus infected plants were selected and grown together with positive virus free plants. 2) Soil-borne transmission, where healthy Cannova were grown in the same soil where several combinations of virus infected plants were grown prior. 3) Insect transmission, where healthy cannova along with infected were grown side by side in the field with interplanting of peppers, well known for aphids (viral vector) susceptibility.

Stripe Beauty = CaYSV+ CaYMV + CaYMV-AP01	(Red Flag)	n = 10
City of Portland = CaYSV	(Yellow Flag)	n = 10
Richard Wallace = CaYSV + CaYMV-AP01	(Brown Flag)	n = 10
Ptoria = CaYMV + CaYMV-Ap01	(Orange Flag)	n = 10
Cannova = CaYMV-AP01	(Silver Flag)	n = 6
Canna Indica = nothing planted with Cannova	(Green Flag)	n = 10
Red Futurity = CaYSV + CaYMV + CaYMV-AP01 + BYMV	(Blue Flag)	n = 10

n = number of plants as samples per flag color.

As a result, there was no transmission of any viruses in plant to plant transmission as well as insect transmission experiment. However, CaYMV-AP01 virus got transmitted to healthy cannova plants through soil-borne transmission. It may be because the healthy cannovas were grown in the same soil where there were remaining plant or root residue carrying the virus after infected plants were removed.

This project was achieved with the help of a graduate student under mentorship and guidance from Drs. Verchot and Dunn. Drs. Dunn and Verchot ordered supplies, arranged for lab or greenhouse space, and established the experimental treatments. The student was responsible for setting up and running experiments, collecting data, and writing-up the results for dissemination to the public.

Goals & Outcomes Achieved:

Our first goal was to develop and optimize a proper diagnostics method, Multiplex RT-PCR to reduce the cost and time needed for canna germplasm screening. That objective was met and the protocol was used to screen plant material in objective 2. The second goal was to provide 1,000 virus free cannas to the industry, which we fell short as some of the cultivars are highly infected leading to lower numbers of clean plants being found. Our third goal was to find out various mode of transmission of *Canna* viruses in the field and greenhouse so that the growers can be informed about the measures to be taken ahead and also the precautions to reduce the disease incidence during production. We found that soil transmission is a viable way for at least one of the canna virus to be spread and have conveyed that information to at least 10 growers. Below are the activities for each objective.

Activities completed:

Objective 1: Develop a Multiplex RT-PCR to screen canna varieties:

In 2015, three common Canna viruses namely *Canna Yellow Streak Virus* (CaYSV), potyvirus, *Canna Yellow Mottle Virus* (CaYMV), pararetrovirus and *Bean Yellow Mosaic Virus* (BYMV), potyvirus, were tested using three different primers and PCR regiments that are optimized to work with these three different primers. Concentration of PCR components and regiments used for three different viruses were optimized for the assurance of reliability and sensitivity of the assay.

Reverse transcription of TNA was carried out using the High Capacity DNA Reverse Transcription Kit (Thermo Fisher Scientific, Waltham, MA, USA) and 500 ng TNA as per manufacturer's protocol. Once cDNA (Complimentary DNA) was synthesized the quality of cDNA was assured by NanoDrop ND-1000 spectrophotometer.

Multiplex RT-PCR reaction was carried out to detect the presence of BYMV, CaYSV, CaYMV. For the detection of CaYMV-AP01, singleplex RT-PCR was carried out. For both of this purpose, 2 µg of cDNA was used along with Go Taq Flexi DNA polymerase (Promega Corp, Madison WI, USA) and 5 µM primers that are listed in Table 4. Conditions of thermal cycling for multiplex RT-PCR include one cycle at 95℃ for 2 min followed by 25 cycles at 95℃ for 45 sec, 52℃ for 45 sec, 72℃ for 45 sec and a final extension at 72℃ for 7 min (Chauhan et al.

2015). Expected amplicon size of CaYSV, BYMV, CaYMV were 695, 382, and 565 respectively (Table 4) (Chauhan et al. 2015; Wijayasekara et al. 2017). For singleplex RT-PCR, thermal cycling condition was one cycle at 95℃ for 2 min, followed by 35 cyclse at 95℃ for 1 min, 56.1℃ for 1 min, 72℃ for 1 min and a final extension at 72℃ for 7 min. Expected amplicon size for CaYMV-AP01 was 1296 bp (Table 4).

For control plasmid, pYM0036P1 containing a fragment of 0036 sequence (CaYMV-AP01) was inserted into the p-GEMT Easy vector. pYSOK7672 control used for CaYSV contains CaYSV genome (OK isolate) fragment of 1,827 bp extending from 7,672 to 9,502 bp, inserted in pCR2.1 vector. The pBYMV382 control for BYMV contains a coat protein fragment of BYMV that is 382 bp in size located from 8,949 to 9,329 inserted into pGEM-T Easy vector. All these controls were used for RT-PCR throughout the experiment while using the same thermal cycle parameters. Nuclease free water was used to dilute 1 ng of each plasmid which was used for each experiment (Chauhan et al. 2015; Rajakaruna et al. 2014). Products of PCR reaction was further analyzed using 1% agarose gel electrophoresis with 2% ethidium bromide stain.
Cloning and plasmid isolation

PCR product obtained using 10 sets of primers (Table 2) were then cleaned using Wizard® SV Gel and PCR Clean-Up System (Promega Corp, Madison WI, USA). Further protocol by pGEM-T Easy vector systems (Promega Corp) was followed for ligation and transformed into high efficiency competent cells; JM 109 (Promega Corp, L2005). Transformed cells by the spread plate method were plated in LB agar containing 100 µg/ml ampicillin, 50 µg/ml X-gal, and 50 µg/ml IPTG and incubated at 37℃ for 16 to 18 hours in order to screen the transformants for inserts. White colonies (at least 5) obtained were streaked in LB media containing 100 µg/ml ampicillin and incubated at 37℃ overnight. Single colonies isolated were then allowed to grow in 5 ml LB media containing 100 µg/ml ampicillin and incubated at 37℃ overnight.

Plasmid DNA was isolated using Wizard MiniPrep kit (thermos Fisher Scientific, Waltham, MA, USA). Following day, restriction digestion (Promega, R6011) using EcoR I was carried out using the protocol by the manufacturer to verify the success of ligation. Finally, to verify the digested product size as expected, DNA was run on 1% agarose gel electrophoresis. Those plasmids that showed the expected amplicon size (Table 2) was then sent for next generation sequencing at the OSU Biochemistry and Molecular Biology Array and Bioinformatics Core Facility. Once, the sequences were obtained, it was aligned and analyzed using NCBI and SDSC biology workbench.

Table: Primers used for identification and detection of viruses in *Canna* Plants

Virus	Primer Name	Amplicon Size (bp)	Primer sequence	Melting Temperature (℃)
CaYSV	Canna-F1	695	GAT CTA ACG CAA CAT ATT CGA AAG	52.2
	Canna-R2		GAT CAT CCA TCA TTA CCC AAT AC	51
CaYMV	CaYMV-3F	565	GAC TTC CTG GGT GCA ACA AT	55.6
	CaYMV-4R		TCT GTG CAA TCT TGG CGT AG	55.2
BYMV	BYMV-F	382	GTG AAT GGA CAA TGA TGG ATG	51.6

	BYMV-R		CAC GAT TGA CAT CTC CTG CTG	55.8

Canna yellow streak virus (CaYSV), *Canna yellow mottle virus* (CaYMV), and *Bean yellow mosaic virus* (BYMV).

PCR Components:	Volume added (µl)
GoTaq Flexi DNA polymerase (Promega Corp.)	5
10mM dNTPs	0.5
25mM MgCl2	1.25
Mixed Forward Primers	2.25
Mixed Reverse Primers	2.25

7.5% dimethyl sulfoxide (DMSO)

approximately 2 mg of cDNA (a final reaction concentration of 80 ng/ml)

Nuclease Free Water to make a total of 20 µl Reaction

All the concentration of PCR components were optimized individually for its sensitivity and final volume was assured for best result.

PCR Regiments:

95°C for 2 min, 1 cycle

95°C for 45 s,
52°C for 45 s, and
72°C for 45 s;
25 cycles

Final extension at 72°C for 7 min

Objective 2: Provide healthy plant material back to Horn Canna Farm to establish a clean nursery of plant material:

Approximately, 150 plants of several different species were screened monthly by planting and replanting in the greenhouse to find over 500 healthy canna rhizomes of at least five different varieties have been provided to Horn Canna farm to further propagate to establish new clean stock. Over the last year, Horn has increased those numbers three fold and plants have remained healthy. The goal was to provide 1,000 virus free rhizomes, however, finding clean material had proven more difficult than we initially thought and we only able to provide half of what we had planned.

Objective 3: To evaluate the modes of transmission, research has been divided into three experiments:

1) Virus infected plants were taken as a source of infection and grown together with healthy Cannovas. This was to check if the healthy Cannova would encounter any infection when their rhizomes are grown together in the same pot or when their leaves come in contact with each other in the field and garden.

2) Soil previously used for growing infected plants were used for growing healthy Cannovas to check if any viruses would be transmitted to Cannovas through the residue remaining in the soil.

3) Healthy and virus positive plants were grown together with inter-planting peppers which are well known to be susceptible to aphids (known vectors for viral disease), to check insect transmission.

Experimental set up for plant to plant and soil-borne transmission

Experiments	Test plants (healthy)	Infected Canna hybrid	Flag color	Virus associated	Plants grown (M/D/Y)
Plant to plant Transmission	Cannova	Stripe beauty	Red	CaYSV+CaYMV+CaYMV-AP01	5/11/16
	Cannova	City of Portland	Yellow	CaYSV	5/11/16
	Cannova	Richard Wallace	Brown	CaYSV+ CaYMV-AP01	5/11/16
	Cannova	Pretoria	Orange	CaYMV+CaYMV-AP01	5/11/16
	Cannova	Cannova	Silver	CaYMV-AP01	5/11/16
	Cannova	Red Futurity	Blue	CaYSV+CaYMV+ByMV+CaYMV-AP01	6/21/16
Soil-borne Transmission	Cannova	Stripe beauty	Red	CaYSV+CaYMV+CaYMV-AP01	5/11/16
	Cannova	City of Portland	Yellow	CaYSV	5/11/16
	Cannova	Richard Wallace	Brown	CaYSV+ CaYMV-AP01	5/11/16
	Cannova	Pretoria	Orange	CaYMV+CaYMV-AP01	5/11/16
	Cannova	Cannova	Silver	CaYMV-AP01	5/11/16
	Cannova	Red Futurity	Blue	CaYSV+CaYMV+ByMV+CaYMV-AP01	6/21/16

(M/D/Y): Month/date/year.

Insect transmission experiment was carried out in a greenhouse inside confined cages where the different combination of viruses infected plants were put along with healthy cannovas and different vectors were introduced (Table 3).

Vector transmission experiment set up

Cage	healthy plant (n)	Infected plant (n)	Infected plants	Virus associated	Vectors	Vectors introduced (M/D/Y)
1	10	3	Stripe beauty	SV + MV + MV-AP01	Bird cherry oat aphid	10/22/16
2	10	3	City of Portland	SV	Bird cherry oat aphid	10/22/16
3	10	3	Richard Wallace	SV + MV-AP01	Bird cherry oat aphid	10/22/16
4	10	3	Pretoria	MV + MV-AP01	Bird cherry oat aphid	10/22/16
5	10	3	Cannova	MV-AP01	Bird cherry oat aphid	10/22/16
6	10	3	Red futurity	MV + MV-AP01 + SV + BYMV	Bird cherry oat aphid	10/22/16
7	4	1	Stripe beauty	SV + MV + MV-AP01	Green peach aphid	1/19/17
8	4	1	Stripe beauty	SV + MV + MV-AP01	Green bug	2/17/17
9	4	1	Stripe beauty	SV + MV + MV-AP01	Sugarcane aphid	2/17/17
10	4	1	Stripe beauty	SV + MV + MV-AP01	Bird-cherry oat aphid	2/17/17
11	4	1	Stripe beauty	SV + MV + MV-AP01	Green peach aphid	2/17/17

(n) = numbers of plants taken
SV = CaYSV; MV= CaYMV; MV-AP01 = CaYMV-AP01

During plant to plant transmission, no viruses were transmitted from virus positive plants to healthy Cannova. During soil-borne transmission, except from CaYMV-AP01 (new badnavirus in Canna hybrids) no other viruses were transmitted. For insect transmission, we tried various

insects such as sugarcane aphids, bird cherry oat aphids, thrips, whiteflies but none of them transmitted any viruses to healthy Cannas.

Highlights of major outcomes include developing the first multiple RT-PCR assay to detect all known viruses in cannas. We have published a paper on "A Reliable and Rapid Multiplex RT-PCR Assay for Detection of Two Potyviruses and a Pararetrovirus Infecting Canna Plants" that has been viewed by various scientists and growers (see under additional information). We have provided over five different cultivars and more than 500 healthy canna rhizomes to the industry and also informed more than 10 different growers about various modes of transmission of a virus. We are trying to reach out to more growers as possible to exchange information.

Beneficiaries:

The research benefited one major canna producer, two canna wholesales, and over 100 plant nurseries that buy direct from the producer. The success has enabled the large grower to regain two major wholesale customers that have not purchased from them in several years. These wholesalers had resorted to purchasing cannas from overseas growers because they did not trust the quality of rhizomes that they were obtaining from the grower in Oklahoma. Across the industry, this was the only virology lab that was screening for viruses in cannas and was the only lab providing virus free plant material to growers both large and small, thus the economic impact would be in the millions over time before the lab was closed in July 2017 when Dr. Verchot changed positions. Dr. Verchot plans to setup and screen cannas in her new role at Texas A&M, which would be valued at hundreds of thousands of dollars per species that she is able to release to growers by taking the information learned from this study. The work we have done in recent years has helped grow the industry in Oklahoma by providing clean stock plants, has created jobs and investment that were once lost due to the virus, and attracted domestic customers wanting virus free plant material. Multiplex RT-PCR is not only a rapid method but also reliable for detection of three viruses at the same time. Multiplex RT-PCR can be carried out for saplings leaves which helps in early detection of virus free plants with much less cost. Similarly, from the transmission research, farmers and nursery growers of Canna can gain huge advantages. From three different experiments, growers are now enlightened with the fact that virus positive plants when grown together with healthy Cannova, don't transmit any virus. Also, the farmers need to worry about possible transmission of viruses when planting where infected plants were grown previously

Lessons Learned:

- We took only healthy Cannova (cultivars) but not any other canna hybrid for our experiments. The research should be targeted towards canna hybrids too, given the huge prospect of it in canna industry.
- Unlike other viruses of Canna, CaYMV-AP01 (a new badnavirus to canna hybrid), doesn't show any morphological or physical symptoms. This remains an area to be explored further. However, CaYMV-AP01 along with CaYMV and CaYSV shows yellowing and necrosis in a plant.

- During soil-borne transmission experiment, no virus other than CaYMV-AP01 virus was transmitted to healthy Cannovas. Although nothing is clearly explored about CaYMV-AP01, it certainly raises a question that soil-borne transmission of the virus is a possibility.
- Canna hybrid (City of Portland) originally infected with CaYSV only, were grown in soil and the soil was used for growing virus negative Cannova plants. The results were unexpected as we determined 100% infection of Cannas with CaYMV-AP01, a new badnavirus, and not CaYSV.
- Although soil, insects, and direct contact were rumored to be means for virus transfer, our results suggest otherwise and virus transfer may occur by pollen transfer, during processing when rhizomes as divided and tools not disinfected, or transmission of sap during harvest.

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Chauhan, R.P., Wijayasekara, D., Webb, M.A., and Verchot, J. 2015. A reliable and rapid multiplex RT-PCR assay for detection of two potyviruses and a pararetrovirus infecting canna plants. 99:1-1695-1703.

Oklahoma Proven Plant Selection Program

Project Summary:

Oklahoma Proven is a promotional program that was created between a partnership with Oklahoma State University and the Oklahoma Nursery and Landscape Association as a way to inform consumers of plant products that are adaptive to Oklahoma's unique growing conditions. A different tree, shrub, annual and perennial is selected each year to be highlighted as Oklahoma Proven. With over 400 Green Industry businesses in operation within Oklahoma they all benefit by the added demand for the featured products. By being made aware of future years' selections the greenhouse and nurseries are able to ramp up their production of the featured years' items to meet the increased demand. This project was built on the success of previously funded specialty crop grants.

The marketing effort is statewide and includes television promotion, publication (poster and brochure) materials to promote the selected tree, shrub, perennial and annual, as well as presentations throughout the year. The Oklahoma Gardening (OKG) television program which has a weekly viewership of 200,000 does segments on the current year's selection. OKG also has a social media presence through Facebook and YouTube. A web site is also maintained with information and images for each of the plants. By educating the consumer about the Oklahoma Proven selections they will know what to ask for when visiting their local nursery or horticulture center therefore increasing sales.

Helping consumers make informed choices will lead to improved landscapes (healthier plants and potentially a reduction in resources such as pesticides, fertilizers, water, etc.) and a buying public encouraged about gardening, which can only create more sales for the Oklahoma green industry. The OKP program allows us to be proactive in terms of selecting superior plant material in light of emerging diseases and other maladies such as emerald ash borer, sudden oak death, pine wilt nematode, etc.; with this in mind we often focus on promoting native plant materials as alternatives to exotic plant material that may not be suited to the Oklahoma's climate, however well-adapted, non-native species are promoted as well.

Project Approach:

The selection committee, made up by industry and educators, discuss and choose plants for coming years. In general we try to plan four to five years ahead for woody plant material and two to three years for herbaceous plants.ONLA helps with getting the word out to industry (growers and retailers) through newsletters and giving a booth and opportunities to present at their annual convention. During the year previous to the promotion of plants, pictures are taken to include in the promotional material and the web site. Promotional materials are then created just prior to the first of the year for the plants to be released.The Cooperative Extension Service provides publishing services to make the brochures and posters as well as create news releases and articles and manage the web site through Agriculture Communication Services; County Extension offices and staff and Extension Master Gardener Volunteers help with distributing brochures through their offices and events as well as programming such as spring garden shows and community workshops and presentations as well as maintaining display gardens featuring the OK Proven plant selections. Materials include 500+ posters, 10,000 brochures, Power Point presentations, information sheets, and updating the web site; these materials are produced each year for the currently selected plants. A poster and a couple brochures are then mailed out to a mailing list consisting of 77 county extension offices as well as about 400 industry establishments (retailers, growers, landscapers, etc) with the invitation to order more if needed.

During the period of the grant covering the 2015-2016 promotional years we promoted the following plants:

2015 – Black gum, *Nyssa sylvatica*, improved varieties (Collector's Choice); hedge maple, *Acer campestre* (Tree); barberry, *Berberis thunbergii* spp., columnar forms (Shrub); Volcano series summer phlox, *Phlox paniculata* Volcano® cultivars (Perennial); and spider flower, *Cleome hassleriana*, improved cultivars (Annual).

2016 – Deciduous magnolia, *Magnolia* deciduous varieties (Collector's Choice); escarpment live oak, *Quercus fusiformis* (Tree); 'Color Guard' yucca, *Yucca filamentosa* 'Color Guard' (Shrub); sedges, *Carex* spp. and cultivars (Perennial); and annual vinca, *Catharanthus*, improved cultivars (Annual)

Additional money was left over after the first two years and an extension was granted. We then produced posters and brochures for the 2017 year promoting the following plants - Jujube or Chinese Date, *Ziziphus jujuba* (Collector's Choice); Fringetree, *Chionanthus* cultivars (Tree); Dwarf Palmetto, *Sabal minor* (Shrub); Milkweed, *Asclepias* species (Perennial); and Firecracker Flower, *Crossandra infundibuliformis* (Annual).

The brochure is popular among our educators and Master Gardener volunteers. We mailed two copies to retailers, educators, and others on our OKP mailing list and invited people to request more copies if they so desired. The brochure is also used extensively by extension educators and Master Gardener Volunteers for workshops and lectures. The poster is also used by the county extension offices and Master Gardener groups to use on display at their offices as well as when they give public presentations and operate information booths at county fairs, home and garden shows, and landscape and garden clinics. Many nursery centers will utilize past posters and brochures to make the consumers aware of previous selections, thus elevating their sales.

Oklahoma Proven continues to enjoy widespread media coverage. Articles are written for many newsletters, magazines, etc., including an article in our monthly newsletter, Horticulture Tips, which is sent to all the county offices and others on the list, and Oklahoma Gardener Magazine includes an article on Oklahoma Proven in their spring issues. The county educators often use Horticulture Tips for articles in their local newspapers and newsletters.

Plantings of the OKP plants are found at many of the display gardens managed by Master Gardeners as well as a display garden at the Oklahoma Gardening studio gardens in Stillwater dedicated to highlighting the Oklahoma Proven plant selections.

Many other agencies use and promote the material and plants: Oklahoma Natural Gas, tree planting project at area elementary schools; The Oklahoma Nursery and Landscape Association supports the program through newsletter reminders and a link to the OK Proven website on their web site; Keep Oklahoma Beautiful; Oklahoma Forestry Services; and the Oklahoma Horticulture Society.

Throughout the year I receive many requests from the county offices and Master Gardener programs for a PowerPoint presentation of the OKP plants. The PowerPoint presentation includes all plants since the beginning of the program, but is updated at the beginning of each year to include the new plant selections.

The Oklahoma Proven website is also updated yearly to include new plants and went through a complete makeover recently, http://www.oklahomaproven.org/. The web site provides easy access to information as well as high resolution images for anyone who would like to use them.

Goals & Outcomes Achieved:

This program has evolved over the years and it has become an educational program with the primary goal of informing the consumer of plants that grow well in Oklahoma, but may be a little less known than the common species and cultivars readily available in the industry. The survey done in 2014 illustrates not only the popularity of the program, but the use of the materials provided to extension office personnel and volunteers to forward that information out to the public. It also gives us a small idea of the value to the industry by showing how much those surveyed spent on Oklahoma Proven plant selections. The fact that we distribute nearly all the brochures and that they are heavily used at main events across the state shows the information is getting out and the public is being informed of other plants suitable for our climate. Activities for distribution included spring garden shows, county fairs, numerous workshops conducted by not only OSU, but the county extension offices (several of these events were mentioned in the report). Plants are also highlighted each year on Oklahoma Gardening, a television show that airs weekly on the public television channel and has a weekly viewership of over 200,000. The posters made are distributed to over 400 industry establishments (retailers, growers, landscapers, etc) for their use and display. No baselines have ever been set, the goal has been to distribute and educate and we feel we have done this very well as indicated by the number of materials sent out and the numerous programs in which the plants are talked about and promoted.

1. Workshops, educational programs, field days and other outreach efforts have served as a venue to promote and educate professionals and the public of plants selected for the program. The following events have served as a venue to help promote the OKP program through presentations, discussions, or distribution of OKP materials – Horticulture Industry Show, GardenFest, ONLA Convention, Extension Educator Horticulture Updates, Camp T.U.R.F., OK Invasive Plant Council Conference, and new Master Gardener training classes (about 250 trained each year) and many others. With these programs we estimate over 1,800 people are exposed to the program each year.

2. The primary GOAL of this project is to help consumers make informed choices that will lead to an improved understanding of the green industry in Oklahoma. Nearly all 10,000 brochures are distributed to counties and organizations who distribute the brochures each year. Most counties with MG volunteers distribute these brochures through their educational booths at spring garden shows and the fall county fairs. In addition these MG volunteers use the information provided, i.e. news releases, newsletters, and Power Point presentations to provide educational programs to their local communities.

A survey was conducted the spring of 2014 through SurveyMonkey. The survey consisted of ten questions and was sent to 300 Master Gardener Volunteers. The result of 100 respondents is as follows.

Q1. Have you heard of the Oklahoma Proven Plant Selection?

Yes – 99 No – 1

Q2. If yes to question one, how did you first learn about it?

County Extension Program – 9
Master Gardener Program – 78

Retail Garden Center/Nursery – 5
Other Program (i.e., plant workshops, conference, etc.) – 8

Q3. Several media sources promote Oklahoma Proven Plant Selections, which have you seen or used?

Brochure – 85
Poster – 45
Website – 49
Magazine article – 25
Power Point presentation – 33

Q4. Have you ever purchased plants from the Oklahoma Proven list after learning of the program?
Yes – 92 No - 8

Q5. When you shop for landscape plants, do you consciously seek out plants on the Oklahoma Proven list?
Yes – 87 No - 13

Q6. Approximately how much do you spend each year on Oklahoma Proven plants?

$0.00 - $49.99 – 33
$50.00 - $149.99 – 45
$150.00 - $299.99 – 16
$300.00 - $499.99 – 3
More than $500.00 – 3

Q7. Did you buy any of the 2013 plants?
Yes – 45 No – 55

Q8. If so, which ones?

Fruits for small spaces – 9
Dakota Gold Sneezeweed – 6
Walker's Low Catmint – 24
Chaste Tree – 26
Winterberry Euonymus – 8

Q9. As a Master Gardener, about how many times or at what frequency per year have you recommended Oklahoma Proven plants to the public?

0 – 4
1-5 – 38
6-10 – 25
11-15 – 9

> 15 – 24

Q10. As a Master Gardener, about how many times have you given presentations about the Oklahoma Proven program to the public?

0 – 73
1-5 – 23
6-10 – 1
11-15 – 1
> 15 – 2

Beneficiaries:

The groups benefiting from this program include the general public, especially those that engage in gardening; Extension Master Gardener Volunteers (1,000+ statewide); the landscape industry personnel and the growers and retailers (over 400 statewide). The Master Gardener Volunteers reach out to the public through numerous programs and report over 2,329,237 educational interventions with Oklahomans and as many as 1,013+ educational and community programs and activities; included in these activities, programs and contacts are opportunity to share the Oklahoma Proven Plant Selection Program.

Lessons Learned:

Through the survey given back in 2014 we know that the public is interested and using the program to make informed decisions regarding the plant material they purchase. This survey only reached out to 300 of the over 1,000 MG's in the state with only 100 responding; however, I think it still gives a clear understanding of the need and want of plant material that is known to be well adapted to the Oklahoma climate. The fact that we distribute nearly all 10,000 brochures each year is also an indication of the desire to learn more.

While we know that the public appreciates and uses the plant material promoted when available, and some growers try to grow the plants and the retailers try to stock them, some of the plants are still not available in certain parts of the state or at all. We need more buy-in and involvement from the green industry.

As we move into a rising digital age, it would be worth our efforts to pursue better ways to promote the program and material through electronic means, such as social media, QR scanning, etc. Printed material is great, but expensive and cumbersome to produce. To reduce costs of printing, in 2017 we released a simple rack card that consisted of just 2017 plants instead of the previously printed fold out brochure, which included all plants and was larger and more expensive.

The public is very interested in the plants that we promote, especially those that tend to garden frequently. Industry buy-in and input needs to improve so that plants are more readily available. The digital age in which we live could be a better method of promoting the plants; such as through apps, social media, the use of QR scanning, etc.

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Additional Information:

Appendix G
Appendix H
Appendix I
Appendix J
Appendix K
Appendix L

Improving the Cold Tolerance and Drought Performance for Oklahoma Sod Production

Project Summary:

The purpose of this project was to increase the profitability for Oklahoma sod producers through the planting, cultivating, and growing of improved bermudagrass cultivars. The goal was to identify and select sod-type bermudagrass cultivars with improved field drought performance and cold tolerance for Oklahoma. We proposed to evaluate the sod tensile strength and sod handling quality of elite germplasm that has been developed through the Oklahoma State University (OSU) breeding program and selected for good overall turf quality through 10-15 years of prior evaluation and screening trials. The specific objectives of this project were to: 1) compare advanced bermudagrass lines showing improved drought resistance and cold tolerance and compare them to the sod industry standard 'Tifway' which shows good sod quality but poor cold tolerance for Oklahoma; and 2) evaluate the sod quality characteristics of these bermudagrasses under simulated sod production conditions for Oklahoma.

This project was important and timely due to the recent, persistent droughts across Oklahoma and the recent record low temperatures experienced these past few winters. In addition, the acceptable sod tensile strength and handling quality are identified by Oklahoma sod producers as key features in selecting a prospective commercially viable bermudagrass. If a bermudagrass is developed for Oklahoma sod production that has better cold and drought survival as well as good sod characteristics, it will increase the profitability of Oklahoma sod producers and sustainability of specialty crop production in Oklahoma.

This project is achievable because the OSU bermudagrass breeding program has worked on development of bermudagrass germplasm since the 1980's. However, limited funding and focus on development of bermudagrasses with good quality, and excellent sod characteristics has not been performed for this market. This project has a high chance for success due to the availability of this germplasm in the program, just waiting to be evaluated for these purposes. This project

was not submitted to another Federal or State grant program and was not built on a previously funded project with the Specialty Crop Block Grant Program.

Project Approach:

Controlled Environment – Plant Propagation: In early 2014-2016, 10 bermudagrass cultivars and experimental lines were propagated in the controlled environment facilities at Oklahoma State University (OSU) – Stillwater. The OSU experimental lines have only been used in our research and breeding program and there is a limited amount of source material. A single, 6-inch core was collected from the field for each bermudagrass line. For the first year of this work, the cores were propagated in our controlled environment facilities from January through July 2014 for preparation for field planting of each Bermudagrass entry. In addition, additional material was prepared and maintained in the controlled environment facility through all of 2015 and 2016. This material serves for backup and for source material for future propagation or field establishment. Material in 2014-2015 was used to establish field plots in Stillwater, OK. Material was further propagated in early to mid-2016 for field plot planting of additional research plots in Bixby, OK.

Field Plot Establishment: Field plots were established at OSU – Stillwater at the OSU Botanical Garden and Turfgrass Research Center in July 2014. Field plots were then established in Bixby, OK in August 2016. The 10 entries were sprigged into 3.7 m2 plots in Stillwater and 5.6 m2 in Bixby with three replications in a randomized complete block design.

Field Plot Maintenance: The 30 OSU – Stillwater fields plots were established in 2014 and maintained for the 2015 and 2016 growing season. Field plots were planted in August of 2016 at the Bixby location. All plots were irrigated to prevent stress, fertilized according to soil test results (292 kg N/ha during the season) and mowed three days per week at 1.5 inches height of cut to simulate a sod production system. Herbicide and other pesticide applications were applied as needed throughout the growing season to control pests. A non-selective herbicide was applied every 10-14 days between plot borders to prevent contamination from one plot to the next.

Data Collection: Sod harvest data has been collected in Stillwater for the 2015 and 2016 growing seasons. Establishment data was collected for the newly established plots in Bixby, OK in 2016. First sod harvest data will be collected in Bixby, OK in 2017. The following data was collected in 2015 and 2016 in Stillwater, OK and will be collected in 2017 in Bixby, OK: establishment (0-100%), spring green-up (1-9 scale where 1 = brown and 9 = green), monthly turf quality (1-9 scale where 1 = dead, 6 = acceptable, and 9 = excellent), seed head expression (1-9 scale where 1 = no seed heads and 9 = complete coverage of seed heads), sod tensile strength (digital force meter readings converted to kg/dm2), sod handling quality (1-5 scale where 1 = complete breakage and 5 = no breakage or cracking), vertical growth (cm/day), and growth habit characteristics. The sod tensile strength and sod handling data were collected at the same time and occurred in July and August of 2015 and June and July in 2016. Sod pads were harvested using a sod cutter (Ryan Jr model) with a 30.4 cm blade width, 1.5 cm depth of cut, and a 40.5 cm sod pad length. The sod tensile strength data was collected using a vertically mounted sod tensile measuring device with a digital force meter. The sod tensile strength was measured at the point where a piece of sod tears in force per unit area (kg/dm2).

Sod Ribbon Grow-in and Maintenance: Similarly as described above, plots were maintained after sod harvest to promote sod ribbon re-growth. Plots were irrigated to prevent stress, fertilized according to soil test results (292 kg N/ha during the season) and mowed three days per week at 1.5 inches height of cut to simulate a sod production system. Herbicide and other pesticide applications were applied as needed throughout the growing season to control pests. A nonselective herbicide was applied every 10-14 days between plot borders to prevent contamination from one plot to the next.

The overall scope of this project was aimed at specialty crop production through sod producers. No other commodities benefitted from this project and the funds from this project were solely used to enhance the competiveness of specialty crops through sod production. In addition, several sod producer stakeholders and sod end-users contributed to this project through stakeholder input for sod production practices and maintenance practices to mimic sod production systems in Oklahoma. Specifically, we worked with a local, Oklahoma sod producer, Charles Binney, Owner and Operator of Riverview Sod Ranch in Leonard, OK, to establish a simulated test plot to evaluate sod production and sod strength of one of our overall good performing experimental cultivars, OKC 1131. Mr. Binney's role was to serve as an outside evaluator and sod producer evaluator of the performance of OKC 1131 and its fit for use as a sod production bermudagrass cultivar in Oklahoma. Based on Mr. Binney's real world sod production techniques and subjective evaluation, it was determined that OKC 1131 had excellent overall turfgrass quality and excellent overall sod strength.

Goals & Outcomes Achieved:

The first and second year data is summarized in Tables 1 and 2. The combination of two-year data of sod production characteristics from Stillwater, OK has shown great improvement of some bermudagrass experimental lines (Tables 1-3). OSU experimental bermudagrass lines OSU 1220 and OSU 1257 have shown sod quality characteristics greater than or equal to Tifway, the sod standard. The findings of this research will continue to aid our breeders in creating improved bermudagrass lines for sod production in Oklahoma. For the newest plots at Bixby, OK, all plots reached a minimum establishment of 70% by early October of 2016 and sod production data was collected in 2017 (Table 3).

Table 1: Sod tensile strength (STS), sod handling quality (SHQ), turfgrass quality (TQ), and vertical growth (VG) for ten bermudagrass entries (Entry) in Stillwater, OK in 2015.

Entry	STS[a]	Entry	SHQ[b]	Entry	Quality[c]	Entry	VG[d]
	kg/dm^2		(1-5)		(1-9)		cm/day
OSU 1257	139.01a	OSU 1220	4.91a	Latitude 36	6.77a	OKC 1131	.160a
Tifway	132.85a	Latitude 36	4.83a	Northbridge	6.77a	OSU 1220	.167ab
OSU 1220	125.10ab	Northbridge	4.83a	OSU 1257	6.77a	OSU 1225	.203ab
Northbridge	109.76b	OSU 1257	4.83a	OKC 1131	6.66a	Tifway	.210bc
OKC 1131	100.94bc	Tifway	4.83a	Midlawn	6.33b	Northbridge	.214bc
OSU 1225	88.64bc	OSU 1225	4.75a	OSU 1225	6.22b	Midlawn	.257cd
Latitude 36	60.41c	OKC 1131	4.66ab	OSU 1220	6.16b	Latitude 36	.268d
OSU 1221	60.71c	OSU 1273	4.33b	OSU 1273	6.11b	OSU 1221	.269d

OSU 1273	58.64cd	OSU 1221	4.16b	OSU 1221	6.05bc	OSU 1257	.273d
Midlawn	36.46d	Midlawn	2.58c	Tifway	5.77c	OSU 1273	.289d

[a]Sod tensile strength as rated with a digital force meter converted to kg/dm^2.
[b]Sod handling quality was rated on a 1-5 scale where 1 = complete breakage and 5 = no breakage or cracking.
[c]Turfgrass quality was rated on a 1-9 scale where 1 = dead, 6 = acceptable, and 9 = excellent.
[d]Vertical growth was measured as vertical bermudagrass growth in cm/day.

Table 2: Sod tensile strength (STS), sod handling quality (SHQ), turfgrass quality (TQ), and vertical growth (VG) for ten bermudagrass entries (Entry) in Stillwater, OK in 2016.

Entry	STS	Entry	SHQ	Entry	Quality	Entry	VG
	kg/dm^2		(1-5)		(1-9)		cm/day
OSU 1220	120.77a	OSU 1257	4.33a	Latitude 36	8.0a	Latitude 36	.215a
OSU 1257	109.19a	OSU 1220	4.25a	Northbridge	7.33ab	OSU 1220	.227ab
OSU 1225	109.06a	OSU 1225	4.25a	OSU 1257	7.0bc	Tifway	.228ab
Tifway	96.58ab	Tifway	4.16a	OKC 1131	7.0bc	OSU 1257	.242ab
Northbridge	69.06bc	Latitude 36	4.08a	OSU 1273	6.67b-d	OKC 1131	.244ab
Latitude 36	64.5bc	Northbridge	3.91ab	OSU 1221	6.67b-d	Northbridge	.248b
OKC 1131	61.01c	OKC 1131	3.66ab	OSU 1220	6.33cd	OSU 1221	.270b
OSU 1221	49.77c	OSU 1221	3.25b	OSU 1225	6.33cd	OSU 1225	.301b
OSU 1273	40.47c	OSU 1273	2.91b	Tifway	6.0d	Midlawn	.392c
Midlawn	3.06d	Midlawn	1.25c	Midlawn	5.0e	OSU 1273	.289d

[a]Sod tensile strength as rated with a digital force meter converted to kg/dm^2.
[b]Sod handling quality was rated on a 1-5 scale where 1 = complete breakage and 5 = no breakage or cracking.
[c]Turfgrass quality was rated on a 1-9 scale where 1 = dead, 6 = acceptable, and 9 = excellent.
[d]Vertical growth was measured as vertical bermudagrass growth in cm/day.

Table 3: Sod tensile strength (STS) and sod handling quality (SHQ) for ten bermudagrass entries (Entry) in Bixby, OK in 2017.

Entry	STS	Entry	SHQ
	kg/dm^2		(1-5)
Midlawn	132.58a	Midlawn	4.2a
OSU 1220	111.22a	OSU 1220	4.3a
OSU 1225	102.48a	OSU 1225	4.7a
Tifway	89.11ab	Tifway	4.2a
OSU 1257	81.46b	OSU 1257	4.3a
OKC 1131	80.79b	OKC 1131	4.0a
Latitude 36	74.15bc	Latitude 36	4.3a
OSU 1273	55.15d	OSU 1273	3.2b
OSU 1221	53.68d	OSU 1221	3.0b
Northbridge	47.67d	Northbridge	4.2b

[a]Sod tensile strength as rated with a digital force meter converted to kg/dm^2.

[b]Sod handling quality was rated on a 1-5 scale where 1 = complete breakage and 5 = no breakage or cracking.

The goal of this project was to obtain sod quality characteristics for advanced bermudagrass germplasm that show enhanced cold tolerance and field drought performance for eventual release for use by Oklahoma sod growers and producers. If a bermudagrass is developed for Oklahoma sod production that has better cold and drought survival as well as good sod characteristics, it will increase the profitability of Oklahoma sod producers and sustainability of specialty crop production in Oklahoma. Success would be measured by the number of germplasm evaluated obtaining sod strength, and harvestability quantitative data along with the number of germplasm advanced and released through the OSU program. We were able to measure the sod quality characteristics of six advanced experimental bermudagrass lines developed at Oklahoma State University, of two standard bermudagrass cultivars developed at Oklahoma State University, and and we were able to compare the performance of the six advanced lines and two cultivars to two industry standard bermudagrass cultivars that are widely used in the bermudagrass sod production industry. In order for this project to be deemed successful, we stated that a detailed evaluation and creation of sod performance data packages for a minimum of two advanced bermudagrass germplasm/lines was the benchmark. We were able to meet and exceed this benchmark as we developed sod performance data packages on six advanced experimental bermudagrass lines (OSU 1220, OSU 1225, OSU 1257, OKC 1131, OSU 1273, and OSU 1221). We have accomplished much with this project and provided valuable data our advanced experimental lines for sod production qualities in Oklahoma.

Related to the benchmark of collecting and providing quantitivate data, we also stated we would be successful in this project if we developed data that could be used for release of a bermudagrass cultivar or variety through the OSU program. Based partially upon the data collected in this research project, the Oklahoma Agricultural Experiment Station officially released OKC 1131 in mid-2017. In addition, the Oklahoma State University Technology and Business Development Center released a call for licensing of OKC 1131 to either a sod production company or sod growers. At the date of this final report, the licensing is still pending. That being said, it is expected that specialty crop sod production growers in Oklahoma will be sub-licensed to grow this new OSU release, OKC 1131 in Oklahoma. Thus, this project has served to enhance the competiveness of specialty crop production growers in Oklahoma by enabling them to utilize improved cultivars for production and growth, and ultimately, sells in Oklahoma.

Another indicator for success for this project is that we stated we would extend our information gained from this project to Oklahoma sod producers and the public. To this end, we held producer field days in Bixby, OK in the summer of 2016 and in 2017. These field days were held in conjuction with the Oklahoma Agricultural Experiment Station in 2016 and with the Oklahoma Sports Turf Managers Association and the Oklahoma Turfgrass Research Foundation in 2017. In 2016, we extended information of this sod production project to 20 producers, 18 University Extension personnel, 8 industry professionals, and 12 from State Agencies, not-for-profit agencies, and non-governmental organizations. In 2017, we extended information of this sod production project to 6 sod producers, 24 city/municipal turf managers, 14 commercial turgrass business professionals, and 12 University extension personnel. We also conducted train-

the-trainer sessions at the 2016 and in 2017 at the Oklahoma Turfgrass Conference whereby the research and extension team provided grass selection, use, production, and management information and proper irrigation methods training to University Extension Educators and Master Gardeners, who will in turn extend the information to their local constituencies. In 2016, there were 275 attendees to the Oklahoma Turfgrass Conference. In 2017, there were 305 attendees to the Oklahoma Turfgrass Conference. In both years, we provided a one day session (8AM-5PM) on sod production for Oklahoma sod producers, including updates of work and results of this project.

The primary major success of this project was providing data that led to the release of a cold hardy, drought resistant, and high sod quality bermudagrass experimental cultivar. This cultivar, with the OSU experimental name of OKC 1131 is being licensed to a sod production company and will be sub-licensed to sod producers in Oklahoma beginning in 2018.

The other major success of this project was extending project results through two producer, stakeholder, and end user field days and through two conferences that included full, one-day sessions focused on sod production for Oklahoma and provided details related to the results of this project.

Beneficiaries:

The major beneficiaries of this project are the specialty crop sod producers in the State of Oklahoma and those working in the turfgrass sod industry in Oklahoma. Oklahoma currently employs approximately 10,000 people in the general turfgrass industry. In addition, the Oklahoma turfgrass industry generates approximately $1 billion annually to the Oklahoma economy with $275 million of value added impact. There are approximately 90 seed and sod farms in operation in Oklahoma with approximately 18,000 acres in production. Oklahoma currently ranks 5th in the United States for turfgrass seed and sod production with a total economic impact of about $80 million annually. The release of OKC 1131 bermudagrass, partially with data provided by this project, will greatly benefit sod producers in Oklahoma by providing them an enhanced product enabling them to be more competitive in the marketplace. While not all sod producers in Oklahoma will directly benefit by release of OKC 1131, all 90 of them are eligible to obtain the permission to grow, produce, and sell this grass in Oklahoma through a license or sub-license. It is expected that up to 5 sod production growers in Oklahoma will take advantage of this opportunity.

Lessons Learned:

The proposed turfgrass irrigation system construction timeline for Bixby, OK was delayed. This delayed the establishment of research plots in Bixby, OK originally planned for 2015 until the summer of 2016. In fact, the entire new irrigation system for turfgrass sod production research in Bixby was not fully completed until November of 2017. While this did somewhat delay this project, we were able to adapt by using the agricultural linear irrigation system in Bixby to establish and maintain plots through 2017. It is surprising that some entries performed differently in Bixby compared to Stillwater (Tables 1-3). This can likely be explained by differing climates, differing conditions, and different soil types at each site. The lesson learned is that sod

production characteristics and data can vary by location and by field, thus showing a need for possible on farm research in future endeavors. This would put our bermudagrass sod entries under real-world sod production systems in addition to those conditions that can be found at our OSU research stations across the State.

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Additional Information:

Results of this project were presented at local and national meetings and are listed below.

1. Gopinath, L., J.Q. Moss, and C. Fontanier. 2017. Physiological responses of turfgrass species to water deficit stress. Student Water Conference, Oklahoma State University, Stillwater, OK.
2. Beyki, S., J.Q. Moss, and R. Raper. 2017. A new piping system design for turfgrass irrigation using AutoCad. Student Water Conference, Oklahoma State University, Stillwater, OK.
3. Segars, C. and J.Q. Moss. 2016. Sod tensile strength: how strong is your bermuda? 27th Annual Research Symposium. Oklahoma State University, Stillwater, OK.
4. Segars, C., J.Q. Moss, D.L. Martin, Y. Wu, and N. Maness. 2016. Bermudagrass: under pressure. *In* 2016 Agronomy abstracts. ASA, Madison, WI.
5. Segars, C., J.Q. Moss, D.L. Martin, Y. Wu, and N. Maness. 2015. Sod tensile strength: how strong is your bermuda? *In* 2015 Agronomy abstracts. ASA, Madison, WI.
6. Wu, Y. J.Q. Moss, D.L. Martin, and N. Walker. 2015. Breeding new bermudagrass cultivars for sustainable turf production. *In* 2015 Agronomy abstracts. ASA, Madison, WI.
7. Martin, D.L., G.L. Miller, A. Chandra, J.B. Unruh, J.Q. Moss, S.R. Milla-Lewis, F.C. Waltz, Jr., W.C. Reynolds, B.M. Schwartz, K.E. Kenworthy, T. Boyer, P.L. Raymer, and Y. Wu. 2015. Outreach education achievements from a 2011-2015 project focused on improving drought and salinity resistance in warm-season turfgrasses. *In* 2015 Agronomy abstracts. ASA, Madison, WI.

Vegetable Variety and Fertility Evaluation for Organic Hoop House Production

Project Summary:

The adoption of hoop houses (synonymous with high tunnels) for use in vegetable production in Oklahoma has increased steadily over the last ten years. While a substantial body of locally proven recommended practices exists for open field vegetable production, comparable information is relatively limited for production in hoop houses. Similarly, locally developed recommendations for organic vegetable production are scarce for Oklahoma. This project aimed to generate information on vegetable varieties that would be suitable for use on organic farms

that utilize hoop houses. Specifically, it was intended to enable the development of research based recommendation to enable growers to choose crop varieties that are productive and least likely to be damaged by insect and disease pests. Previous research in Oklahoma made possible by a Specialty Crops Block Grant showed that several edible leafy greens crop species were well suited to production in hoop houses. However, in this research crop evaluation was in most cases limited to a single cultivar. Leafy greens are a crop group for which consumer demand exists for organically grown product. Because organic production is limited in regard to options available for preventing crop damage from insect pests and plant diseases, it would be of value to growers to know if differences exist among crop species and crop cultivars for susceptibility to insect pests and plant diseases when grown in hoop houses. Thus, the first objective of this project was to "Evaluate varieties of at least 5 specific cool season vegetables for productivity and insect pest and disease susceptibility in hoop houses", with selection of crops being based on survey of growers.

Organic vegetable crop production requires adequate mineral nutrition to produce marketable yields of a quality product and only organic approved nutrient sources may be used. These sources may be mineral based, manure based or plant and animal by-products. Manure based sources are among the most economical and readily available, but are also a potential source of food borne human pathogens. In order to compare manure based nutrient sources to non-manure based sources, a second study objective was to "Compare manure-based and mineral-fertilizer-based methods for maintaining soil fertility for vegetables grown in hoop houses on Organic fields." All of the leafy greens crops variety evaluations were conducted on each of two different soil fertility management regimes.

The information generated during this study should be of interest to growers ranging from commercial organic farms to farmers' market growers, to home gardeners. Although conducted under certified organic constraints the information is applicable to all edible greens crop producers. Similarly, agriculture professionals who conduct education and outreach with producers would be interested in this information. Thus, a third project objective was to "Disseminate project results to OSU Extension Educators and specialty crop producers through outreach events and publications."

Project Approach:

Trials were conducted on certified organic land at the Wes Watkins Agricultural Research and Extension Center http://oaes.okstate.edu/frsu/watkins-research . In 2014 and 2015 the trial site was prepared by leveling and bedding the soil and installing 3 portable hoop houses, each measuring 12 feet wide and 40 feet long. Within each house there were two raised beds which divided the floors of each house into two beds about 4 feet wide. Soil samples were collected from each bed to determine baseline soil fertility, which was later used to calculate soil fertility amendment needs.

In early 2015 growers were surveyed at educational events and via email inquiries to determine which leafy greens crops were of greatest interest. Information was received from at least 22 growers and was used to determine which crop species to include in the trials. Kale and Mustard were among the crops of greatest interest and these crops were the major focus of the trials.

Spinach and Swiss chard were also of interest and were included in the trials, although to a lesser extent than the kale and mustard, primarily due to space limitations. For each of the crops of interest, suppliers of organically grown seed were identified and lists of varieties to be included in the trials were developed and seeds were requested.
For each of the two soil fertility treatments soil test results were obtained and suitable nutrient sources for meeting the soil nutrient deficiencies were identified. For the manure based treatment a locally produced composted poultry litter product was selected. For the non-manure based treatment, nutrient sources included animal by products (bone meal and blood meal) and mineral sources (potassium sulfate).

Planting of initial trials was intended for mid fall of 2015 and was to use direct seeding. However, dry summer conditions followed by wet field conditions in the fall delayed application of fertilizer and manure treatments. Due to this delay, crops were started in a greenhouse to allow for soil dry down but not delay crop establishment more than necessary. The fall / winter planting for 2015/2016 included 14 kale, 13 mustard and 5 spinach varieties and these were transplanted into the hoop houses in December 2015 and January 2016. Crops were maintained until bolting occurred (mustard) or until July 1 for kale.

A second planting was made in late 2016 or early 2017 and crops and varieties included 15 kale, 15 mustard and 4 Swiss chard. Plants were again established using transplants. Soil test results showed that nutrients levels were close enough to the desired values that further nutrient addition was thought to not be necessary. Sidedress fertilizer was applied in this planting when plants showed signs of possible nutrient deficiency.

During each of the cropping cycles periodic visual evaluations were made on all crops in the trials. Crop specific factors included general appearance, uniformity, bolting and blemishes.

Insect pest presence/damage and plant disease symptoms were evaluated these were present. Evaluations were generally made using a 1-10 scale to allow comparison of varieties for the evaluation factors. Crop yield determinations were made periodically by harvesting mature leaves without destroying the entire plant. Plant leaves were counted and weighed to provide values that would enable comparison of varieties.

Project partners contributed to conduct this research by providing expertise in specific areas. Dr. Hailin Zhang, Professor of Soil Science, assisted with the decision making process regarding soil test result interpretation and nutrient source selection. Dr. Lynn Brandenberger, Professor of Food Crops, provided guidance on production and management techniques for leafy greens crops. He assisted with selecting crop measurement and evaluation techniques. Dr. Eric Rebek, Vegetable Entomologist (although not specifically listed as a cooperator) provided guidance with insect pest identification, infestation assessment and control recommendations. Dr. Jason Warren, Soil Scientist provided guidance regarding soil management. Dr. Merritt Taylor assisted with preparation and planting of the first growing season of the trial but retired before project completion.

Goals & Outcomes Achieved:

Goal 1 was to evaluate varieties of at least 5 specific cool season vegetables for productivity and insect pest and disease susceptibility in hoop houses. The crops to be evaluated were to be determined by surveying growers in order to focus efforts on crops of greatest interest to the current industry.

- Based on survey of growers we determined that kale, mustard, Swiss chard and spinach were among the crops of greatest interest. For kale and mustard, we determined that approximately 15 varieties of each were available as organic seed and suitable for use in the trials. Smaller numbers of chard and spinach varieties were available for use. This knowledge of varieties available as organic seed will be helpful to growers who need to ascertain this information when purchasing seed.

- Two crops cycles for each of kale and mustards were grown, one in each of the 2015/2016 trial and one in the 2016/2017 trial. Each trial was established late in the first year of the cycle. In both cases, mustards were grown through about April, at which time crop growth was terminated due to crop bolting, which renders the crop no longer marketable. Kale showed minimal bolting in both trials and was evaluated through July in the first trial and through August in the second trial. The discovery that kale can crops can be maintained through the summer months could be useful for producers who are interested in early production in late summer and fall.

Result highlights:

Mustard varieties: Crops generally grew well in the hoop houses with good vigor and color. Mustards were very susceptible to powdery mildew, which is known to be a disease that is favored by hoop house culture. One variety was a newly released line that was developed for resistance to this disease. More detailed data analysis is needed (which is planned) to see if it differed in susceptibility to the disease from any of the other varieties. In general, mustards grew to the size at which harvest would begin and bolted (produced a flower stalk) soon afterwards. Many of the mustard varieties had an excellent appearance at this time and would have been of marketable quality just prior to bolting. More detailed data analysis (which is planned) may show that varieties differ in the tendency to bolt. The bolting occurred earlier than expected. This was likely due to warm late winter and early spring conditions. Being inside hoop houses would have further increased he temperatures but this was kept to a minimum by opening the houses for ventilation. Temperatures in the crop canopy were recorded continuously so a description of the micro environmental conditions of the crop can be provided (which is planned).

Kale varieties: Kale varieties grew well in hoop houses and had good vigor and color. Kale showed less susceptibility to diseases that did mustard. There were marked differences in susceptibility to powdery mildew with only a limited number of varieties showing susceptibility. This is an example of the potential value of the trial results to growers. In general, although kale is less susceptible than mustards to this disease, certain kale varieties should be avoided in hoop houses because of this factor.

Insect pests: Several insect pests were found on the crops periodically and caused damage such as leaf perforations, surface feeding on leaves, discoloration and contamination caused by webbing or exudates on the leaf surfaces. All of these are important in that they reduce crop quality. Insects that had substantial impact included harlequin bugs, aphids, diamondback moth

caterpillars and cabbage looper. Other insects that were present on occasion but with limited distribution were grasshoppers, cucumber beetles and stink bugs. For the insects causing substantial impact, evaluations were made to determine the relative incidence on the crop varieties and analysis of this data (which is planned) may show difference in crop variety susceptibility to damage from some of these insect pests.

Goal 2 was to determine how manure-based and mineral-fertilizer-based methods compare for maintaining soil fertility for green crops grown in hoop houses on Organic fields. These fertility regimes were established at the beginning of the study and used for the duration of the project. Based on general observation of crop growth in the trials, both approaches to fertility management were suitable for good crop growth. Soil test results were obtained at the end of the project and these results will be analyzed (which is planned) to show if either approach is superior for maintaining soil fertility levels. Detailed analysis of crop yield data (which is planned) will also show if either fertility source was superior to the other for impact on overall crop growth. As indicated earlier in this paragraph, once analysis is completed, it is not expected that sizeable differences will be found for the two soil fertility regimes. If so, this will be a positive finding in that it will show that growers have fertility management options available such that the use of manure for the production of organic leafy greens will not be a necessity.

Goal 3 was to disseminate project results to OSU Extension Educators and specialty crop producers through outreach events and publications. During each year of the project the project was featured in field day events that targeted Cooperative Extension Educators, growers, agribusiness professionals and scientists. Results were presented at grower oriented events including regional meetings, local county educational programs and scientific conferences. The trial was also featured in the Oklahoma Gardening Television Show in 2016.

Specific events include:

- October 2015 Organic Oklahoma Conference in Oklahoma City – Introduce project and conduct grower survey to assess interest in specific greens crops
- August 2016 Field day at the trial site
- October 2016 Organic Oklahoma Conference in Oklahoma City – Oral presentation
- February 2017 Vegetable growers meeting in Claremore, OK – Oral presentation
- April 11, 2017 Field day at the trial site
- April 18, 2017 – Horticulture grower meeting in Pauls Valley, OK – Oral presentation
- February, 2017 Southern Region American society of Horticultural Sciences annual meeting in Mobile AL – Poster presentation
- August, 2017 Present project results overview to Vegetable Researchers from southeastern US states.
- September, 2017 McCurtain County fall gardening demonstration festival – oral presentation

Major Successful Outcomes:

Kale was found to be well suited to production in high tunnels and prolonged harvest was found to be possible, including over-summering for resumed production in the fall. In general, diseases were not a great concern with kale, with the exception that a limited number of varieties were

susceptible to powdery mildew, thus making them poor choices for use in organic high tunnels. Insect pests were found to be a potential problem and the project served to document which specific insects may be of concern for growers interested in the production of this crop in organic high tunnels. These insect pests were manageable using organic approved insecticides, thus providing potential producers with the knowledge that insect pests may not be a problem that is without solution for kale production.

We showed that mustards that exhibit excellent appearance in early spring could be produced in high tunnels. However, this production was found to be short lived in that plants shifted to reproductive growth soon after reaching the stage where marketable leaves are produced. Prolonged production in high tunnels could possibly be achieved by using multiple plantings made at short time intervals to enable the harvest of marketable leaves prior to the shift to the flowering mode, keeping in mind that as temperatures increase flowering may at some point occur before useful leaf production occurs. In addition to the problem of a limited production period, mustards were also found to be highly susceptible to powdery mildew. This is a disease that is favored by high relative humidity, a condition that occurs in high tunnels.

Spinach and Swiss chard were evaluated to a lesser extent than were kale and mustards. This was due to less available varieties and to less available space in the high tunnels. There was some indication of general variety suitability to production in the high tunnels. In particular, one cultivar of Swiss chard was found to be more tolerant of cold conditions than the others that were included in the trial.

Beneficiaries:

Beneficiaries of this project are ultimately growers and their customers who desire high quality vegetables. The results are of particular interest to those interested in organically grown vegetables but should also be useful to those who are not concerned about organic status.

Results were presented in an ongoing manner as the project progressed. Based on attendance at the various outreach events where interim results were presented an estimated 300 people, including growers, extension educators, and scientists are aware of the work underway. Details of the interim results are published online at https://www.hortindustriesshow.org/ (page 104) and available to the public.

A detailed report of the trial results is in progress and will provide a comprehensive summary of the crop variety evaluation results and the soil fertility management results. This will be made available on the Oklahoma State University Horticulture Department website in the Commercial Vegetable Section http://www.hortla.okstate.edu/ (see Research and Outreach Section).

Lessons Learned:

It was initially intended to have two separate crop plantings in the periods of late fall/ early winter and again in late winter / early spring. We underestimated the time requirement for establishing the trials, which did not adequately allow for weather condition limitations on getting the trials established. Consequently, there was a single trial for each growing season. One

useful finding of this was the fact that kale crops can be grown for a much longer period than we anticipated. In fact, a kale planting made in winter in a high tunnel can last for nearly a year, and possibly longer. This could be of value to the grower as a single planting could be used for an extended period of production.

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Appendix M
Appendix N
Appendix O

Native Medicinal Plants as Cash Crops

Activities Performed:

The purpose of the project was to develop a protocol for growing, harvesting, drying, and storing Echinacea while maintaining high levels of medicinal activity in the dried plants. A portion of the budget was for clearing of the land and site preparation. During 2015 most of the activity and receipts submitted was for the site preparation. A total of $14,060.35 (38% of total award) of grant funds were spent before the contract was terminated.

The last invoice ODAFF received was in November 2015. I started trying to contact Ms. Davis after not hearing from her the first six months of 2016 with no success with phone calls, emails and certified letters to any avail. The sub-recipient failed to submit their 2nd annual report nor did she complete the paperwork to extend her contractual agreement and purchase order with ODAFF and a decision was made to terminate the contract and purchase order agreement. At this time the project was turned over to ODAFF's Office of General Council. The remaining balance or $22,790 was returned to USDA.

Specialty Crop Professional Development for Educators

Project Summary:

The purpose of this project was to provide meaningful and relevant professional development for Oklahoma educators. The goal of the project was to include education for teachers through

several venues including workshops, farm visits, farmers markets tours, orchard and grove visits, and more. The specific issue that the Ag in the Classroom staff wanted to address was that teachers in Oklahoma did not realize what specialty crops are grown in the state and their nutritional value. As a result, students were not being educated about healthy food choices.

The specialty crop professional development tours and workshops addressed this problem by taking teachers on-site for specialty crop visits and provided up-close and personal interaction with producers. These professional development opportunities provided teachers an opportunity to travel to other parts of the state and visit with growers, producers, and farmers market vendors to understand their mission and issues. Workshop breakout sessions were held at the state summer conferences in 2015 and 2016, with activities and lessons focused on specialty crops taught by outstanding Ag in the Classroom teachers. Oklahoma specialty crop growers were invited to the conference for participation in discussion group mini-sessions. Teachers' meals at each event, tour and workshop included specialty crop foods provided and prepared by local growers.

This project was important and timely because the health and nutritional choices of Oklahoma students and teachers is steadily declining. Americans are being inundated with misinformation through social media, news shows, commercials, billboards, television and more. It is the goal of the Ag in the Classroom staff to make sure that factual information is shared with educators to combat the misperception of students and teachers in the state. The objectives of this project were to increase the knowledge of specialty crops grown in the state, increase the consumption of specialty crops grown in the state and increase the dissemination of factual information about the crops for teachers to take back to their classrooms.

This project built on other Specialty Crop Block Grant projects that Ag in the Classroom has received funding for. These projects include: 1) “Harvest of the Month” Poster sets which were created for teachers and school cafeterias to use to educate students about eating healthy, specialty crops which are grown in Oklahoma. Teachers who attended the traveling “Specialty Crop Development” road trips and State Summer conference received these poster sets to complement the new knowledge received on the tours. 2) “Specialty Cropopoly” Board games were created to engage students in the classroom and challenge them to learn about the specialty crops, as well as practice good financial literacy practices. Teachers also received these games for attending the tours and conference. 3) Additionally, teachers received a free copy of the “Specialty Crop Ag M(AG)azine” and “Specialty Crop Ag Activity Book” and were allowed to request free classroom sets of whichever magazine was most beneficial to their students. These magazines provide another opportunity for teachers to share their new knowledge with students in an educational and informative manner.

Project Approach:

During the summer of 2015, 349 Oklahoma educators were educated about specialty crops that are grown in Oklahoma. These educators were able to attend rolling workshop/tours in the Shawnee, Tulsa, Gore, and Poteau areas. They were also able to choose sessions at the State AITC Summer conference which specifically focused on specialty crops. During these tours and workshop sessions, the educators were able to talk to producers who raise Christmas trees,

blueberries, blackberries, vegetables, peaches, and pecans. They were also able to sample food dishes made from these crops, and learn new information about how the crops grow and the nutritional benefit of eating the crops, as well as the economic impact their sales make on Oklahoma. They were provided with resources to use in their classrooms to educate their students about eating healthy and why they should eat specialty crops in their diets. And they watched as talented teachers highlighted activities to do with students in the classroom to educate them about their experiences. As a result of the summer tours and workshops in 2015, potentially 8,725+ students are being educated about specialty crops because their teachers were able to experience the crops in a hands on approach.

During the summer of 2016, 416 Oklahoma educators were educated about specialty crops that are grown in Oklahoma. These educators were able to attend rolling workshop/tours as well as sessions at the State Ag in the Classroom (AITC) Summer Conference, which specifically focused on specialty crops. The tours took place in three different parts of Oklahoma: Hydro/Anadarko area, Stillwater/Oklahoma City area, and the Gore/Poteau area. The educators were able to visit pepper, sweet potato, and vegetable farms, farmers markets, orchards and grape vineyards, and visit with local producers in Oklahoma. As a result of the summer tours and workshops in 2016, potentially 10,400+ students are being educated about specialty crops because their teachers were able to experience the crops personally.

In 2017, there was still money left in the grant to fund one more tour. Fifty educators from across Oklahoma traveled in the Claremore/Miami area with Oklahoma Ag in the Classroom to experience Specialty Crops, up close and personal. Teachers were able to pick blueberries and blackberries. They enjoyed a lunch that was grown and prepared by the Vinita FFA Chapter. These students have a garden and harvested lettuce and kale for the salad, and made homemade blueberry cheesecake! Teachers also toured J&M Mushroom Farm, everyone was amazed at how much science is involved in growing mushrooms. As a result of this final summer tour in 2017, potentially 1,250+ students are being educated about specialty crops. *This brings the three-year total number of educators reached to 815 with a potential of 20,375+ students reached.*

AITC staff purchased headsets for participants to wear during the traveling tours. These headsets allowed all participants to hear the producer from any distance and ensured that they were able to increase their knowledge. During the tours, the participants get off the buses and walk through fields. It can be difficult to hear the producer talking when you are at the back of the group and they are walking away from you and talking while they walk. The headsets eliminated this problem. Several teachers stated that the headsets allowed them to “always be able to hear” and others said they helped them “stay on task.”

The Oklahoma Pecan Growers Association, Oklahoma Fruit & Vegetable Association, and Oklahoma Farm Bureau are represented on the AITC advisory board, and members of these groups were project partners for the tours and conference. This board was instrumental in the planning process for the workshops, tours and conference. The Oklahoma Farm Bureau (OFB) is the largest agricultural organization in the state and many of their members are involved in specialty crop production. When organizing the tours and the summer conference, these organizations were contacted and they made suggestions for tour stops that would highlight specialty crops grown in Oklahoma. Tour stops featured visits to farms whose owners belong to

one or more of these organizations. During the summer tours, the Ag in the Classroom staff arranged tours at two pecan groves, as well as two pecan processing factories. One of the OFB State Directors owns the pecan processing plant that was a tour stop. Tour stops also included peach orchards, fruit and vegetable farms, you pick berry farms, Christmas tree farms, honey producers, a mushroom farm, and grape vineyards. The producers at these stops belong to one of the organizations listed above and/or participate in the Oklahoma Farmers Market program, Agritourism program, or Made in Oklahoma program. Oklahoma Farm Bureau also played a key role in the state summer conference. They had members attend the conference to visit with the educators about specialty crops grown in Oklahoma, they assisted in administering surveys of educators, and they were room host during the specialty crop workshops at the conference.

Goals & Outcomes Achieved:

The purpose of these tours was to provide meaningful and relevant professional development for Oklahoma educators. The educators were able to visit farms, farmers markets, orchards and groves, and visit with local producers in Oklahoma. The original goal was to provide professional development opportunities for 1000 educators. While only 815 educators participated in the professional development opportunities, the Ag in the Classroom staff still believes that the project was a success. Without it, these teachers and their students, still would not know about many of the Specialty Crops grown in Oklahoma, their nutritional benefit, nor the economic impact on the state.

AITC staff provided seven different traveling workshops for teachers to attend. The workshops took place in different parts of Oklahoma: Tulsa area, Shawnee area, Hydro area, Stillwater area, Claremore/Miami area, and twice in the Gore/Poteau area. Teachers were also given the opportunity to attend specialty crop sessions at the 2015 and 2016 State Summer Conferences.

Tulsa 2015 Tour Results: Before the tour, the educators were given a pretest and at the conclusion of the tour, they were given a posttest. Both the pretest and the posttest had True and False statements about specialty crops. The average score on the pretest was 76%. After the tour, the same test was given and the average was 79%.

Shawnee 2015 Tour Results: The average pretest score was 66% and the post test average score was 73%.

Gore/Poteau 2015 Tour Results: The average pretest score was 69% and the posttest average score was 80%.

2015 State Summer Conference Results: Four specialty crop workshops were offered for teachers to attend. The teachers who attended these sessions were given a survey to fill out. Prior to the workshops only 86% knew what an Oklahoma Specialty crop was. At the conclusion of the workshops, 100% of the teachers said that they now knew what Oklahoma Specialty crops were and intend to teach their students about specialty crops and use the new resources and ideas they gained from the workshops.

Overall Results for 2015 Conclusion: These increases, while small, showed the AITC staff the importance of educating the teachers about specialty crops in order to ensure they are encouraging students to eat fruits and vegetables. It also showed the need for a better survey. The tests used in 2015 were not effective in measuring the educator's change in knowledge. Therefore new pre and posttests were created to better measure the increase of educator's knowledge of available and nutritious specialty crops.

Hydro 2016 Tour Results: Before the tour 65% knew what a specialty crop was, however after the tour 100% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip only 50% thought peaches were a specialty crop, 40% thought edamame was, 65% thought pecans were and 55% thought cantaloupe was a specialty crop. However, after the tour 100% knew peaches were a specialty crop, 100% knew edamame was, 100% knew pecans were and 79% knew cantaloupe was a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein only 25% answered pecans before the tour. However, after the tour 100% answered pecans.

Stillwater 2016 Tour Results: Before the tour 65% knew what a specialty crop was, however after the tour 97% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip 79% thought peaches were a specialty crop, 64% thought edamame was, 76% thought pecans were and 64% thought cantaloupe was a specialty crop. However, after the tour 100% knew peaches were a specialty crop, 100% knew edamame was, 100% knew pecans were and 91% knew cantaloupe was a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein 47% answered pecans before the tour. However, after the tour 85% answered pecans.

Gore/Poteau 2016 Tour Results: Before the tour 43% knew what a specialty crop was, however after the tour 98% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip 57% thought peaches were a specialty crop, 34% thought edamame was, 77% thought pecans were and 27% thought cantaloupe was a specialty crop. However, after the tour 88% knew peaches were a specialty crop, 98% knew edamame was, 91% knew pecans were and 92% knew cantaloupe was a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein only 27% answered pecans before the tour. However, after the tour 90% answered pecans.

2016 State Summer Conference Results: At the AITC State Summer Conference four specialty crop workshops were offered for teachers to attend. The teachers who attended these sessions were given a survey to fill out. After attending these workshops, 72% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. When asked to select the Oklahoma specialty crop from these choices: banana, strawberry, rye, and canola, 87% chose Strawberry. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein 59% chose pecan.

Overall Results for 2016 Conclusion: The original goal of this grant was to see a 25% increase in the knowledge of specialty crops grown in Oklahoma. The results of the tests given during the tours showed an increase of more than 25%, so it is believed the tours were successful in promoting Oklahoma Specialty Crops. While the numbers for the summer conference were not as good as the tour results, the AITC staff is still pleased because a significant number of educators were correct in their answers.

Claremore/Miami 2017 Tour Results: Before the tour 66% knew what a specialty crop was, however after the tour 98% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip 58% thought peaches were a specialty crop, 40% thought edamame was, 70% thought pecans were and 51% thought cantaloupe was a specialty crop. However, after the tour 69% knew peaches were a specialty crop, 98% knew edamame was, 86% knew pecans were and 91% knew cantaloupe was a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein only 34% answered pecans before the tour. However, after the tour 69% answered pecans.

Overall Results for 2017 Conclusion: The original goal of this grant was to see a 25% increase in the knowledge of specialty crops grown in Oklahoma. The results of the tests given during the tours showed mostly increases of more than 25%, so it is believed the tours were successful in promoting Oklahoma Specialty Crops.

Beneficiaries:

The specialty crop beneficiaries of the project are the growers and farmers market participants that saw, and will see, increased consumption of the fruits, vegetables, and nuts grown and sold in the state. On each of the tours, Specialty Crop products were purchased for the participants to sample. They were also given time to shop at each of the tour venues. Therefore, the growers saw a direct impact on sales the day that we were there, but other growers will see an increase in sales in their area as the teachers returned home.

Other beneficiaries include the teachers and students who gained valuable knowledge regarding their own health and nutrition choices. The number of educators that benefitted from this project was 815, the students that could potentially be impacted is 20,375+. Other educators were also indirectly impacted as teachers who participated in the tours scheduled professional development workshops at their schools. The project aided the specialty crop beneficiaries through the knowledge gained in workshops, tours, and resources provided. The project also benefitted the beneficiaries through the opportunity to eat the specialty crops and learn first-hand the nutritional value of the specialty crops, putting to rest any of the misinformation provided through media.

Lessons Learned:

When the grant was written, the goal of the AITC staff was to increase the educators knowledge of available and nutritional specialty crops in the state by 25%. The results of the surveys in 2015 did not indicate a 25% increase in knowledge. However, the problem was not the amount of new knowledge; the problem was creating a pre and post test that accurately measured the increase in

knowledge. One way that the AITC staff adapted the testing on the third trip, was to send the test to the producers to view ahead of time. This allowed them to address the questions and give the answers as they spoke to the group. During the first trip to the Tulsa area, the test results only improved by 3%. For the Shawnee trip, they increased by 7%. However, on the third trip to the Gore/Poteau area the scores improved by 11%. The AITC staff evaluated the questions asked and created a better test to use during the 2016 and 2017 tours.

AITC staff also planned for 500 educators to participate in the tours and summer conference in both 2015 and 2016. Unfortunately, only 349 educators participated in 2015 and 416 in 2016. However, the AITC staff was pleased with this number because it is more educators than those who attended the 2014 professional development opportunities. When planning for 2016, the staff looked for more ways to promote both the tours and the summer conference in hopes of continuing to increase the number of educators reached with these professional development workshops, and it worked. One positive take away, was that there was money left to offer one more Professional Development tour in 2017, and 50 teachers benefitted from the additional tour.

The surveys given at the 2016 summer conference were not given correctly. The presenters who gave the four workshops were asked to give the survey in a pre and post manner to correctly measure growth. However, there was a misunderstanding and the surveys were only given once. Some of the respondents changed their answers on their surveys so growth could be seen, however not all of them did. Therefore growth could not be measured. All that could be reported was the total percentage answered for each question. On the tours, the AITC staff teaches the participants and ensures that correct information is given to increase their knowledge. At the conference, the presenters are asked to cover the information, but the staff is not in the rooms during the whole workshop so it is unclear what information the presenter's did/did not share. Another factor that improved the 2016 and 2017 tours was the 2015 experience. The AITC Staff had more knowledge of great Specialty Crop venues and were able to plan better. Also, since the Gore/Poteau tour was a repeat, it was much easier to plan. The teachers loved the opportunity to sample the products. Many had never picked peaches from a tree and enjoyed the experience. Others had never tried fresh blueberries or blackberries and enjoyed sampling as they picked. Many were excited to find you-pick orchards in their areas to take their families and students to!

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Additional Information:

N/A

Farmers Market Garden Grants

Project Summary:

In 2015, the Oklahoma Department of Agriculture received 28 grant applications from Oklahoma Grown Farmers Markets and awarded 24 of the proposals. Funding levels were determined by the number of vendors participating at the market on a weekly basis. The markets were selected by an application process with a panel of judges that scored the applicants. The grants were utilized to solely promote the consumption, purchase and production of specialty crops through billboards, print and radio advertising and chef demonstrations. While consumers continue to become more health conscious and concerned about better eating habits, market managers continually look for new ways to reach the community. Out of the 24, all of the farmers markets awarded consist of small producers who rely on direct marketing to sell their products. Farmers Markets continue to be a major outlet for growers to sale their fruits and vegetables and the grants help impact growers and the sale of specialty crops across the state.

As this project builds on previous work of the specialty crop grant program, reports show that markets across the state have seen an increase in consumer demand and specialty crop production. Over $2,758,880.00 was reported in specialty crop sales from the 24 Oklahoma Grown Markets that received grants. By offering grants to these Oklahoma Grown Farmers Markets, we have increased the demand and competitiveness for Oklahoma Grown specialty crops and attracted new customers and vendors to our markets.

Project Approach:

The Oklahoma Department of Agriculture awarded 24 Oklahoma Grown Farmers Markets with specialty crop grants. Grants were made available on a competitive basis to existing and start up 100% Oklahoma Grown Markets. Funding levels were determined by the number of vendors participating at the market on a weekly basis. Those markets with an average of 6-10 vendors weekly were eligible for up to $1,000, markets with 11-20 vendors could receive up to $2,000 and those markets with over 21 vendors weekly qualified for a maximum of $3,500 to promote specialty crops within their markets. The applications were reviewed by ODAFF staff and evaluated by an outside committee. Grants were distributed in two advancements with the market receiving their first advancement in advance and their second advancement after a progress report and receipts were turned in to ODAFF staff documenting how the first advancement was spent. After the grant was completely spent, the market sent a final report along with all receipts and examples of how the money was spent to promote specialty crops. Markets that were awarded used the grant funding on advertisements, newsletter publishing, signage and promotional ads to draw consumers to the market to purchase specialty crops. Staff also visited a number of markets that were awarded the grant to ensure the funds were used properly.

Goals & Outcomes Achieved:

The main goal with this project was to enhance the competitiveness of specialty crops while building consumer confidence in locally grown produce. Reports show there are more than 775 growers that participate in Oklahoma Grown Farmers Markets with 125 new growers selling at these markets this year. The grant funds raised customer awareness and demand with over

$2,758,880.00 in sales this year at Oklahoma Grown Farmers markets. With consumer demand and vendor participation continuing to grow, ODAFF feels that specialty crop advertising, signage, marketing promotion and newsletter publishing continue to be a good avenue to reach consumers in city and rural areas.

Beneficiaries:

The beneficiaries of these programs were current 100% Oklahoma Grown Farmers Markets, vendors, market managers, city officials and the buying customer. Markets that receive grant funds continue to show an increase in sales and vendor participation at their market along with giving the consumer more options of fresh, locally grown produce.

Lessons Learned:

Splitting the grant into two installments has tremendously helped make sure the grant funds are spent properly ahead of time instead of having to try and get grant funds returned to ODAFF for purchases not approved. Also, sending out a guide of acceptable advertisements and examples of ideas has also helped with this problem.

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N/A

Plasticulture Garden Grants

Project Summary:

The Plasticulture garden grants are a continuation of a program partially funded by previous specialty crop grants. With the need for more locally available fresh fruits and vegetables the Oklahoma Department of Agriculture utilizes the grants to encourage limited resource farmers to grow specialty crops to sell in the community and at farmers markets. Participants are selected through a competitive grant process in which applications are reviewed by a panel of specialty crop industry leaders. Once selected, individuals can participate for a maximum of three years with the grant funds covering the cost of installing the plastic, drip irrigation and supplies for up to one acre of production. ODAFF utilized a portion of the grant funds to contract with 4 individuals that have appropriate equipment to assist with the instillation of gardens so that they are completed in a suitable time to maximize the growing season.

Project Approach:

A press release was sent to statewide news publications to notify growers that applications were being accepted along with notifying cooperative extension staff at Oklahoma State and Langston Universities about the Plasticulture grant program. ODAFF also posted the information to their agency website and Facebook pages. To be eligible individuals must qualify based on Langston University's definition of a limited resource farmer as a person with a direct or indirect gross farm income of no more than $100,000 in each of the two previous years and has received little or no assistance from the government. The grants were awarded through a competitive process with a 4 member committee scoring and ranking the applications. The number of proposals varies each year as spots open up from individuals completing their 3 years in the program or when participants drop out. Once applications are scored and ranked, the Oklahoma Department of Agriculture notifies the applicant to let them know if they were approved or denied.

In 2015 ODAFF adopted a new policy of requiring all new participants to attend a meeting to receive their contracts. Two meeting dates were selected and locations were chosen in close proximity to the attendees. During the meeting ODAFF staff passed out the contractual agreements along with additional paperwork and reviewed the contracts with everyone to eliminate any confusion about what is required of both parties. The rules of the program were reviewed and the participants were told the name of the contractor who would be installing their gardens. Also during the meeting the Plasticulture coordinator tried to go over helpful growing tips since the participants have not had any experience growing on plastic.

Participants must have their water and soil tested to ensure that adequate supply and quality are available for the production of specialty crops. Gardens sizes can range from ¼ acre up to one acre in size. Individuals are required to have all the ground preparation and soil ready for the raised bed process before contacting the contractor to install the garden. ODAFF Plasticulture coordinator along with 4 contractors lay the raised beds and drip irrigation while covering the bed with a sheet of plastic.

ODAFF requires participants to sell a minimum of 50% of the specialty crops they grow. This generates revenue for the farmers along with providing access to healthy fruits and vegetables to both their families and people in the community. Participants are required to submit annual production reports documenting the weight of produce sold and the sale of the specialty crops. Failure to comply and turn in production reports results in termination from the program.

Goals & Outcomes Achieved:

The Plasticulture program was designed to help limited resource farmers with their production of specialty crops by using more efficient growing methods. Twenty nine new gardens were installed in 2015 in addition to the 25 gardens for those in year 2 and 3 of the program for a total of 54 gardens. Timing of installation is very important when putting in gardens and the sooner they are installed, the growers chance of being successful in increased. Year-end production reports are due to ODAFF by December 31st and they are being reviewed at this time. Early analysis shows that growers had a very successful growing year in 2015 but until all reports are logged it is not determined if the total dollar amount in sales increased from the previous year.

Beneficiaries:

Fifty four (54) individual farmers participated in the Plasticulture program directly benefited through increased revenue from the production of specialty crops. Consumers who live around the participants also benefit from the program due to living in rural areas of the state that could be classified as "food deserts" where there is not ample access to fresh fruits and vegetables. By selling either directly from the farm or through one of the many OK Grown Farmers Markets, this provides those consumers with produce that is fresh and healthy.

Lessons Learned:

Oklahoma received an unseasonably large amount of rainfall and cooler temperatures during the early growing period and then very limited rains in July and August. By utilizing the benefits provided by Plasticulture the raised beds and ground covering kept the seeds and plants safe from the adverse effects of the weather. Some producers that were new to the program and not experienced with Plasticulture had to replace some plants that died do to being too dry during the wet period. The Plasticulture coordinator contacted all the participants to remind them the even though we were getting rainfall the plants were being protected and would need to receive their moisture from irrigating.

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N/A

Farm to School Specialty Crop Awareness

Project Summary:

The purpose of this project was to increase the awareness of specialty crops for school food service professionals, resulting in growth of local specialty crop use in their school meal programs. The specialty crop awareness tours addressed this goal by taking Child Nutrition personnel on-site for specialty crop visits and provided up-close and personal interaction with producers. These specialty crop awareness opportunities provided the participants an opportunity to travel to other parts of the state and visit with growers, producers, and farmers market vendors to understand their mission and issues. The tours took place in the Stillwater/Oklahoma city area and Hydro area during 2016. In the summer of 2017, the tours took place in Tulsa and OKC/Mustang areas. All four tours also had educational activities focused on specialty crops

taught by Farm to School Staff. The participants meals on each tour included specialty crop foods provided and prepared by local growers.

This project was important and timely because the health and nutritional choices of Oklahoma students, teachers and child nutrition personnel is steadily declining. Americans are being inundated with misinformation through social media, news shows, commercials, billboards, television and more. It is the goal of the Farm to School staff to make sure that factual information is shared with Child Nutrition staff to combat the misperception of students in the state. The objectives of this project were to increase the knowledge of specialty crops grown in the state, increase the consumption of specialty crops grown in the state and increase the dissemination of factual information about the crops for Nutrition Educators to take back to their schools. This project did not build on a previous Specialty Crop Block grant.

Project Approach:

During the summer of 2016, 85 Child Nutrition Specialists were educated about specialty crops that are grown in Oklahoma. These professionals were able to attend rolling workshops/tours which specifically focused on specialty crops. During these tours the child service personnel were able to talk to producers who raise the crops and learn new information about how the crops grow, as well as the nutritional benefit of eating the crops. They were provided with resources to use in their cafeterias to educate students about eating healthy and why they should eat specialty crops in their diets.

Two workshops/tours were offered during June and July of 2016. The tours took place in two different parts of Oklahoma: the Hydro/Anadarko area and the Stillwater/Oklahoma City area. During the Hydro tour participants toured a large sweet potato and watermelon producer's farm. They also had lunch at a winery and had a cooking demonstration by the chef who demonstrated how to use berries and pecans while preparing delicious and nutritious desserts. The Stillwater tour allowed Nutrition Providers to pick fresh peaches and also to learn nutritional information about peaches, pecans, grapes, and berries. The participants were able to pick fresh asparagus and other vegetables at a large vegetable farm and also visited a farmer that grows carrots for schools in Oklahoma.

In 2017, 100 Farm to School Nutritionist were once again educated about specialty crops. They had the opportunity to travel in the Tulsa area or in the Oklahoma City area. Participants were able to meet farmers at Farmers Markets and on the farm and visit with them about the crops they grow. They also had time to shop for fresh fruits and vegetables that aren't often found at stores. They were able to pick blackberries and blueberries straight off the vine. Participants toured a pecan processing facility and learned about pecan harvesting and processing. They enjoyed a Farm to Table meal where a chef gave a tour of the restaurant and explained how they take their food from the farm to the table. After lunch, Nutrition Extension Specialist gave cooking demonstrations with recipes that could easily be used in the cafeteria.

Significant partners in this project were professors from Oklahoma State University Department of Nutritional Sciences, Oklahoma State University School of Hospitality and Tourism, Oklahoma State Department of Education Child Nutrition director, and the National Farm to

School SW Regional Farm to School lead from the USDA. They were represented on the Farm to School Advisory Conference Committee and helped in the planning and presenting of the conference. Additionally, Farm to School staff from Ohio, Arkansas, and Texas were instrumental in the conference and participated as panelists, along with farmers and child nutrition directors from Oklahoma who participate in the Farm to School program. The keynote speaker was a certified School Nutrition Specialist through the School Nutrition Association.

Goals & Outcomes Achieved:

The purpose of these tours was to provide meaningful and relevant specialty crop awareness opportunities for Oklahoma nutrition experts. The nutrition educators were able to visit farms, farmers markets, orchards and groves, and visit with local producers in Oklahoma. The original goal was to provide professional development opportunities for 200 school food service professionals. While this goal was not met, the tours came extremely close providing 185 child nutrition specialists and educators the opportunity to learn about specialty crops grown in Oklahoma. The Farm to School staff were thrilled with these numbers and consider this project a success. Without it, these nutrition specialists and the students they feed, still would not know about many of the Specialty Crops grown in Oklahoma, their nutritional benefit, nor the economic impact on the state.

Before each of the tours, the Child Nutrition Specialists were given a pre-trip quiz about specialty crops. After the tour, the same quiz was given and the results were compared.

2016 HYDRO TOUR RESULTS: Before the tour 63% knew what a specialty crop was, however after the tour 93% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip only 25% thought peppers were a specialty crop, 38% thought asparagus was, and 56% thought rye was. However, after the tour 75% knew that peppers were, 70% knew that asparagus was, and 67% knew that rye was not a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein 53% answered soybeans while only 20% answered pecans. However, after the tour only 19% answered soybeans and 74% answered pecans.

2016 STILLWATER TOUR RESULTS: Before the tour only 28% knew what a specialty crop was, however after the tour 97% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip only 36% thought peppers were a specialty crop, 42% thought asparagus was, and 40% thought rye was. However, after the tour 100% knew that peppers were, 100% knew that asparagus was, and 88% knew that rye was not a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein 37% answered soybeans, 26% answered beef, and 33% answered pecans. However, after the tour 97% answered pecans. Before the tour, only 9% knew that eight strawberries provide 140% of the recommended daily intake of Vitamin C for kids. However, after the tour 85% knew this nutrition fact.

2017 TULSA TOUR RESULTS: Before the tour only 43% knew what a specialty crop was, however after the tour 82% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip only 49% thought peppers were a specialty crop, 53% thought asparagus was, and 45% thought rye was. However, after the tour 84% knew that peppers were, 92% knew that asparagus was, and 87% knew that rye was not a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein 43% answered soybeans, 28% answered beef, and 30% answered pecans. However, after the tour 77% answered pecans. Before the tour, only 10% knew that eight strawberries provide 140% of the recommended daily intake of Vitamin C for kids. However, after the tour 74% knew this nutrition fact.

2017 OKLAHOMA CITY/MUSTANG TOUR RESULTS: Before the tour 50% knew what a specialty crop was, however after the tour 88% knew that a specialty crop is a crop that is cultivated or managed by people and used for food, medicinal purposes, or aesthetic gratification. Also before the trip 57% thought peppers were a specialty crop, 69% thought asparagus was, and 36% thought rye was. However, after the tour 94% knew that peppers were, 97% knew that asparagus was, and 82% knew that rye was not a specialty crop. Finally, when asked which of these choices: beef, pecans, soybeans or milk, was a specialty crop and a good source of protein 38% answered soybeans, 17% answered beef, and 45% answered pecans. However, after the tour 91% answered pecans. Before the tour, only 24% knew that eight strawberries provide 140% of the recommended daily intake of Vitamin C for kids. However, after the tour 97% knew this nutrition fact.

The original goal of this grant was to see a 25% increase in the knowledge of specialty crops grown in Oklahoma. The results of all surveys show an increase of more than 25%, so we believe the workshops/tours were successful in promoting the Oklahoma Farm to School program, as well as Oklahoma Specialty Crops.

Beneficiaries:

The specialty crop beneficiaries of the project are the growers and farmers market participants that saw, and will see, increased consumption of the fruits, vegetables, and nuts grown and sold in the state. On each of the tours, Specialty Crop products were purchased for the participants to sample. They were also given time to shop at each of the tour venues. Therefore, the growers saw a direct impact on sales the day that we were there, but other growers will see an increase in sales in their area as the food service specialists returned home. Many farmers who grow specialty crops are not connected to the schools to sell their products locally, so hopefully through these tours, connections have been made and more local grown foods will be sold and purchased through the Farm to School Program. As they plan menus for school cafeterias, they are now better equipped and more knowledgeable to purchase specialty crops and prepare them for meals.

Other beneficiaries include the Child Nutrition specialists and the students they serve who gained valuable knowledge regarding their own health and nutrition choices. The number of nutrition specialists that benefitted from this project was 185, the students that could potentially be

impacted is 50,000+. This number is difficult to determine, because the school districts that attended vary in size, but 50,000 is the lowest number that should be impacted. These students will be able to experience specialty crops served on their school breakfast and lunch trays, try a new specialty crop through a taste testing opportunity, or learn nutrition facts as they go through the school lunch line. The project aided the specialty crop beneficiaries through the knowledge gained in workshops, tours, and resources provided. The project also benefitted the beneficiaries through the opportunity to eat the specialty crops and learn first-hand the nutritional value of the specialty crops, putting to rest any of the misinformation provided through media.

Lessons Learned:

When the goal was originally written, it was under the direction of a different state coordinator, however she left the position and new staff took over. Therefore, there was a delay getting the tours started. The original tours were planned to take place in 2015 and 2016. However, due to the staff changes, the tours took place in 2016 and 2017. These tours were a huge success, and grew in number of participants. As a result of these tours, the new Farm to School staff was able to visit with the Nutrition experts in the schools and determine the needs of the program to move forward. The participants were very grateful for an opportunity to meet and interact with their local producers.

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U-Pick Marketing Promotion

Project Summary:

The Oklahoma Agritourism Program's goal for this project was to increase visits to Oklahoma UPicks and farmers markets for the purpose of increasing Oklahoma specialty crop sales.
We set out to create a cohesive marketing campaign to first, raise general awareness of the time (seasonality) and place (U-pickfarms and retail outlets) that you can purchase these specialty crops focusing on U-Pick operations and farmers markets. The second goal for this campaign was to create tools that the farmers can use to educate and enhance the customer experience while at the farm.

Project Approach:

The first step was to seek out and select a creative agency that could assist the Agritourism program in creating the artwork for this campaign. We did the approved RFP process and Jordan Advertising won the bid for this project. We decided we needed a campaign that would both educate and entice a new audience that may not have been aware of the opportunities of where to find specialty crops locally or how to take care of and consume them after purchased. After our wine trail project was received with so much success we decided to create something similar with our u-picks to give a reason for consumers to talk about and take notice of these specialty crop outlets. We decided that these trails needed to have a fun, youthful and creative vibe with the goal to get people seeing this possible purchase as a food experience, following the fresh, healthy and whole food trends to attract a whole new demographic and get as much attention for these specialty crops as possible. The campaign was divided into The Oklahoma Jelly Making Trails.

After we created the campaign our marketing company purchased social media and we bid and purchased signs for each venue that sold specialty crops or value added products made with specialty crops. Items printed were signs with crop facts about each specialty crop, recipe card with most popular specialty crops, and a rack card size map of the Oklahoma Jelly Making Trails with information on each location what specialty crop they offered and their contact information.

Once the campaign was created and printed materials were complete, we shipped all educational and promotional materials to each producer to use for their own promotion. We started in April 2015 with strawberries season and carried the campaign through each crop season and ended in late August with peaches. We have collected a lot positive feedback from producers and will do an official survey right before the next season. The project specifically benefited our producers with strawberries, blueberries, blackberries, peaches, edible herbs and flowers, elderberries, various vegetables, and those that make jellies and jams from these products.

Goals & Outcomes Achieved:

A campaign was launched to create awareness and drive traffic to increase the demand for the Agritourism's U-pick specialty crops. The campaign consisted of grouping the u-picks into trails for marketing purposes. This consisted of a map/rack card brochure, recipe cards and signage at the producer site and an online campaign. Including a landing page with the url www.okjellymaking.com.

There were short and long term outcomes to this project. We have seen immediate impact on awareness and visitors to the farm but we also anticipate this campaign to be used year over year and will benefit the u-pick producers each of these seasons it will be used.

The goals were to increase awareness and educate the public about the availability of these specialty crops as well as the care, storage and processing of these crops. These goals were met on every account. We had 3 blog posts and our 2 major newspaper publications cover the trails. We increased our social media sometimes to over 900% reach with a steady over 100% reach over the previous year.

From direct effect of this grant we have had increase in Facebook, Instagram, Pinterest, website views, and free press for our producers. Facebook likes increased over 1,200, during the peach season; Facebook reach rose to over 95,000, our videos that we shared of the campaign have been viewed more than 240,000 times. We encouraged the consumers click through to our website and our website visits were up over 400% year over year during the months of the U-Pick Seasons.

Beneficiaries:

There were 46 producers included on the Jelly Making Trails. Each of these producers has been highlighted and 3 producers each with different crops were covered by bloggers and shared on their social media. These producers were all growers or sellers of the specialty crops that were listed in the original plan.

Lessons Learned:

This project was very successful and we learned that there is a huge demand for these fresh products from a younger demographic as well as the older demographics. We confirmed just how responsive customers are regarding the experience around the u-picks. We learned that giving them education about the produce before and after their purchase encourages them to take the step to try the local and fresh produce.

In surveying the u-picks while creating this campaign we discovered that one of their biggest obstacles is getting customers to know they are there and when they will have produce. If you can make them understand when and where to purchase the product and overcome some of the common buying objections (I don't know how to pick it, I don't know what to do once I make the purchase) you can sell more of it.

The next step in this process is to educate and help consumers know when, where and how to get the fresh local specialty products.

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Additional Information:

Appendix B
Appendix C
Appendix D
Appendix E
Appendix E
Appendix G

Specialty Crop Educational Demonstration Video

Project Summary:

This grant was written to allow Ag in the Classroom staff to provide high-quality, professionally developed videos to provide motivation, demonstration, instruction and information to educators about Specialty Crops and related resources and how to incorporate those into their core curriculum. Specialty crop resources developed for the AITC program including lessons, SmartBoard activities, posters, games, and recipes will be taught in classrooms and captured in these professional, engaging videos, each lasting approximately two minutes each.

Education budgets have been reduced, including the budgets for professional development for teachers and administrators. AITC staff wanted to create quality, useful videos teachers and administrators could access in a variety of settings. These videos may be watched by individual teachers on plan times or at home, by a group of teachers in a professional learning community, or by the entire staff during a faculty meeting. The short length of these videos makes them accessible and inviting for teachers to use.

This project continues to build on previous SCBG projects that AITC has received funding for. These projects include the Specialty Crop Magazines which teachers all over Oklahoma are using to educate students about specialty crops. The videos highlight and show ways the teachers are using the magazines and other specialty crop resources to teach the AITC lessons. These videos provide an excellent model for other teachers on a variety of ways to best utilize the magazine and other specialty crop resources.

All of the SCBG projects, like “Harvest of the Month” posters, “Specialty Crop Smart Board” lessons, and the “Specialty Crop” magazine, work together with the Specialty Crop Educational Video to enhance teachers and students understanding, awareness and consumption of specialty crops.

Project Approach:

Oklahoma Ag in the Classroom developed, filmed and uploaded seven high-quality, professionally produced video vignettes to the Oklahoma Ag in the Classroom Youtube channel and the Oklahoma Ag in the Classroom Webiste. The titles of the videos include: Red Dirt Veggie Tie Dye, Bubbles in Cabbbage Juice, Oklahoma’s Berry Best, A Tough Nut to Crack, Good Grapes, Pumpkin Pie in a Bag, and A Pair of Pears.

AITC staff contacted and located outstanding educators using AITC specialty crop resources that felt comfortable demonstrating and promoting specialty crop lessons. The teachers were then filmed teaching and modeling their lessons.

The videos were then uploaded to the Oklahoma Ag in the Classroom website. The website featured different specialty crop educational videos on the main page of the website each month. The videos were highlighted in the electronic newsletter that AITC staff sends out each month.

The videos were also uploaded to the Oklahoma Ag in the Classroom Youtube channel. The videos have been shared at the Oklahoma AITC State Conference by AITC staff and different teachers from around the state. These videos were also part of the presentation Oklahoma AITC staff presented at the National Ag in the Classroom Conference. This allows the videos to have a wider audience than just Oklahoma teachers.

The videos have received positive reviews from conference participants as well as classroom teachers and administrators. To date the videos have been viewed 932 times either through the AITC website or the Youtube channel. The videos will continue to be highlighted on the Oklahoma AITC website and shared with teachers during workshops and presentations.

Goals & Outcomes Achieved:

One of the goals for this project was to complete ten video vignettes. Because of a series of delays beyond AITC's control in sending and receiving bids for this project, to stay within budget the decision to make seven videos instead of ten was reached. The videos were finished and available on the AITC website and Youtube in the middle of the first quarter of 2016. The videos have been available for less than ten months.

The best way for AITC staff to document whether or not the specialty crop educational videos are reaching their target audience is by monitoring the number of views each video receives. To date this is the number of views each video has:

Red Dirt Veggie Tie Dye—214 views
Bubbles in Cabbage Juice—74 views
Oklahoma's Berry Best—95 views
A Tough Nut to Crack—49 views
Good Grapes—92 views
A Pair of Pears—82 views
Pumpkin Pie in a Bag—326 views
This brings the total to 932 views.

If each view represents a teacher who teaches an average class of 20 students, then the videos have impacted more than 18,640 students so far. Therefore, increasing their knowledge, understanding, and awareness of specialty crops in Oklahoma. The goal is that this increased knowledge of specialty crops will increase the consumption of specialty crops by those teachers, students and their parents. The potential for more exposure for specialty crops is still a reality because the videos continue to be featured on the Oklahoma AITC website and featured in workshops and presentations around the state.

Beneficiaries:

Oklahoma producers of specialty crops that sell their products at local farmers' markets or market their products to Oklahoma retailers benefited from the production of these videos because students who have increased their knowledge of specialty crops through exposure to the

videos and the lessons behind them hopefully shared their knowledge with parents and asked them to buy these fruits and vegetables for them to eat outside of school.

Lessons Learned:

While creating the videos, AITC staff discovered the difficulties of synthesizing an hour's lesson into a two-minute summary and still keeping the key components of the lesson. The goal of the videos is to provide a short, succinct model of specialty crop lessons and keep all the necessary components within the time frame.

When teachers' knowledge increases the ability to impart that new knowledge to their students increases. Although there is not a direct way to measure this outcome, AITC staff is confident that student's knowledge, understanding and awareness of specialty crops has increased because of their teacher's exposure to the specialty crop educational video.

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Oklahoma Ag in the Classroom Website:
http://oklahoma4h.okstate.edu/aitc/

Oklahoma AITC Youtube channel:
https://www.youtube.com/playlist?list=UUHrMYiovhGnrRSuDJk6l5RQ

Specialty Crop-opoly Game

Project Summary:

This grant was written to allow Oklahoma Ag in the Classroom staff to create a Specialty Crop-opoly Game as a resource to be used in 3rd-12th grade classrooms across Oklahoma to engage students in an exciting way, and then use the excitement to teach them about local specialty crops, their nutritional value and the importance of consuming more fruits and vegetables. Disseminating improved information about fruits and vegetables is critical to the overall health and well-being of Oklahoma students. Childhood obesity in Oklahoma has increased by 148% since 1990. Oklahoma continues to rank toward the bottom of all states in fruit and vegetable consumption.

AITC staff wanted to create a resource that is fun and engaging but is also a learning tool. The Specialty Crop-opoly is played like Monopoly, but all of the information is about specialty crops of Oklahoma. Each time the game is played, students will learn about specialty crops and their nutritional information. Along with the specialty crop information, students will engage in other areas of curriculum as well-reading, mathematics, and social studies.

This project allows teachers a venue to educate students about healthy food choices, therefore empowering them to make healthy food choices when they are deciding what to eat. This resource helps students learn about making healthy food choices that include local fruits and vegetables available in different seasons in Oklahoma.

Project Approach:

Oklahoma Ag in the Classroom developed, printed and distributed to classrooms across Oklahoma the Specialty Crop-opoly for grades 3rd-12th.

2,000 copies of the game were originally printed. Approximately 1,600 of the games have been given to classroom teachers at a variety of teacher events. These games have been distributed to teachers who have been trained in using Ag in the Classroom materials. Teachers are not given a game unless they receive training. Games have been distributed at On the Road with Ag In The Classroom, AITC State Summer Conferences, Oklahoma State Department of Education's Engage OK and Encyclomedia conferences, many individual school's professional development days, and workshops held across the state. This resource has also been shared with pre-service teachers when AITC staff present workshops at state universities.

This is a popular resource with teachers and students alike. Because teachers network with each other, Specialty Crop-opoly is often a requested resource with teachers and administrators when they are scheduling a professional development session.

Goals & Outcomes Achieved:

AITC staff often hear that Specialty Crop-opoly is a favorite resource given to teachers at a workshop. AITC needs to document the benefits of the information learned from Specialty Crop-opoly. This is done using a QR code on the box and on a playing card in the game that takes the players to a survey asking a few simple questions.

One of the measurable goals of the resource is to increase the knowledge of available and nutritional value of the specialty crops in Oklahoma. The survey received 100% of the responses. The totals so far for the questions include. 1.) Is this a fun way to learn about specialty crops grown in Oklahoma—over 98% say yes 2.) How many specialty crops do you remember? Name them without looking at the game. 41.82% could name 5; 27.27% could name 10; 9.09% could name 15; 10.91% could name 20; and 10.91% could name more than 20. 3.) Now that you have played the game will you—52.73% said they would eat more fruits and vegetables; 32.73% said they would try some form of fruits and vegetables; and 14.55% said there would be no change in their fruit and vegetable consumption. 4.) Before you continue what is one nutritional fact you learned about Oklahoma specialty crops? Some answers include: Strawberries contain

significant levels of phytonutrients; Summer squash is very low in calories and high in fiber; High levels of antioxidants help my body function at a higher level.

Beneficiaries:

Oklahoma producers of specialty crops that sell their products at local farmers' markets or market their products to Oklahoma retailers benefited from the production and distribution of this game because students have increased knowledge and awareness after playing the game. They will be more apt to ask their parents to buy Oklahoma grown fruits and vegetables and make the decision to choose these foods when given the opportunity.

Lessons Learned:

Although there is a QR code for each game, there is no guarantee that teachers will have each new group of students complete the survey every time a new set of students plays the game. There is no way to ensure that data is collected each time the game is played. AITC will continue to inform teachers during professional developments and workshops about the QR code and ask them to have students complete the survey.

AITC will continue to perform professional development workshops for teachers and students around the state and promote and give this resource to those classrooms until the remaining 400 are distributed. The results of this project will continue to be shared with the AITC advisory board, specialty crop growers and other interested stakeholders.

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Appendix A

OKLAHOMA FARMERS MARKET GROWER CONFERENCE

Project Summary:

The Oklahoma Nutrition Information and Education Project (ONIE) organized, implemented, and evaluated the third annual Oklahoma Farmers' Market Conference in 2017. The conference provided education and outreach opportunities to specialty crop growers, farmers' market managers, community supporters, and Agritourism sites from across the state. The conference

offered presentations on a variety of topics including marketing and social media, accepting SNAP, Senior Farmers' Market Nutrition Program (SFMNP), and Chickasaw Nation benefits, growing-season planning, how to establish or expand a farmers' market or Agritourism site, comply with health regulations, build stronger collaborative networks among specialty crop producers, and improve local economies. The conference offered a comprehensive approach to the marketing of specialty crops. Each conference topic directly supported the enhancement of the retail sale of specialty crops in Oklahoma. Overall, the conference improved specialty-crop retail sales, expanded the number and quality of access points to purchase specialty crops, and improved the local economy throughout the state. . This project did not build on a previous Specialty Crop Block grant.

Project Approach:

With the support of the Oklahoma Department of Agriculture, Food & Forestry, and in collaboration with the Oklahoma Department of Human Services, Oklahoma Agritourism, and the Oklahoma Tobacco Settlement Endowment Trust, ONIE hosted the third annual statewide farmers' market conference that was held on February 23, 2017. Approximately 350 farmers' market managers, vendors, and participants from interested community organizations attended the conference.

To arrange the details of the 2017 Oklahoma Farmers Market and Agritourism Conference the ONIE Project conducted conference planning meetings with representatives from organizations across the state that support farmers markets and specialty crop growers. Such organizations included the ONIE Project, ODAFF, the OSU-OKC Farmers Market, Integris Health, OKDHS, the Oklahoma Food and Farm Alliance, the Oklahoma Tobacco Settlement Endowment Trust, and the Regional and Eastern Food Banks of Oklahoma. Through these meetings the conference committee identified the Embassy Suites Hotel in Oklahoma City as the conference location. A contract was executed with the hotel and audio-visual vendor, and other outside caterers.

Upon finalizing the date and location of the conference an online registration survey was created using Qualtrics survey software and managed by ONIE staff members. After the registration survey was complete ONIE and ODAFF designed and printed postcards that were distributed to farmers market managers across the state to promote the conference. Social media and email was used to promote the conference to interested parties. Once conference breakout session topics and speakers were identified and secured, we created and printed the conference agenda (see attached). The ONIE Project then created breakout session and post-conference evaluation forms that were distributed to conference attendees to evaluate interest in subject and knowledge gained. The conference was hosted on February 23rd with 350 attendees. Immediately following the conference, the evaluation data from the breakout sessions and overall conference was analyzed by ONIE staff members using SPSS software.

Project partners contributed financial support and in-kind support to the conference. TSET provided $2,500 to the conference for speaker honoraria and an honorarium and travel expenses for the keynote address. Oklahoma Agritourism provided $2,000 to support the venue rental expenses. All other support was in-kind and included volunteers to staff the conference as well as moderate the breakout sessions.

Goals & Outcomes Achieved:

The conference was successful in fulfilling the goal of providing an opportunity for farmers markets and specialty crop producers to connect and form collaborations with other producers and farmers markets and expand their social networks with a variety of community organizations including representatives of health departments, the Oklahoma Tobacco Settlement Endowment Trust, American Indian nutrition programs and other organizations that support farmers markets. This was achieved through providing networking opportunities at conference as well as the creation of a Facebook farmers market discussion group (Oklahoma Farmers' Market Network). The conference also fulfilled the goal of increasing attendee knowledge of topics presented at the conference as indicated in the evaluations of each breakout session and overall conference. The success in achieving the goal of providing citizens of Oklahoma with greater access to locally grown specialty crops was documented by an increase in the number of registered farmers markets, SNAP-accepting markets, and direct marketing farmers.

•Enhance the competitiveness of specialty crops through increased sales at Oklahoma farmers' markets

Outcome Measure: Gross sales data for specialty crops sold at Oklahoma farmers' markets is not available. SNAP and Senior Farmers' Market Nutrition Program (SFMNP) redemptions at farmers' markets is an excellent proxy for specialty crop sales at farmers' markets because these benefits can only be used to purchase food items. . SNAP sales at Oklahoma farmers markets increased from $137,731 in 2016 to $173,655 in 2017, a 26.1% increase. This increase in sales exceeded our goal of a 15% increase.

- Enhance the competitiveness of specialty crops through increased access

Outcome Measures: A significant outcome measure for this goal is an increase in the number of farmers' markets in the state and an increase in the number of farmers' markets and direct marketing farmers in the state that accept SNAP. The number of farmers markets in the state increase from 78 in 2016 to 82 in 2017. The number of farmers' markets that accept SNAP increased more dramatically. There are now 28 farmers' markets in the state that accept SNAP benefits compared to 22 in 2016. In 2016 there were no direct marketing farmers in the state that accepted SNAP compared to 6 direct marketing farmers that accept SNAP benefits in 2017.

- Enhance the competitiveness of specialty crops through enhancing or improving the economy as a result of specialty crop development

Outcome Measures: The outcome measures for the previous two goals are evidence of the success in improving the local economy through specialty crop development and enhanced economic opportunities for specialty crop farmers. An increase in the number of farmers' markets and direct marketing farmers in the state and increased SNAP redemptions at farmers' markets represent improved economic prospects for specialty crop producers.

Beneficiaries:

The beneficiaries of the Oklahoma Farmers' Market Conference include Oklahoma specialty crop growers who sell at farmers' markets and managers of Oklahoma farmers' markets that sell specialty crops. Community members who support farmers' markets and the increased access to specialty crops (i.e. government officials, health departments, non-profits) also benefited from the conference. Oklahoma citizens who patronize the local farmers' markets also benefit from enhanced access to fresh, quality specialty crops. Approximately 350 people directly benefited from attending the conference. Benefits from the event also reached beyond conference attendance because those who attended the event shared new ideas and resources acquired at the event with their respective communities and markets. Consumers who purchase specialty crops also benefited by getting farm-fresh, quality agricultural products. The project benefited conference attendees through the acquisition of new knowledge, ideas, collaborations and resources that could be used to increase specialty crop production and retail sales in Oklahoma. The economic impact of the conference includes the increased production of specialty crops and retail sales throughout the state, and additional economic activity and resources for the local rural economy.

Lessons Learned:

We have now organized and held three conferences that have grown in popularity each year. We are thoroughly familiar with the logistics of planning and running a successful conference, and the 2017 program evaluation of the overall conference and individual sessions have shown that the attendees endorsed the experience and gained valuable insights on a variety of topics about how to better attract and satisfy consumers demand for locally produced specialty crops.

The biggest problem and potential improvement for the project is finding a suitable venue to host the conference at a reasonable cost. Each year, the conference has exceeded the capacity of the facility and we have had to find a larger site each year in anticipation of increased attendance. This has been the biggest problem we experienced. As the conference has grown, there are fewer and fewer potential venues that can accommodate the event. The major issues with the venue are ballroom and breakout room capacity, audio/visual capabilities and expenses, and parking.

As the result of a suggestion received during the 2017 conference evaluation activities, we established an Oklahoma Farmers' Market Network group on Facebook (https://www.facebook.com/search/top/?q=oklahoma%20farmers%20market%20network) that currently has 111 members. This group page provides a venue to share information, promote local events and opportunities, and exchange ideas with network members.

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N/A