Ohio Department of Agriculture

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## CONTENTS PAGE

FINAL REPORTS

## PROJECT REVEIWS

**Project Title: CIFT – High Pressure Processing of Ohio Grapes**

**Project Summary**

The following final report describes the results of the "High Pressure Processing of Ohio Grapes" project coordinated by CIFT, with the objective being to implement the High Pressure Processing (HPP) technology to treat wine and grape juice. The project drew on work previously completed in the wine and juice industries that demonstrated potential for high quality, high value-added products could be produced from Ohio grapes using the HPP technology.

High Pressure Processing (HPP) is an emerging technology that is increasingly used for the processing of foods and drinks. HPP exposes products that are encased in a liquid filled container to pressure applied isostatically (at all points on the surface of the container) at levels reaching 87,000 psi. This process effectively kills many pathogenic bacteria, and denatures spoilage enzymes, thereby extending the shelf life of many processed foods and drinks, without degrading their sensory characteristics by exposing them to heat. Due to the lack of heat applied, sensory characteristics are maintained, and minimal use of preservatives is necessary so products with "clean" labels result. Ohio has a number of installations with high pressure processing systems that were able to be utilized to help develop and demonstrate the value and consumer appeal of this technology on Ohio grapes.

The purpose of this project was to identify, produce, evaluate, and promote value added products that use Ohio grapes (juice and wine), and are processed using HPP. Ohio is a national leader in the HPP technology, as well as the sixth largest grapes producer (see table below).

**Top States' Annual Gallons Produced in 2016**

| Rank | State | Total Produced (Gallons) | % of Total |
|---|---|---|---|
| 1 | California | 680,272,512 | 84.35% |
| 2 | Washington | 40,747,190 | 5.05% |
| 3 | Ney York | 27,696,308 | 3.43% |
| 4 | Pennsylvania | 12,405,181 | 1.54% |
| 5 | Oregon | 11,822,972 | 1.47% |
| 6 | Ohio | 5,938,738 | 0.74% |
| **7** | Michigan | **2,576,238** | **0.32%** |
| 8 | Kentucky | 2,176,059 | 0.27% |
| 9 | Vermont | 2,172,526 | 0.27% |
| 10 | Virginia | 2,157,395 | 0.27% |
| --- | Others | 18,512,772 | 2.30% |
| | **Total U.S.** | **806,477,891** | 100.00% |

Growing grapes and making wine is a long-term commitment, both financially and physically. New vineyard plantings require three to five years before yielding a full crop, with another one to three years of aging for wine to be ready for sale. Unlike many industries, once vineyards and wineries are established they are effectively rooted and tied in place – an Ohio vineyard cannot

simply be relocated to another region or outsourced to another country. Wine and grapes are inextricably tied to the soil from which they are grown. Moreover, wine and their products and allied industries diversify local economies and create employment and new market opportunities. In 2016, there were 265 wineries in Ohio producing wine, up 51% from 175 wineries in 2012. Based on information collected from the Ohio Grape Industries Committee and the Ohio Department of Taxation, total wine produced in Ohio in 2016 was 1,227,000 gallons, or approximately 516,000 nine-liter equivalent cases. There are only slightly more than 900 acres of wine grapes in Ohio and 311 wineries manufacturing wine, so the percentage of Ohio grapes used for wine production is a very small percentage. The vast majority of wineries are sourcing fruit, juice and/or concentrate from outside of Ohio.

Overall, 90% of the state's wineries had sales or production of fewer than 5,000 gallons annually (roughly 2,100 cases). Additionally, fewer than ten wineries had wine production of between 5,000 and 10,000 gallons in 2016. Less than 5% of the remaining wineries had production in excess of 10,000 gallons in 2016, or sales in excess of 5,000 cases. With so few Ohio wineries producing the majority of the wine, one of the barriers of the HPP technology is the expense. Small wineries, which account for 90% of those in Ohio, do not make enough wine to justify the additional cost of the HPP technology.

**Trend of Growth in Ohio Wineries**

| Year | # of Wineries |
|---|---|
| 2016 | 265 |
| 2012 | 175 |
| 2008 | 124 |
| 2004 | 109 |

Source: Wine Institute, OGIC, TTB

This project utilized HPP to treat several products; specifically, wine, grape juice and later hops, grown at the Agriculture Incubator Foundation (AIF) in Bowling Green, Ohio, that were high pressure processed before being used to make beer. Data from previous studies strongly suggests that shelf life can be improved, preservative use lessened or minimized, and flavors enhanced as they are treated with HPP. Data also suggests that the technology can control microbes and also "wild yeasts" that can affect the fermentation process adversely. This processing eliminates the need to add sulfites, which, in addition to causing allergic reactions in some, possess acrid flavor characteristics. Reducing the use/presence of sulfites could result in more vivid flavor profiles in both wines and juices. As mentioned, there is a significant amount of data to support this hypothesis.

As internationally-known sommelier Olivier Magny points out, the sulfites added to mass-produced wine are "usually derived from petroleum and added in high quantities," giving them the potential to cause headaches in some consumers. (Sarnoff, R. 2013 May 13. Sulfites and Wine: The Headache Connection. Mommy Greenest. [accessed 2018 October 9]. http://www.mommygreenest.com/sulfites-and-wine-the-headache-connection/.).

Nutrition expert Joy Bauer warns wine aficionados to "proceed with caution" when purchasing wine to which sulfites have been added. "Check labels carefully," she adds, "to avoid this sneaky migraine trigger." (Bauer, J. 9 Common Migraine Triggers. Joy Bauer. [accessed 2018 October 9]. https://joybauer.com/photo-gallery/common-trigger-foods/sulfites/.). HPP processing has fortuitously been shown, via peer-reviewed research, to offer the capability to diminish the widespread use of $SO_2$ as a wine preservative. (van Wyk, S., Farid, M., and Silva, F. 2018. $SO_2$, High Pressure Processing and Pulsed Electric Field Treatments of Red Wine: Effect on Sensory, *Brettanomyces* Inactivation and Other Quality Parameters During One Year Storage. Innovative Food Science and Emerging Technologies. 48: 204-211.).

Sulfites, however, are not the only "culprit" causing headaches in wine drinkers. Naturally occurring tannins in wine have also been identified as a source of headaches. (Carlson, D. 2016 May 25. What's Really Causing That Red Wine Headache. Chicago Tribune.). HPP processing reduces the amount of tannins. (Tao, Y., Sun, D., Gorecki, A., Blaszczak, W., Lamparski, G., Amarowicz, R., Fornal, J., and Jelinski, T. 2012. Effects of High Hydrostatic Pressure Processing on the Physicochemical and Sensorial Properties of a Red Wine. Innovative Food Science and Emerging Technologies. 16: 409-416.).

The positives of HPP wine processing notwithstanding, does HPP negatively affect sensory factors, such as taste and appearance? Research suggests that it does not. A recent study concluded that while HPP processing may change the color of wine, flavor and aroma remain unaffected; in fact, overall "global sensorial assessment" is better than that for the untreated product. (Santos, M.C., Nunes, C., Cappelle, J., Goncalves, F.J., Rodrigues, A., Saraiva, J.A., and Coimbra, M.A. 2013. Effect of High Pressure Treatments on the Physicochemical Properties of a Sulphur Dioxide-Free Red Wine. Food Chemistry. 141(3): 2558-2566.).

**Project Approach**

The initial approach to this project was to produce samples of the various products using the HPP technology, generate data demonstrating their value, and use the samples and supporting data to promote production. Along with the production of these products, the goal was to reach out to consumers across the state of Ohio, wineries, and potential markets for the product. Additionally, the project generated "fact sheets" describing cost data, production processes, packaging, and other parameters necessary to help demonstrate the economic potential of the products. Activities also included promotion of these results, with the goal being to present information about HPP to wineries across Ohio and those involved in the production of grape juice. The effectiveness of the plan was measured by the number of meaningful interactions with potential users of the technology. The final measure was the number of business relationships that were established between and among Ohio institutions as a result of this project. The overall successful completion of this project resulted in the development of high value-added products for Ohio grapes, the validation of their consumer acceptance, the establishment of the business relationships required to produce and market them, and the promotion of their use.

**Goals and Outcomes Achieved**

As mentioned, the eventual outcome of the project was a significant increase in the production of wine and juice grapes that would be enabled by the demonstration of high quality products using the HPP technology for grapes. To support the longer-term goal of increased revenue and economic betterment for Ohio growers, the initial goals of this project were:

**Goal 1:** Increase the knowledge and awareness of the opportunities represented by HPP processing within this market. Included was an increase in awareness of the products and their advantages, a review of the increased revenues made possible, and acknowledgment of the facilities available for local processing. In order to accomplish this goal, CIFT implemented numerous activities to promote knowledge and awareness of the HPP technology for wine throughout the state of Ohio:

- CIFT attended the 2017 Ohio Grape and Wine Conference to share information about what HPP has to offer to the grape/wine industry of Ohio; approximately 200 growers from across the state were in attendance. Feedback from growers with whom CIFT spoke was positive.

- CIFT hosted an HPP Technology Showcase tour for Columbus and Cincinnati area wineries/interested growers, along with two representatives from the Ohio Grape Association, to demonstrate the potential for the HPP technology. Presentations relating to how HPP works, packaging considerations, current and emerging applications for food and drink products, and assistance for development, along with comparisons with food items currently using HPP, were featured to further exemplify the benefits of the technology. Additionally, participants were able to taste two samples of wine – one sample had undergone HPP and the other had not. CIFT reached out to 35 wineries in the Central Ohio Wine Region and 26 wineries in the Ohio River Valley Region. Outreach was through the Ohio Grape Association via email, personal phone calls to winery owners, and follow up personal emails. Twelve individuals attended the event.

- Directly after the Technology Showcase tour was completed, CIFT conducted a focus group among the attending wineries, to discuss their reactions to the HPP process and their feelings about it, as well as to discuss whether their customers are looking for sulfite free wine. Discussion among the wineries about the HPP technology was robust. The main barrier the wineries in the focus group saw to the HPP process was, as mentioned earlier in this report, that 90% of wineries in Ohio make fewer than 5,000 gallons of wine, and the winery owners/growers felt that this technology would not be cost effective for them.

- Continued meetings and discussions with a company throughout the project resulted in this company opening a “tolling” facility in Delphos, Ohio. The facility is managed independently and takes products suited for HPP, resulting in an increase of local Ohio processing potential for specialty crops. The opening of this facility in Ohio is a huge economic win for the state. A tolling facility is the first step towards addressing the concerns of smaller processors in that an operation does not need to purchase equipment in order to benefit from HPP; rather, it can have products processed for a fee fairly

locally. The closest such option previously was in Wisconsin. Should the market be willing to bear the added cost associated; it is a unique business proposition. This facility could be a game changer for the small companies, including wineries, across the state.

- CIFT published an article about HPP in the Ohio Grape Industries Monthly newsletter, which reaches over 300 growers across the state:

High Pressure Processing - from CIFT
The quality and safety of the food consumers eat and drink today have become critical factors influencing their choices. High Pressure Processing (HPP) is an emerging preservation technology that is increasingly used for the safe processing of foods and drinks. HPP subjects products that are encased in a liquid filled container to pressure applied uniformly at levels reaching 85,000 psi. This process effectively kills many pathogenic bacteria, and denatures spoilage enzymes, thereby extending the food/drink shelf life without degrading their sensory characteristics. A whole range of food and drink products are currently being treated by HPP, including fruit juices, seafood, and meat products. Recently, the wine industry has been challenged to meet consumer demands to reduce the amount of SO2 added to wine, especially since it has been associated with health risks such as allergic-reactions incurred by sulphite-sensitive individuals. For winemakers, the use of HPP has the potential to decrease the amount of SO2 added to raw grapes, thus allowing them to offer their customers wine with the same properties found in untreated wine.

To learn more about HPP for wine, please join us for an Open House on June 20 at 10:30 a.m. at Avure Technologies. CIFT is coordinating this initiative to enhance Ohio's reputation as a "center for excellence" in the production of food and drink products with high quality, enhanced food safety, and minimal use of chemical preservatives.
Hear presentations relating to:

o What is HPP and how does it work for wine?
o Packaging considerations applicable to the process
o Ways to utilize HPP
o Current and emerging applications for food and drink products
o Assistance available for development

The program will be hosted by Avure Technologies

- CIFT attended two wine festivals in July 2018 and September 2018, and spoke with more than 70 consumers, each of whom tasted HPP processed grape juice and completed a survey that focused on their thoughts about the HPP process and sulfite-free wine. Interestingly, consumers who were familiar with the addition of sulfites to wine said they purchased wine almost twice as many times a year as those who did not indicate familiarity. Purchasers who were unaware of the addition of sulfites were also more apt to buy Ohio wine, as opposed to more frequent buyers who only procure Ohio wine in about 20% percent of their overall purchases. Additionally, about one-quarter of all wine

purchases among these latter respondents were of Ohio wines. A common complaint heard from those who do not buy Ohio wines is that they are "too sweet."

Regarding sulfites in wine, most consumers with whom CIFT spoke at the festivals were aware of the possible negative effects associated with the addition of sulfites to wine. However, over half had not heard of sulfite-free wine. When introduced to the idea, an overwhelming number of respondents said they would be interested in purchasing sulfite-free wine, and on average, buyers indicated that they would be willing to pay $2.00 more per bottle. About a quarter of respondents indicated that they would not be willing to pay additional for this type of wine. Finally, regarding the purchase of sulfite-free *boxed* wine: more than 75% of those surveyed responded affirmatively. However, persons who eschew boxed wine are those who purchase wine more often. For this reason, future packaging development should focus upon developing a bottle that can withstand HPP.

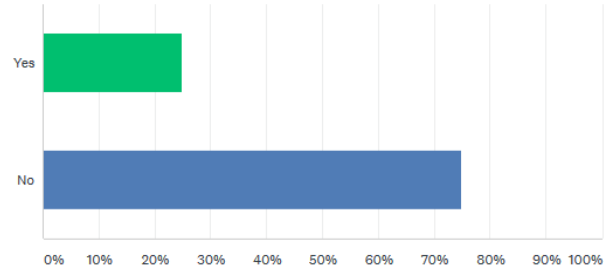
Crocker Park Wine Festival, Summer 2018, Westlake, Ohio

Art on the Hill Wine Festival, Summer 2018, Mantua, Ohio

- CIFT conducted an online survey, which was distributed by the Ohio Grape Industry to 300 growers, 32 of whom responded – for a response rate of more than 10%. Questions about HPP were asked, to help understand what growers know about HPP, their thoughts about sulfites, and whether they are interested in the HPP process and/or sulfite-free wine. Following is some of the data that was obtained from respondents:

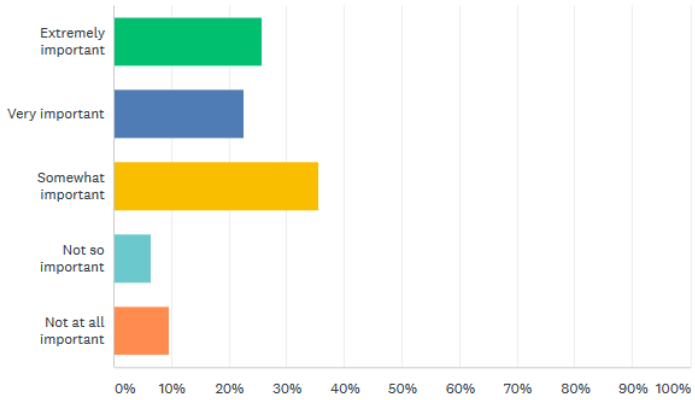
Prior to reading the above, were you familiar with High Pressure Processing?

Answered: 32 Skipped: 0



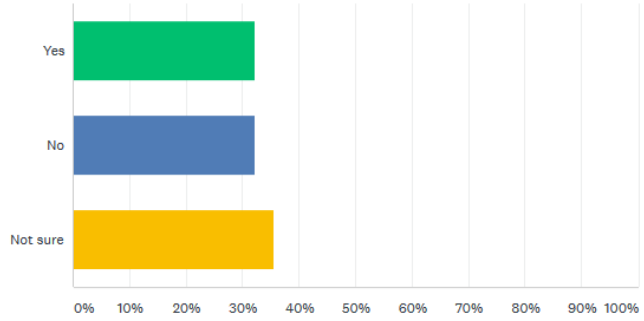

How important is it to you to extend the shelf life of wine?

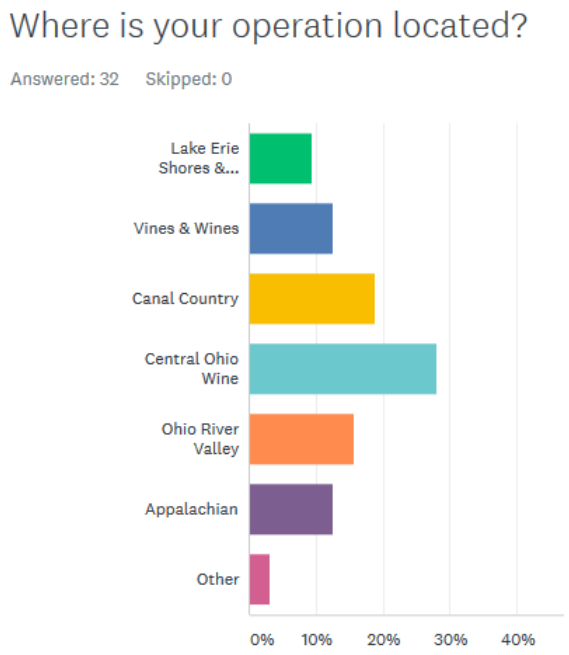
Answered: 31 Skipped: 1

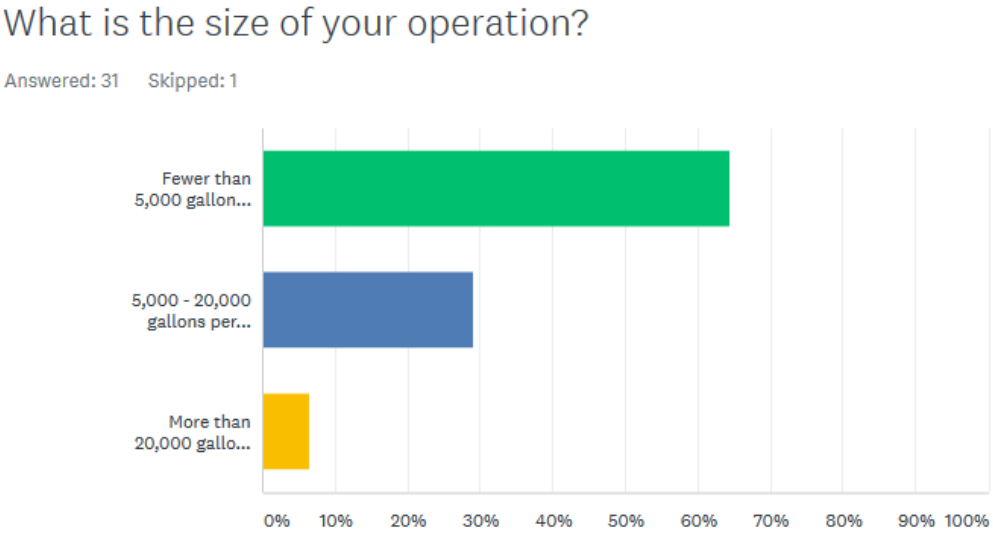



HPP Technology requires flexible packaging. Would you be willing to offer sulfite-free wine in a plastic pouch in a box?

Answered: 31 Skipped: 1






- CIFT conducted qualitative research among Ohio grocers, including Kroger, Churchill's, and several surveyed anonymously though the Ohio Grocers Association to understand their thoughts about the new technology and whether customers were interested in sulfite free wine. Grocers were asked whether any of their customers ever inquire about the sulfite level of wine, and whether the grocer carries it. One grocer said that "a small but growing number of people" had expressed interest. When queried as to whether customers tended to be familiar with effects such as acridity and allergic reactions associated with sulfites in wine, a fellow grocer responded: "Somewhat, but generally my customers are just interested in natural and healthy wine." Another grocer stated that only wine customers with specific allergy/sensitivity to sulfites demonstrated heightened concern. Regarding consumers' willingness to pay more for sulfite free wine, responses ranged from "no" to "yes within reason." Generally, it seems as though a small group of

consumers would be willing to pay more if they have a sensitivity. Grocers overall said they were disposed to pay more to stock sulfite free wine if it has a reasonable shelf life, but more importantly, if consumers are inclined to pay higher prices for it. When grocers were asked about the importance of increased shelf life, which the HPP technology could provide, some thought it was not important, while others thought it was very important, especially if wine is code dated. "Shelf life is important to us. With new items, we want to be reassured that we will be getting a return on our product investment. A limited shelf life will make me more cautious about ordering a product." Finally, grocers were asked about their thoughts on preservatives in wine, and their use being minimalized by HPP – and that reducing the sulfites could result in more vivid flavor profiles in wines. They felt that this would help sales, and also that "natural, organic, and biodynamic wines tend to have more diverse/complex flavors." One skeptical grocer commented that "Acidity, sugars, and tannins are the primary preservatives in wines and are critical elements in the final flavor profile of wines. I would be hard pressed to convince educated wine consumers that reducing these preservative elements would result in 'enhanced' flavors, and that removing the natural occurrence of sulfites in high quality grapes also 'enhances' the flavor. Tasting is believing." A final question to grocers involved today's consumers wanting beverages and juices focused on health and wellness, and they are also looking for high quality products with natural and fresh ingredients, which data suggests that HPP helps to provide. One grocer responded to this idea by stating that "health and wellness, natural and fresh, are important to consumers and therefore are important to us." Another respondent said, "Yes, especially 20 to 40 year olds." The key words that grocers used to describe the benefits of the HPP technology include: fresh, natural, sulfite free, and more flavorful.

- CIFT conducted qualitative research among some Ohio restaurateurs, including Mancy's, Local Thyme, and Real Seafood to understand their thoughts about the new technology and whether customers were interested in sulfite free wine. At most, the customers of these establishments rarely inquire as to the availability of sulfite free wine or choose wine based upon health and wellness concerns. Nor did the results display a trend toward a willingness on the part of patrons to pay more for sulfite free wine, although one restaurant manager opined that customers might pay more "if educated on the advantages" thereof. Without a clear market for HPP wine, the restaurants surveyed did not express an overt willingness to offer it. Nonetheless, shelf life was revealed as decidedly important: once a bottle of wine is uncorked any unconsumed contents are thrown away in as little as three days from the date it is opened. Not surprisingly, under the circumstances, restaurants would embrace a technology that could lengthen the shelf life of the contents of an opened bottle of wine. In fact, longer shelf life was identified as the most important benefit of HPP processing from the standpoint of restaurateurs. Secondly, restaurant managers expressed enthusiasm for HPP's potential for flavor enhancement: "fantastic" and "excellent" were among the responses received.

**Goal 2:** The initial, short term goal of the initiative was to produce samples of the various products, generate data that demonstrates their value, and use the samples and supporting data to promote production. Specifically, the goal within the first year was to produce multiple gallon sized samples of five varieties of Ohio grape-based wines and three types of grape juice.

- Four batches of wine were processed and fermented; two batches used HPP technology and two batches did not, and were designated as follows: HPP Vidal, Non-HPP Vidal, HPP Catawba and Non-HPP Catawba. The wine was bottled. Comparisons were drawn for both batches (HPP vs. no HPP) in terms of flavor, appearance, aroma, and quality. Testing on Brix levels continued throughout the project. It was anticipated that there would be limited differential in flavor between the HPP and non-HPP products, which it was believed was related to the variety of juice. The expected benefit of HPP to the enhancement of natural flavors was also monitored. A sensory evaluation was performed on the wine as well. This processing run did not produce the desired results in that the wine had a poor flavor. Uncertainty existed as to whether this was due to the varieties selected (the only ones available at the time) or to challenges in the fermentation process, since this was the first time juice was fermented by the partner. It was decided to conduct another trial the following season.
- A second round of juice from the 2016 grapes was obtained from two wineries in Ohio. The Vidal had a Brix between 17 and 18, total A acid of 8 grams/liter, and pH of 3.2. 10 grams of yeast (Lalvin BA11) was used to begin fermentation which should yield roughly 12% alcohol in the end product. Since the juice was straight from the press, some enzyme was added to aid in settling. The juice was chilled at 45 to 50 degrees and allowed to settle for 24 to 48 hours. It was then adjusted to approximately 22 Brix using granulated cane sugar and inoculated with yeast. Once the fermentation began, the temperature was maintained at 55 degrees F. Typically $SO_2$ is added during the crush (35 to 50 ppm) to inhibit the natural yeast and allow for extra settling time. The purpose of this project was to avoid this last step and determine if HPP will prevent oxidation and maintain the quality of the wine without $SO_2$ being added. The above mentioned Vidal was added to the testing, while another Catawba was purchased for comparison to the previously integrated juice from last season (both fresh and frozen).
- A third round of juice from 2017 grapes was obtained for testing from two wineries in Ohio. Unfortunately, sulfites were inadvertently added to the juice by the wineries, and the unavailability of new juice made re-scoping of this project necessary. The inclusion of sulfites at time of harvest is a standard approach by wineries. This will need to be further communicated if the desire is to ultimately achieve a sulfite-free product. It was decided that CIFT would test the HPP process on samples of Ohio grown hops. One batch of fresh hops was put through the HPP process, and the other batch was not. Then, a local Ohio brewer used each batch of hops to make separate batches of beer, so as to compare the two once fermented. Fresh hops in the cone typically need to be fermented within 24 hours to achieve optimum flavor and overall results. These cones were processed with HPP to determine if the shelf life could be extended and therefore present more of an opportunity for brewers to capitalize on the fresh product. Many indicate a desire for the fresh hops, however, ultimately turn to pellets due to time constraints and availability.

**Goal 3:** Along with the production of these products, the project generated “fact sheets” that describe cost data, production processes, packaging, and other parameters necessary to help demonstrate the economic potential of the products. Activities in the first year of the project also

included the preparation of a plan to promote these results to wineries and producers of high quality, non-thermally processed grape juice.

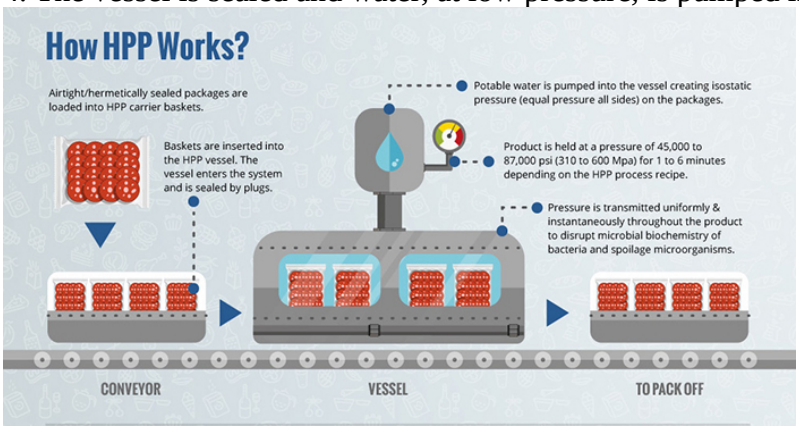
## FACT SHEET 1: HPP PRODUCTION PROCESSES PROCEDURE

1. The wine is packaged (restricted to boxed wine at present).

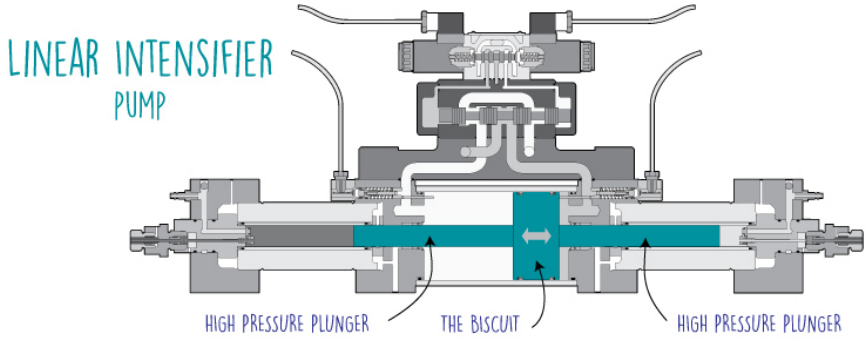
2. Packages are loaded into a cylindrical container.

3. The container enters the pressure vessel (this is not a continuous process as only one container can be handled at a time).

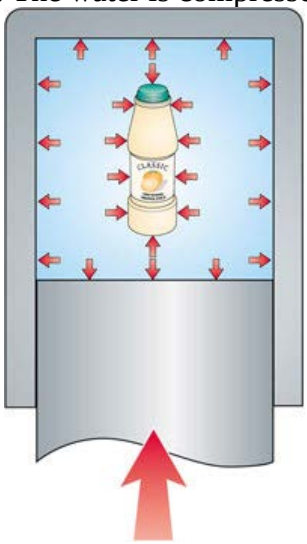
4. The vessel is sealed and water, at low pressure, is pumped in.



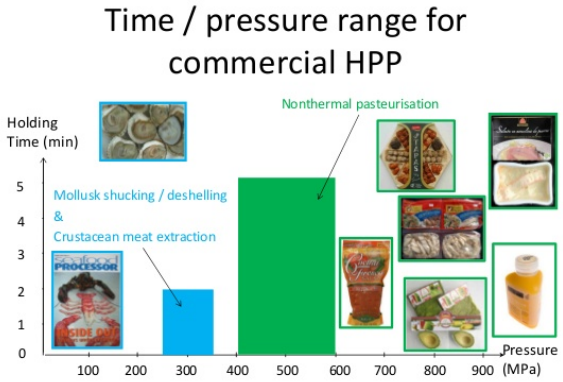

5. An intensifier pump is used to fill all voids with water.



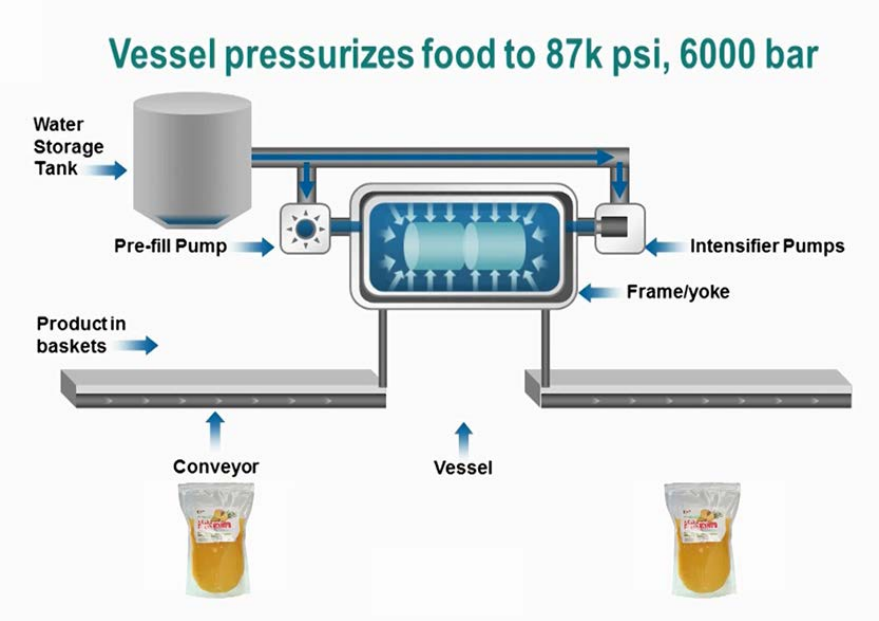

6. The water is compressed (87,000 psi).



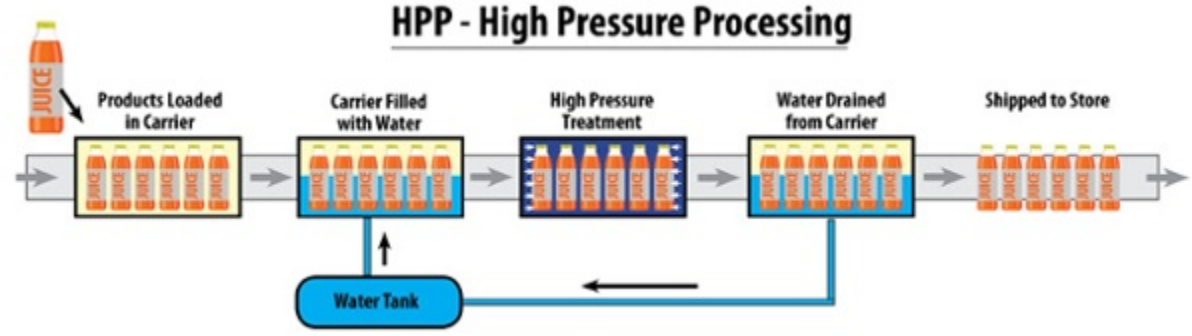
7. The high pressure is maintained for three to five minutes.




8. Pressure is released.




9. Water is drained and recirculated for subsequent use.



10. The container exits the pressure vessel.


11. The container is unloaded.


**FACT SHEET 2: HPP PACKAGING**

The HPP process operates at 87,000 psi. Consequently, "packaging materials are required to be flexible enough to withstand the mechanical stress caused by hydrostatic pressure while maintaining physical integrity . . . glass bottles are not well suited for HPP: [t]hey are not able to recover the shape and size after HPP and because of their lack of water and pressure resistance." (Hyperbaric-Blog. 2014 December 16. Packaging: An Essential Part of the Success of HPP Technology. [accessed 2018 September 18]. http://blog.hiperbaric. com/en/packaging-an-essential-part-of-the-success-of-hpp-technology.). Thus, HPP processing of wine is currently limited to boxed wine.

CIFT's wine consumer survey results indicate, however, that individuals who purchase wine more frequently are less apt to purchase box wine; preferring instead wine in traditional glass bottles. Yet, these consumers are an important component of the wine-buying public at large. Under the circumstances, it would seem that research and development of glass bottles able to tolerate HPP would be a worthwhile endeavor. In the interim, a possible alternative that might palliate the trepidations of these consumers (at least those who prefer bottled wine out of habit alone) is the HPP processing of wine in plastic bottles. HPP processing of fruit juices in PET

(polyethylene terephthalate) bottles is a common technique successfully utilized in the beverage industry. Research conducted at the Institute of Vine and Wine Sciences in Bordeaux, France, indicates, however, that wine in PET bottles (not subjected to HPP) has only a limited shelf life of six months (with white wines displaying more negative compositional changes over that time frame than reds). (2010 May 14. Wine Experts Turn Their Noses Up at Plastic Bottles by Claiming It Only Lasts Six Months. Daily Mail (London).). This result would seem to indicate that HPP processing of wine in plastic bottles might be a fertile area for additional research and an opportunity to expand the packaging modalities available to vintners.

## FACT SHEET 3: HPP COST ANALYSIS

While efficacious, HPP processing remains an expensive proposition. The price of HPP food processing machinery ranges from $2 million to $3 million dollars. In addition, peer-reviewed research indicates that HPP processing costs are significantly greater than those associated with common thermal pasteurization; as much as seven times so. The same study found, for example, that electricity usage alone was slightly over 26 percent greater for HPP processing than it was for thermal pasteurization. (Sampedro, F., McAloon, A., Yee, W., Fan, X., and Geveke, D.J. 2014. Cost Analysis and Environmental Impact of Pulsed Electric Fields and High Pressure Processing in Comparison with Thermal Pasteurization. Food and Bioprocess Technology. 7(7): 1928-1937.).

Will HPP be cost-effective for Ohio vintners? At CIFT's focus group with Ohio winemakers, conducted on June 20th of this year, the consensus of attendees was that the answer is "no." Participants pointed out that 90 percent of Ohio wineries produce 5,000 gallons or less annually, making them small-scale operations, and would be deterred by cost from adopting HPP technology. And this fact must be considered in light of CIFT's finding (based upon consumer surveys at wine festivals) that only 24.68 percent of total Ohio wine purchases are of Ohio-made wine.

Will consumers pay more for HPP wine? CIFT's wine festival surveys revealed an overwhelming interest among attendees in the purchase of sulfite-free wine; 89 of 95 respondents (93.68 percent) stated that they would consider buying sulfite-free wine treated via the HPP process. However, when asked how much more they would pay for such wine, 22.11 percent (21 of 95 respondents) indicated that they could abide no price increase whatsoever. Even among the 74 respondents who were open to paying more for HPP wine, the average price increase that they were willing to tolerate to do so was only $2.00.

Ohio grocers and restaurateurs, contacted by CIFT, were rarely unequivocally positive when queried on their willingness to purchase HPP wine. Answers ranged from flat refusals to: "It would depend on the clientele asking for it," "Yes, as long as it has a reasonable shelf life," and "If there is continued customer demand." Only one retailer positively indicated "yes."

In conclusion, there is pronounced consumer interest in procuring HPP wine and also some interest, albeit hesitant, among retailers in offering it for sale. However, it remains an open question as to whether purchasers will pay enough extra per bottle to make HPP processing financially attractive to vintners. Further work could be done in this regard. Of course,

overcoming winemaker's cost concerns will become much easier if further engineering development of HPP equipment reduces the acquisition and operations costs thereof.

Economists at Colorado State University have studied the possible financial benefits of utilizing high pressure processing in wine production. Their findings show that quality and price are generally more important to consumers in making a purchase decision than a low level of sulfites. Regardless, they did identify a statistically significant willingness among wine buyers to pay more ($0.64 per bottle) for sulfite free wine, as long as it is of a comparable price and quality with its non-sulfite free counterpart. When focusing upon those who experience headaches after consuming wine with sulfites, the inclination to pay extra manifested itself in a $1.23 per bottle increase. The study suggested that the greatest economic benefit of HPP wine sales may accrue to producers who target a niche market, such as those individuals who suffer from wine-induced headaches. (Appleby, C., Costanigro, M., Thilmany, D., and Menke, S. 2012. Measuring Consumer Willingness to Pay for Low-Sulfite Wine: A Conjoint Analysis. American Association of Wine Economists, Working Paper No. 117.).

Interestingly, CIFT's consumer surveys revealed that consumers would pay $2.00 per bottle more for sulfite free wine, exceeding the amounts reflected in the Colorado State study. This figure, on its face, might be considered encouraging to Ohio producers. However, as previously noted, Ohio winemakers have expressed diffidence toward utilizing the HPP process given that most of them operate on a relatively small scale.

Fortunately, a solution for Ohio winemakers has taken shape. Hydrofresh HPP, an affiliate of the Keller Logistics Group, has recently opened an HPP processing/tolling facility in Delphos. '"This is exciting, state-of-the-art technology that will aide in the growth of locally produced natural and organic products," states Hydrofresh HPP President, Don Klausing. "HPP is a value-added service that ensures food safety, extends shelf life, preserves the food's nutritional value, reduces the amount of preservatives needed, and reduces waste. This will be the only High Pressure Processing tolling facility in this part of the country and we are already experiencing tremendous demand for our services."' Says Bryan Keller, President and Chief Executive Officer of the Keller Logistics Group: '"[A]dding HPP to our suite of services will help our customers, and future customers, meet the growing demand of providing products with small, natural ingredient decks. With the additional square footage available at the Hydrofresh HPP site, we'll be able to give our customers flexibility in storing their product pre-and-post HPP processing, along with providing a temperature-controlled storage facility for our food customers. Hydrofresh HPP will be the first HPP toll service provider to offer its customers a complete HPP solution; from managing their inbound transportation, HPP product processing, value-added packaging, through cold storage, and distribution."' (Press Release. 2018 January 31. Keller Logistics Group.).

The processing services offered at the new Hydrofresh HPP facility will be available to Ohio vintners. Therefore, it is imperative that they be made known of these services. Outreach in this regard has not yet occurred; therefore, it is advisable that future efforts focus on disseminating this valuable information. It also must be remembered that most Ohio wineries are in the northeastern part of the state, at a distance from Delphos, so further analysis of the transportation costs involved should be made in order to determine whether or not they are prohibitive for the

large number of small producers. Lastly, since HPP processed wine represents a potential niche market, specific efforts aimed at market development seem warranted.

**Goal 4:** By the completion of the project after year 2, the goal was to have presented information and product samples to each of the more than 200 wineries in Ohio and individuals involved, or potentially involved, in the production of grape juice. Although "word of mouth" promotion and publicity began immediately after project initiation, this was to be an organized effort during the second year of the project. Because the first batch of the HPP'd product did not taste good, and the second batch contained sulfites making it inutile, product samples could not be provided to the wineries and growers. Instead, information was presented to those involved in the production of grape juice.

To measure performance against this goal, CIFT and the other members of the project team tracked several statistics. First, the promotional plan included a number of events. Live, "stand alone" events and presentations made at other events were held, including at the CIFT Annual Member Meeting, the Food Industry Summit, and a number of Agriculture Breakfasts that CIFT hosts monthly throughout the year, were all held for a total of six presentations. An electronic webinar was not conducted – instead, CIFT held a live focus group. The effectiveness of the plan was measured by the number of meaningful interactions with potential users of the technology. Assuming that there are around 250-300 potential users of the technology in Ohio (about 220 wineries and as many as 100 producers of grape juice), CIFT tracked monthly market penetration, With the newsletter to the Ohio Grape Association, the presentations, the tour of the HPP facility, and face to face and phone conversations held, CIFT believes it connected with 150 wineries and producers of grape juice in Ohio throughout the length of this project.

**Goal 5:** The final measure of the project was the number of business relationships that were established between and among Ohio institutions. Although, as stated above, most of this activity will occur after completion of the project, the expectation is that, with the new tolling facility for HPP located in Delphos, there is a possibility that some companies may develop projects that involve Ohio grapes in juice or wine. The major barrier at this time is the expense. As a direct result of this project, CIFT has developed strong business relationships with a number of Ohio institutions. Firstly, CIFT now has a partnership with the Ohio Grape Association, as well as a number of wineries that participated in the Avure Tour and focus group, and also with those wineries that completed the online survey about the HPP Process. Additionally, Avure, manufacturer of the high pressure processing equipment, has become a member of the CIFT consortium, and is actively working with CIFT on a variety of projects involving the HPP technology. The most impactful event/relationship from this project was the finalization of the tolling facility discussed earlier. Emphasis on the market potential for sulfite free wine will continue to be a focus.

Outcomes Achieved

The successful completion of this project resulted in the development of high value added products for Ohio grapes, the validation of their consumer acceptance, the establishment of the business relationships required to produce and market them, and the promotion of their use. Specific steps to achieving these outcomes, are noted below.

1. *Establish initial internal project work plan.* Completed.

2. *Present project concept to potential participants.* Completed.
3. *Conduct tours of the labs for partners and interested growers.* Completed.
4. *Identify participants and acquire samples for processing.* Completed.
5. *Process samples of wine and juice. Completed.*
6. *Perform microbiological testing of samples. Completed.*
7. *Complete pro-forma cost analyses for products. Completed.*
8. *Compile all work completed relating to research and market potential. Completed.*
9. *Completion of promotional material. Completed.*
10. *Process additional samples of wine and juice. Completed.*
11. *Scheduling of individual contact with growers, 20% of total. Completed.*
12. *Complete additional presentations Completed.*
13. *Scheduling of individual contact, cumulative 40% of total. Completed.*
14. *Establishment of first business relationship. Completed.*
15. *Scheduling of individual contact, cumulative 60% of total. Completed.*
16. *Complete two additional presentations. Completed.*
17. *Scheduling of individual contact, cumulative 80% of total. Completed.*
18. *Investigate packaging options and consumer preferences. Completed.*
19. *Establishment of second business relationship.* Completed.
20. *Completion of final microbiological testing.* Completed.
21. *Establishment of additional business relationship(s). TBD*
22. *Completion of final project reports and promotional materials.* Completed.

**Beneficiaries**

The target audience for this initiative was broad. First and foremost, specialty crop grape growers interested in this new technology for processing wine were interested and provided information (focus groups, online survey, and wine festivals) and remained engaged in this project throughout the duration. Secondly, consumers and sellers (grocers, restaurants) were interested in learning about a technology that could provide a longer shelf life, a sulfite free product, and an allergen free product. The fact that the new tolling facility could provide the product locally was a definite plus. There was desire among some consumers, and therefore among some grocers and restaurateurs, to be able to purchase/offer this product, even at a premium. A major barrier for this technology for wine makers in Ohio is that more than 90% of wineries produce fewer than 5,000 gallons annually, which makes the technology at this time somewhat cost prohibitive.

The following is a summary of beneficiaries affected by this project's accomplishments and/or the potential economic impact of the project:

- 200 growers/wineries attended the Ohio Grape/Wine Conference and learned about HPP.
- 12 winery owners participated in a focus group about HPP.
- 300 Ohio growers received the HPP article in the Ohio Grape Industries Newsletter.
- 95 wine festival attendees tasted sulfite free grape juice and completed a survey.
- 32 growers completed an online survey about HPP.
- 5 Ohio grocers participated in qualitative research about HPP.
- 3 upscale Ohio restaurateurs participated in qualitative research about HPP.

The total estimated number of beneficiaries affected by this project is approximately 400 (estimated due to possible overlap of growers who attended conference, participated in focus group, received newsletter, and completed online survey).

**Lessons Learned**
The main obstacle for this project was the grapes – they are only available for a very small time during the fall, which caused delays and having to do several batches. Another issue was the time it takes for fermentation to take place – this also caused a delay to the project timing. Because the initial batch did not provide clear and sufficient results, another test of HPP on grape juice had to be conducted, and continuation of the test on the fermentation process and monitoring of the impacts of HPP was carried into the next year. Without the early results it was difficult to communicate with growers and wineries. General discussions around the technology could be achieved but without some indication as to the level of success for HPP, meaningful interactions were delayed.

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**Additional Information is attached:**
The Economic Impact of Ohio Wine and Wine Grapes – 2016, A study commissioned by the Ohio Grape Industries Committee
Performance Under Pressure – HPP and Packaging Article

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**Project Title: OEFFA- Increasing Ohio Specialty Crop Competitiveness with Organic Production and Food Safety Compliance**

**Project Summary**
The purpose of this grant, awarded to the Ohio Ecological Food and Farm Association, was to help farmers meet the increasing demand for organic, local and safe food by providing direct technical support and educational programming to help beginning and existing organic farmers improve organic production and marketing skills and knowledge, help others transition to certified organic production, and work with farmers of all sizes and levels of on-farm experience to establish food safety plans and implement them. At the time of this grant, there was a lot of anxiety around the impending federal food safety implementation, as well as dealing with organic certification compliance.

**Project Approach, Goals and Outcomes Achieved**
#1: Ohio organic specialty crop farmers will increase competitiveness by improving their production and marketing practices.
Activity 1(a): On Demand Technical Assistance: 206 cumulative hours were dedicated to this effort.

- Provided on-demand response to questions and requests for assistance from specialty crop farmers relating to production and marketing. Responded to 303 calls, fielding questions and providing resources for fertility inputs, pest control practices, and marketing concerns. Approximately 15% of the calls came from consumers seeking access to locally produced crops, who were then referred to and linked with local producers. This activity served farmers because it directed interested buyers to them. Approximately 25% of calls were concerning access to markets and marketing strategies. Most of the calls covered a wide spectrum of production concerns. Understanding soil test results and determining appropriate amendments and specific amounts to apply was the most frequently requested service. Approved pest control products and sources of supply was a close second. The benchmark under this goal was 300 farmers assisted, which was achieved during the grant period.

- Recommendation: This grant gave organic and transitioning organic farmers knowledgeable assistance on demand, directing them to resources to help them solve problems and make progress on the immediate challenge facing them. This depth of support is presently unavailable within the land grant Extension support model. It is recommended to develop greater capacity to serve organic specialty crop producers within the Ohio Department of Agriculture framework.

Activity 1(b): Facilitate information exchange and peer-to-peer learning: 502 cumulative hours were dedicated to this effort.

- Continued development of an information exchange network, provided referral service for growers with questions to tap individual farmer's expertise, continued recruitment of network participants, and coordinated farmer-led workshops and farm tours.

    - Presented workshops on the certification process at 22 events and three webinars, where we also recruited farmers to participate in the network.

    - Organized 13 OEFFA-sponsored farmer-led/hosted farm tours focused on specialty crop production and marketing; participated in four tours sponsored by Ohio State Extension; and three tours sponsored by Clintonville Farmers Market.

    - Presented two workshops on specialty crop production and marketing and presented one webinar on lot coding and trace-back auditing, where we also encouraged farmers to participate in the network of farmers willing to mentor other farmers. Thirty-seven of the 2017 conference workshops and more than 40 of the workshops organized for the 2018 OEFFA conference were specialty crop related, 25 of which were led by farmers.

- Recommendation: Farmers learn best from other farmers, and when they are networked with experienced farmers, beginning farmers succeed at greater rates. Developing strategies and initiatives to encourage peer-to-peer networking, support and mentoring is emphatically recommended.

#2: Increasing access to new specialty crop markets.
Activity 2: On Demand Technical Assistance: 360 cumulative hours were dedicated to this effort.

- Provided on-demand response to questions and requests for assistance from specialty crop farmers relating to USDA National Organic Program compliance, transitioning into certified production, and developing an Organic Systems Plan (OSP).

    - Responded to 209 calls concerning issues of compliance, completing OSP, and steps towards a successful transition. Personal attention was provided to assist farmers in understanding and accurately completing OSPs for submission. Concerns surrounding transition to organic production and connecting farmers to reference resources were most of these calls. Consultations addressing specific non-compliances and identifying a viable path toward resolution were approximately 30% of these calls. The benchmark was 40 Ohio transitioning specialty crop farmers receiving technical assistance in understanding organic certification standards and process; this project greatly exceeded its target number. The other benchmark was 30 Ohio specialty crop farmers beginning the transition to certified organic production or submit their first Organic Systems Plan to an organic certifier during this grant period; a total of 67 producers were assisted in achieving certification through this project, again exceeding projected numbers.

    - Presented three workshops on OSP development and NOP certification process at the 2016 Small Farm and the Ohio Women in Agriculture conferences sponsored by Ohio State Extension. An additional six workshops were presented to agricultural service providers in 2017.

  By providing individualized attention and assistance to farmers considering transitioning into organic production, we have helped relieve farmer apprehension. Our promotion of organic marketing opportunities at general farm conferences is one way we captured the attention of farmers who were unaware of organic's advantages. By providing hard copies of resources directly into the hands of those considering transition, we have increased the likelihood of those farmers applying for certification.

- Recommendation: The lack of data for pricing organic specialty crops limits operators' ability to competitively price their products, and to create reliable enterprise budgets for their operations, which is essential to productively and profitably managing their businesses. Developing projects collecting and disseminating organic specialty crop pricing data for use by producers to improve financial management and risk loss providers in administering specialty crop insurance programs is recommended.

- Recommendation: Intensify efforts to engage specialty crop producers at conferences and other community gathering opportunities to promote the organic marketing alternative.

#3: Development and implementation of on-farm food safety plans.

Activity 3(a): Do-It-Yourself Risk Assessment Template development: 59 cumulative hours were dedicated to this effort

- Created and distributed a template/checklist for farmers to self-conduct an on-farm risk assessment.

  Researched existing resources; adapted and reiterated to reflect on-farm realities in Ohio; released drafts to 12 farmers for on-farm use to review, test, edit and critique. The Risk Assessment Checklist is estimated to have been accessed each time the resource page was visited.

  While this resource was necessary and useful early in the project, subsequent resources released by Food and Drug Administration, Produce Safety Alliance, National Sustainable Agriculture Coalition, and state university extension offices made this document obsolete. When OEFFA submitted this grant proposal, a risk assessment tool from the on-farm perspective was unavailable. Once into the grant period, our partners in farmer support services also recognized its absence and created stronger and more applicable documents than the ones we created. These resources were posted on OEFFA's website, as well as included in its case study publication (see below). After compiling the comprehensive resources, we estimate more than 100 farm operations have accessed it online. So, while the benchmark was 50 farmers will access and utilize the templates OEFFA created, the overall goal to get resources into farmers' hands were met; just not in a way that was initially envisioned.

- Recommendation: There's been general acknowledgement that farmers are going to need resources and training to understand and comply with the Food Safety Modernization Act (FSMA). So many entities have emerged to provide help, including the Produce Safety Alliance, North Central Region Center for FSMA Training, Extension, and Technical Assistance, Local Food Safety Collaborative, and the National Sustainable Agriculture

Coalition, just to name a few. One could argue there's too many resources to wade through, which is why having an entity play the role that OEFFA has historically provided—to answer questions, direct resources, and help farmers navigate through the process—is going to be needed in the coming years as FSMA implementation slowly roles out.

Activity 3(b): On-farm Risk Assessment and Food Safety Plan (FSP) Development: 432 cumulative hours were dedicated to this effort.

- Identified and recruited participants, conducted on-farm assessments and audits, provided continuing support for Food Safety Plan (FSP) development and implementation.
    - Conducted nine on-farm assessments, outlining GAP and FSMA Produce Safety rule protocols and compliance concerns. Provided resources for risk assessment and FSP development.

    - Developed eight farm-specific FSPs. Of the participating farms, one was required by their wholesale distributor to attain a third party GAP/FSMA compliant certificate; one has withdrawn from distributing in the wholesale market due to apprehension surrounding the Produce Safety rule; three serve the wholesale market with distributor request to attain third party certification prior to the end of the implementation period; two see successful certification leading to expanded distribution opportunities; two view the experience as educational opportunity for future growth, and one farm dropped out due to personal reasons.

      One benchmark for this activity was to have 10 farms with food safety plans in place that can or have passed a food safety audit. We also assisted four other farmers who individually developed FSPs with our guidance, thus—adding in the case study farms—we met this benchmark.

      The other benchmark was that 10 farms would access a market that would not have been able to without the food safety assessment and plan. Of the eight farms included in the case-study publication, three have accessed markets previously unavailable until they demonstrated food safety compliance through a third-party audit. During the time this grant was administered, the FSMA regulation implementation timeline was extended, pushing the compliance deadline for some producers beyond the grant period; some buyers were (are) waiting to until FSMA is finalized and implemented. Therefore, we fell short on this benchmark.

    - Conducted nine initial audits, four readiness reviews, and performed four mock recalls.

- Three participating farms attained GAP/GHP harmonized third-party audit and certification. Each farm scored above 90% compliance.

- Coordinated a farmer led on-farm workshop covering FSMA water quality standards, and specific aspects of the farm's FSP and documentation procedures.

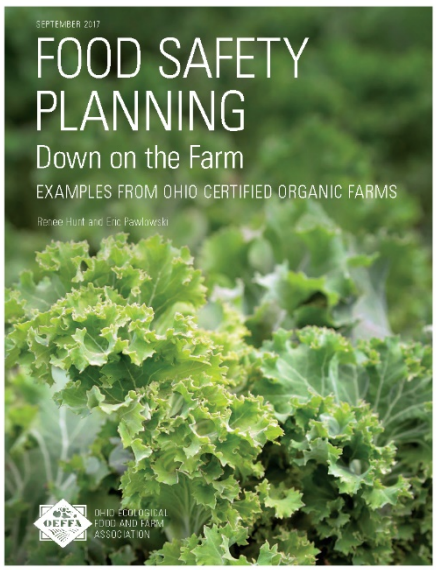
- Recommendation: As the implementation timeline was extended, so too must support services be extended to assist the needs of operators seeking third-party food safety certification.

Activity 3(c): Case Studies of FSP and implementation: 286 cumulative hours were dedicated to this effort.

- Created farmer-friendly publication documenting the experiences, efforts and results of farmer participants.

  - Attended and documented details of all food safety farm visits (identified in the above section), in writing and with pictures. Participating farms in 2016 were: Brickel Creek Organic Farm (Jamestown, OH), Green Edge Gardens (Ames, OH), Jorgensen Farms (Westerville, OH), and Mother Earth Farms (Dundee, OH). Visits were selected to encompass farms representing the four corners of the state and central Ohio locations, and in variations of marketing plans (e.g. CSA, institution, wholesale), which allowed us to meet our scale and production focus diversity goal. All of these plans have been completed, with two farms successfully attaining certified status. Risk assessment checklist was developed with farmer input and released for on-farm use. A Farm Safety Plan (FSP) development manual has been compiled and distributed for participants' use in plan creation. In 2017 an additional four farms were visited and mock-audits conducted. The participating farms were: Jon Smith Farm (Ravenna, OH), Earth Source Produce (Morrow, OH), Little Riley Creek Farm (Bluffton, OH), Maplestar Farm (Auburn Township, OH), and Dangling Carrot Farm (Williamsport, OH). Of these farms four farm plans were completed with one farm dropping out of the program for personal reasons (Dangling Carrot).

  - Drafted, edited and published a 24-page document describing each of eight farm's experiences. The benchmark was at least eight farms would be featured in the case study. A total of 500 copies were printed for distribution, plus the document was



made available on the OEFFA food safety website for electronic distribution.

- Recommendation: While circulating electronically is cost and time efficient, the case-study publication is a valuable resource to distribute as a hard copy. This printed document is used as an active recruiting tool to pragmatically introduce specialty crop farmers to the Produce Safety rule and supporting certification services. Farmers learn best from other farmers and being able to recognize themselves standing in another's boots working through a similar experience has proven to be an effective motivation to begin creating an individualized FSP. It is recommended to keep this publication in print, especially for engagement with the Plain community.

Activity 4: Evaluation: 51 cumulative hours were dedicated to this effort.
For the farmers we have worked with on the food safety plans, it is clear—by the results, as well as verbal communication—that they have welcomed and have benefitted from the resources and guidance provided by this project.

To understand how helpful the project's on-demand assistance has been to specialty crop growers, the following questions were asked to farmers that had contacted us during the period of this grant:

1. ***Did contacting us help you resolve what you needed help on?*** 56% of the respondents strongly agreed, 40% agreed, and 4% were neutral. The benchmark was 90% reported they were satisfied or very satisfied with assistance received, thus exceeding this projected number.
2. **Did you learn something new?** 64% of the respondents strongly agreed, 28% agreed, and 8% were neutral.
3. **Did we help you make a decision?** 44% of the respondents strongly agreed, 32% agreed, 12% were neutral, 4% disagreed, and 8% said the question was not applicable.
4. **Did we help you improve production, become more efficient, and/or improve profits?** 16% of the respondents strongly agreed, 28% agreed, 28% were neutral, 4% disagreed, and 24% said the question was not applicable. The benchmark was more than 50% report they have made a beneficial change that improves the farm business operation; 44% did say they saw a benefit, and another large portion (52%) were either neutral or found the question not applicable. Not all changes made will yield immediate results, so there is a very real chance that benefits of the assistance happened outside of this grant period.

**Beneficiaries**
This grant met the goal of meeting 300 farmers' production and marketing needs, and exceeded projections of transitioning to organic production by fielding 209 calls and helping 67 farmers to become certified organic. Nine farms received on-farm assessments and individualized help with

developing their farm food safety plans (see above section for the name of participating farms). Seven additional farms were assisted in developing their own self-created plans. At the time of this report, OEFFA has distributed all copies of the case study publication to farmers and farm advocates.

**Lessons learned**

OEFFA experienced a greater demand than was initially estimated for support of organic production and marketing questions, and help with transitioning to organic. According to the Organic Trade Association (OTA), the organic food market hit $45.2 billion in sales in 2017. Fruits and vegetables continued to be the largest organic food category with $16.5 billion in sales in 2017 on 5.3 percent growth. Fresh produce accounted for 90 percent of organic fruit and vegetable sales. The demand for support is clearly increasing. OEFFA looks to and encourages ODA to lead in the development of services to keep this sector of the produce industry vibrant, vital, and on its continued path of growth.

For the food safety work, the seasonal workload of the project staff and the farming season did not always mesh. Farmers have very little time to focus on procedures during the spring and summer production seasons. There was a challenge synchronizing schedules when audits and observations must be conducted when processes are being performed (that is, during the farming season). Two potential participants were unable to dedicate time to focus on FSP education and development and withdrew their participation when the scheduled farm visit time came. One additional farm withdrew during the process due to personal circumstances. Greater awareness of seasonal time constraints, and a full commitment towards food safety implementation are required from both the operator and the service provider.

Farmers are aware of the risks related to their specific operation and are sincere in attempting to avoid contributing to negative food safety concerns. Our experience during on-farm visits clarified this perception. We did see, however, the need for farms to take the next steps to put procedures in writing, and in some cases, clarify, add, and/or improve procedures. Farmers thinking through their systems, developing contingencies, testing assumptions, and reassessing results through feedback loops are actions that can prevent crisis. In addition to benefiting from fresh (outside) eyes (i.e., a readiness audit), having an annual employee training and conducting a self-audit to review the status of the farm's system is important, and is just good practice. We also learned providing clear direction and templates to follow can be immensely helpful to farmers who already feel overwhelmed by the rules and are on tight timelines. Once the outline of what goes into a farm food safety plan was understood, farmers were quite adept at translating individual procedures into a uniformly formatted document.

**Funding Expended**

A final reimbursement form and report of expenditures was submitted to the Ohio Department of Agriculture via email August 10, 2018. Please let us know if additional reporting is needed.

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**Project Title: Development and Delivery of Resource-Efficient, Ecologically Sustainable Strawberry Production and Marketing Systems for Ohio**

**Project Summary**
This project developed unbiased research-based information and strawberry production educational resources for Ohio. Information obtained from this project has and will help Ohio growers capture some of the $165.3 million dollars in annual strawberry sales and related jobs currently sourced out-of-state by Ohio's retail and wholesale produce buyers. Ohio growers face many challenges to increase strawberry production and to meet the marketing demand. This project provided unbiased research information, tools and educational training for growers to effectively manage these challenges. To overcome these production barriers, detailed information and resources are needed to make informed decisions to grow their strawberry business. This project helped advance Ohio strawberry production by accomplishing five outcome-orientated objectives: 1) Developed and published guidelines for insect, disease, irrigation and fertilization management, 2) Established strawberry research and educational field trials at Piketon, Ohio to better inform grower management recommendations, 3) Advanced production methods to produce strawberries for four months compared to the traditional one-month Ohio production system, 4) Developed online resources to provide strawberry growers with tools to be successful in expanding and adopting new strawberry production practices, and 5) Provided training on all aspects of strawberry production through field days, annual winter workshops, and a project website, and 6) Developed a strawberry plant propagation protocol that can be adopted by Ohio's nursery industry to produce plug plants required for the new production systems.

**Project Approach**
This project was conducted only on the specialty crop strawberries at the Ohio State University (OSU) South Centers/Piketon Research & Extension Center at Piketon, Ohio (lat. 39.07° N, long. 83.01° W), elevation 578 feet. The experimental soil is designated as a DoA—Doles silt loam, with 0–3% slopes. It is a deep, nearly level and somewhat poorly drained soil. Typically, the soil surface is a brown, friable silt loam about 20 cm deep and beneath this the subsoil is about 18.5 m. At each harvest, yield data and fruit quality attributes were observed and recorded. Plant growth characteristics, fruit quality attributes, insect and disease susceptibility and tolerance, and winter injury percentages were monitored and recorded. These field research studies were used as teaching tools where in-field and in greenhouse demonstrations, workshops, hands-on trainings and field days were conducted. The data collected from the field and greenhouse studies was statistically analyzed, summarized and published annually in research reports that were provided to attendees of educational trainings and were posted on the

strawberry research and education web site
https://southcenters.osu.edu/horticulture/fruits/strawberries.

**Goals and Outcomes Achieved**

This project generated the proposed short-term outcomes identified at the onset; however, project results will continue to provide many positive long-term outcomes over time for Ohio's strawberry industry. Five of the short-term outcome-oriented objectives were met upon completion of this project: 1) Developed and published protocols for insect, disease, irrigation, winter protection, season extension, and fertilization management for Ohio strawberry production. 2) Established a strawberry research, education and demonstration site at Piketon to better inform clientele of management recommendations and to collect unbiased research based information for all Ohio growers. 3) Developed an online strawberry resource directory and module to provide growers with tools to be successful in this growing industry. 5) Provided training on all aspects of strawberry production through field days, winter workshops, and a strawberry project website. 6) Developed a strawberry plant propagation protocol fact sheet that can be adopted by Ohio's nursery industry to facilitate the development of an Ohio-grown strawberry plant propagation industry.

Measurable outcomes from this project benefiting specialty crop growers, the Ohio produce industry, and the public included:

- Ohio clientele interested in growing strawberries have access to a comprehensive protocols, unbiased research-based results for disease and insect management, irrigation, season extension techniques, and fertilization that are available online and in print.
- The OSU strawberry production program provided a diagnostic center for growers to send samples for disease or pest identification.
- Established field research, education and demonstration trials at the OSU South Centers in Piketon, which provided unbiased research-based data to inform our recommendations with opportunities for the public to participate in field days and workshops hosted at this site.
- Strawberry production training resources, research reports and publications are available online for public viewing. These training resources cover: pre-plant soil treatment, bed shaping, irrigation system installation, variety selection, planting, management of pests and diseases, irrigation operation recommendations, weed management, fertilizer program recommendations and fruit quality marketing parameters.

- Field days, tours, trainings and workshops held at this site provided updates on research findings. Attendees had opportunities to provide feedback regarding their needs, knowledge, perceptions, and challenges regarding strawberry production.

- Field research data collected from this project was collected and used to develop strawberry plant propagation protocols that Ohio farms and nurseries have adopted to diversify nursery production to include strawberry plant propagation and sales.

**Work plan tasks, accomplishments, results, conclusions and recommendations**

**PROJECT ACTIVITY 1. A PROTOCOL FOR STRAWBERRY SEASON EXTENSION AND MANAGEMENT** Weekly collections of disease, insect and fertility samples from the Piketon field research site were observed and analyzed. Irrigation management- this project developed an unbiased research based irrigation management protocol for Ohio specific strawberry production. Fertilization- a proper fertilization protocol was tested, monitored and evaluated. Season Extension- Trials were established using a randomized complete block designs. Treatments were replicated in the field and greenhouse/high tunnel treatments. An existing greenhouse/high tunnel located at Piketon was used for this research. At each harvest, yield data and fruit quality attributes were observed and recorded. Plant growth characteristics, fruit quality attributes, insect and disease susceptibility, and winter injury percentages were monitored. A growing degree day model was developed to assist Ohio growers with making winter protection decisions to maximize winter protection, extend the harvest season, enhance yield and overall plant growth. Findings were made available to growers in the form of Extension bulletins through the VegNet website (vegnet.osu.edu), email, an established OSU growers list-serve, the Ohio Strawberry web page and the Ohio State University's Fact Sheet system. Project partners Bergefurd, Harker, Lewis, McGlothin and summer students performed this work.

**PROJECT ACTIVITY 2. PIKETON STRAWBERRY RESEARCH SITE.** A strawberry research site including field, season-extension tunnel structure and greenhouse research trials were established at Piketon to collect replicated and site-specific field research and production data. Tasks performed included:

- Site preparation (deep till, install drainage as needed, add compost and organic matter as needed, built raised beds, installed plastic mulch and drip irrigation)
- Install season-extension/high tunnel/greenhouse demonstration system within field system. Testing of new matted-row and plasticulture strawberry cultivars, including day-neutral and everbearing varieties was conducted. Soil fumigant testing that will help reduce incidence of soil-borne pathogens including insect, disease and weeds was evaluated. Glucosinolate products were compared to an untreated check as the control for their effects on strawberry production, plant growth, yield, fruit quality and fumigation properties in a replicated trial.
- Project partners Bergefurd, Harker, Lewis, McGlothin and summer students performed these tasks.

**PROJECT ACTIVITY 3. DEVELOPMENT OF AN ONLINE TRAINING MODULE**

- We used OSU-approved software to create an online web site accessible to the public. Experts from our project team developed and posted curriculum resources and publications focused on strawberry season extension production, greenhouse and field production. Copies of PowerPoint presentations were created and posted.
- Project partners Bergefurd, Harker, Lewis, McGlothin and summer students performed this work.

**PROJECT ACTIVITY 4. OUTREACH: FIELD DAYS AND WINTER WORKSHOPS**

- A field day was hosted annually near harvest at the Piketon research site to train and educate attendees of the new production and management techniques.
- A survey was conducted at the workshops to get attendees feedback on their satisfaction in field days and workshops to determine their knowledge, perceptions and practices related to strawberry production.
- Project partners Bergefurd, Harker, McGlothin performed these tasks.

Field days and educational workshops were conducted and taught throughout the duration of the project. Topics taught at all educational programs included strawberry crop management, season extension techniques, integrated pest management techniques, soil preparation, mechanical harvesting aids, drip irrigation management, fertigation management, weed control, winter protection techniques, crop nutrient management, fruit quality analysis, petiole sap analysis, marketing and good agricultural produce safety practices.

1. 2/2/16 Strawberry Workshop, Oasis Conference Center, Loveland, OH, 68 participants
2. 2/16/16 Strawberry Workshop, The Ohio State University, Columbus, OH, 32 participants
3. 2/26/16 Ohio Strawberry IPM Workshop, The Ohio State University, Columbus , 24 participants
4. 3/12/16 Strawberry Crop Management, Wilmington College, Wilmington, OH 32 participants
5. 5/25/16 Strawberry Field Night, Piketon, OH, 61 participants
6. 6/22/16 Strawberry Field Day, Berlin Heights, Ohio 121 participants
7. 10/14/16 Strawberry Field Day, Piketon, OH 18 participants
8. 11/8/16 Strawberry Agri-science Day, Piketon, OH 82 participants
9. 3/9/17 OSU Strawberry Workshop, OSU Lima campus, Lima, OH 42 participants
10. 3/17/17 NW Ohio Strawberry Growers School, Archbold, OH 78 participants
11. 5/25/17 Strawberry Field Night, Piketon, OH 58 participants
12. 5/25/17 Strawberry Agri-sciences Field Day, Piketon, OH 117 participants
13. 1/6/18 Greenhouse Strawberry Workshop, OSU, Columbus, OH 52 attendees
14. 4/27/18 Farm to Strawberry Workshop, Piketon, OH 83 attendees
15. 5/17/18Strawberry Nutritional Sciences Field Day, Piketon, OH 112 participants
16. 5/17/18 Strawberry Field Night, Piketon, OH 34 participants
17. 6/16/18 Strawberry Field Day, Lowell, OH 78 participants
18. 10/9/18 Strawberry Production Class, Owensville, OH 12 participants

Surveys of participants were conducted at educational programs pre and post event, these surveys included visual observations and acquisition of cognitive skills as evaluation tools appropriate for the audience that supported teaching effectiveness, knowledge gained, and

usefulness of the information. Results of workshop and educational event participant surveys indicated they gained insight into strawberry crop management, strawberry integrated pest management, strawberry season extension technologies, pesticide application procedures, label interpretation, and implications of disease pressure and application timing on strawberry quality.

**PROJECT ACTIVITY 5. DEVELOP STRAWBERRY PLANT NURSERY PROPAGATION PROTOCOL** Strawberry plant production and propagation management protocols were established using the research-based information gathered from the Ohio research location. Project partners Bergefurd, Harker, McGlothin, Lewis performed these tasks.

**The baseline research results and data collected from this project are outlined in the research reports and protocols outlined below.**

### Objectives of research study

These field research trials investigated potential season extension improvements in plasticulture strawberry production. Previous research has identified a functional and profitable system, but new variety testing and new season extension techniques are needed.

### Scope of Research

This study was conducted at the Ohio State University (OSU) South Centers/Piketon Research & Extension Center at Piketon, Ohio (lat. 39.07° N, long. 83.01° W), elevation 578 feet. The experimental soil is designated as a DoA—Doles silt loam, with 0–3% slopes. It is a deep, nearly level and somewhat poorly drained soil. Typically, the soil surface is a brown, friable silt loam about 20 cm deep and beneath this the subsoil is about 18.5 m. At each harvest, yield data and fruit quality attributes were observed and recorded. Plant growth characteristics, fruit quality attributes, insect and disease susceptibility and tolerance and winter injury percentages were monitored and recorded.

### Methods

Strawberry tips were stuck Fall 2015, August 17, 2016 and August 9, 2017 into 50-cell plug trays containing Metro Mix 360 soilless media and placed on stone under mini wobblers during the month of August. Planting media was kept moist using an electronically timed misting schedule to promote root development. The resulting plugs were transplanted to the field on September 17, 2015, September 22, 2016 and September 15, 2017 by waterwheel transplanter and watered in with 20-20-20 water soluble starter fertilizer. Strawberry plants were planted in double rows with 12 inches between rows and plants. Field preparation included application of 60 units of nitrogen, phosphorus, and potassium pre-planting, and formation of a raised bed. Prowl H20 herbicide was applied prior to the bed being covered with black plastic and trickle irrigation under the mulch. Beds were formed with a commercial bed shaper. After transplanting to the field two applications of calcium nitrate was applied through the drip tape 5.25 pounds was applied each fertigation. The floating row cover was put in place to protect the plants from the winter temperatures. Plant growth was monitored and recorded throughout the winter. To

control disease, a standard commercial fungicide program was followed. Calcium nitrate was injected through the drip tape beginning in early April and continued through harvest in an attempt to maintain optimum plant growth and berry fruit quality.

2016 strawberry field harvest began on April 29, and continued until June 8th when the matted-row strawberries concluded. 2017 field harvest began on April 26th and continued until June 2nd when the matted-row strawberries concluded. The day-neutral strawberries harvest resumed July 5th and continued until the first week of August. 2018 strawberry field harvest began May 11th and continued until June 4th. Day-neutral harvest resumed July 8th and continued until August 1st when temperatures shut flowering down.

2017 greenhouse towers were planted December 8th 2016. Towers consisted of 6 pots with four plants per pot. Pots were filled with a rice hulls, perlite and coconut coir. Fertilizer was applied at each irrigation cycle throughout the growing period.

Greenhouse Towers were planted on November 21st 2017 using plug plants that was started in August. Towers consisted of 6 pots with four plants per pot. Pots were filled with a Metro Mix 360 soilless media. Fertilizer was applied at each irrigation cycle throughout the growing period. Greenhouse harvest began February 2nd with the last harvest August 20th.

**Outcomes & significance of outcomes**

Table 1: Yield's from 2016 cultivar evaluation

| *Cultivar* | *Pounds per Acre* | *Pounds per Plant* | *Fruit per Plant* | *Average Fruit Weight (oz.)* | *Soluble Solids* |
|---|---|---|---|---|---|
| *San Andreas* | 7084.8 A | 0.487 A | 10.267CD | 0.79 A | 8.05 ABC |
| *Benecia* | 6833.1 AB | 0.470 AB | 13.67 BC | 0.77 A | 6.32 BC |
| *Albion* | 6663.9 AB | 0.458 AB | 4.74 D | 0.75 A | 9.9 A |
| *Camino Real* | 6510.3 AB | 0.448 AB | 11.65 C | 0.71 AB | 8.32AB |
| *Camarosa* | 6510.3 BC | 0.401 BC | 20.9 A | 0.64 B | 6.4 BC |
| *Chandler* | 6510.3 CD | 0.341 CD | 19.97 AB | 0.57 CD | 6.2 C |
| *Sweet Charlie* | 6510.3 D | 0.314 D | 7.25 CD | 0.53 D | 8.72 A |
| *Festival* | 6510.3 D | 0.307 D | 10.93 CD | 0.53 D | 6.2 C |
| *LSD* | 1153.4 | 0.079 | 6.43 | 0.10 | 2.03 |

**Treatments with the same letters are not significantly different*

Table 2: Yields from 2016 Matted Row cultivar evaluation

| *Cultivar* | *Pounds per Acre* | *Average Fruit Weight (oz.)* | *Soluble Solids* |
|---|---|---|---|
| *Sonata* | 10688 A | 0.43 AB | 8.52 B |
| *Mayflower* | 9860 A | 0.46 A | 8.25 B |
| *Galletta* | 9678 A | 0.41 AB | 8.6 B |
| *Earliglow* | 9593 A | 0.32 C | 10.6 A |
| *Jewel* | 7770 AB | 0.45 A | 10.35 A |
| *Rubicon* | 6448 AB | 0.46 A | 9.5 AB |
| *Laurel* | 4484 B | 0.37 BC | 8.52 B |

| | | | |
|---|---|---|---|
| *Sonata* | 10688 A | 0.43 AB | 8.52 B |
| *LSD* | 4939.6 | 0.08 | 1.45 |

*Treatments with the same letters are not significantly different*

Table 3: Yield from Day Neutral Evaluation Spring Harvest 2017.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per Acre* | *Average Fruit Weight (oz.)* | *Soluble Solids* |
|---|---|---|---|---|---|
| *Sweet Ann* | 11.39 A | 0.54 A | 8541 A | 0.82 A | 7 A |
| *San Andreas* | 12.90 A | 0.42 A | 6591 A | 0.51 B | 6 B |
| *Albion* | 8.56 A | 0.34 A | 5378 A | 0.64 B | 6 B |
| *LSD* | 6.01 | 0.21 | 3402 | 0.15 | 0 |

**Treatments with the same letters are not significantly different*

Table 4. Yields from Day Neutral Evaluation Summer Harvest 2017.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per Acre* | *Average Fruit Weight (oz.)* |
|---|---|---|---|---|
| *San Andreas* | 6.8 A | 0.14 A | 2198.8 A | 0.020 A |
| *Albion* | *6.27 A* | *0.12 A* | *1891.8 A* | *0.018 A* |
| *Sweet Ann* | 1.93 A | 0.01 A | 289.4 A | 0.011 A |
| *LSD* | *6.89* | *0.15* | *2369.2* | *0.010* |

**Treatments with the same letters are not significantly different*

Table 5: Yield from Cultivar Evaluation 2017.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per Acre* | *Average Fruit Weight (oz.)* | *Soluble Solids* |
|---|---|---|---|---|---|
| *Camarosa* | 24.82 AB | 0.80 A | 12460 A | 0.52 C | 8.25 CB |
| *Chandler* | 28.80 A | 0.72 AB | 11350 AB | 0.41 DEF | 7.75 CBDE |
| *Flavor Fest* | 20.57 BC | 0.62 AB | 9763 AB | 0.48 CDE | 8.5 AB |
| *Sweet Ann* | 11.13 DEF | 0.56 BC | 8840 BC | 0.81 A | 6.75 CFDE |
| *Festival* | 11.76 DE | 0.38 CD | 6063 CD | 0.51 CD | 6.22 FE |
| *Camino Real* | 15.73 CD | 0.38 CD | 6022 CD | 0.39 EF | 6.37 FDE |
| *Sweet Charlie* | 16.99 CD | 0.35 DE | 5590 DE | 0.34 F | 9.92 A |
| *San Andreas* | 11.71 DE | 0.35 DE | 5520 DE | 0.47 CDE | 7.75 CBDE |
| *Lucia* | 8.85 EFG | 0.30 DE | 4810 DE | 0.56 C | 8.87 AB |
| *Scarlet* | 4.95 FGH | 0.22 DE | 3479 DE | 0.71 AB | 6.75 CFDE |
| *Albion* | 5.50 EFGH | 0.18 EF | 2805 EF | 0.48 CDE | 5.37 F |
| *Ruby Red* | 3.92 GH | 0.16 EF | 2532 EF | 0.66 B | 9 AB |
| *White Carolina* | 1.65 H | 0.01 F | 235 F | 0.14 G | 7.87 CBD |
| *LSD* | 6.33 | 0.20 | 12460 | 0.09 | 1.54 |

**Treatments with the same letters are not significantly different*

Table 6: Yields from Matted Row Cultivar Study 2017.

| *Cultivar* | *Pounds per Acre* | *Average Fruit Weight (oz.)* | *Soluble Solids* |
|---|---|---|---|
| *Sonata* | 11875 A | 0.40 A | 6.25 B |
| *Laurel* | 4394 D | 0.36 AB | 5.5 C |
| *Galletta* | 5804 CD | 0.42 A | 7.25 A |
| *Earliglow* | 7459 BCD | 0.32 B | 6.25 B |
| *Rubicon* | 8830 ABC | 0.42 A | 7.25 A |
| *Jewel* | 9648 AB | 0.39 AB | 7.25 A |
| *Mayflower* | 9793 AB | 0.42 A | 6.3 B |
| *LSD* | 3674 | 0.06 | 0.34 |

Table 7: Yield from Cultivar Evaluation 2018.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per Acre* | *Average Fruit wt. (ounces)* | *Soluble Solids* |
|---|---|---|---|---|---|
| *Chandler* | 17.57 A | 0.64 BA | 11235 BA | 0.58 FE | 6.75 BA |
| *Camino Real* | 16.01 BA | 0.72 A | 12616 A | 0.73 DC | 4 C |
| *Flavor Fest* | 13.77 BA | 0.59 BAC | 10340 BAC | 0.68 DE | 6.75 BA |
| *Fontiras* | 11.79 BCD | 0.65 BA | 11336 BA | 0.88 BA | 5 BAC |
| *Ruby June* | 12.68 BC | 0.54 BDC | 9378 BDC | 0.67 DE | 6.5 BAC |
| *Sweet Charlie* | 7.82 EFD | 0.2 EFG | 3531 EFG | 0.42 G | 7.25 A |
| *Festival* | 13.73 BA | 0.44 DC | 7730 DC | 0.51 GF | 6.75 BA |
| *Sensation* | 9.31 ECD | 0.37 ED | 6465 ED | 0.64 DFE | 7 BA |
| *Scarlet* | 4.06 FG | 0.25 EF | 4385 EF | 0.98 A | 6 BAC |
| *Lucia* | 4.5 FG | 0.2 EFG | 3518 EFG | 0.71 DCE | 7.5 A |
| *Camarosa* | 17.8 A | 0.71 A | 12429 A | 0.64 DFE | 7.25 A |
| *San Andreas* | 11.8 BCD | 0.63 BA | 11002 BA | 0.84 BC | 5.75 BAC |
| *Cabrillo* | 12.36 BC | 0.57 BAC | 9902 BAC | 0.72 DC | 5.5 BAC |
| *Sweet Ann* | 2.71 G | 0.15 FG | 2600 FG | 0.93 BA | 6.75 BA |
| *Berrielle* | 6.92 EFG | 0.05 G | 946 G | 0.12 H | 4.5 BC |
| *Albion* | 13.81 BA | 0.72 A | 12603 A | 0.84 BC | 5.25 BAC |
| *LSD* | 4.32 | 0.17 | 3003 | 0.13 | 2.53 |

**Treatment with the same letter are no significantly different.*

Table 8: Yield from Day Neutral Evaluation Spring Harvest 2018.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per Acre* | *Average Fruit wt. (ounces)* | *Soluble Solids* |
|---|---|---|---|---|---|
| *Albion* | 13.81 A | 0.72 A | 12603 A | 0.84 A | 5.25 A |
| *San Andreas* | 11.8 A | 0.63 BA | 11002 BA | 0.84 A | 5.75 A |
| *Cabrillo* | 12.36 A | 0.56 B | 9902 B | 0.72 A | 5.5 A |
| *Sweet Ann* | 2.71 C | 0.14 C | 2600 C | 0.93 A | 6.75 A |
| *Berrielle* | 6.92 B | 0.05 C | 946 C | 0.12 B | 4.5 A |
| *LSD* | 2.68 | 0.013 | 2283 | 0.21 | 3.11 |

**Treatment with the same letter are no significantly different.*

Table 9. Yields from Day Neutral Evaluation Summer Harvest 2018.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per Acre* | *Average Fruit wt. (ounces)* |
|---|---|---|---|---|
| *Albion* | 2.28 BC | 0.048 B | 842.7 B | 0.35 A |
| *San Andreas* | 5.57 BA | 0.115 A | 2008.2 A | 0.32 BA |
| *Cabrillo* | 7.48 A | 0.122 A | 2136.1 A | 0.27 B |
| *Sweet Ann* | 2.11 C | 0.045 B | 787.2 B | 0.34 A |
| *LSD* | 3.32 | 0.058 | 1024 | 0.05 |

**Treatment with the same letter are no significantly different.*

Table 10: Yields from Greenhouse Strawberry Production 2018.

| *Cultivar* | *Fruit per Plant* | *Pounds per Plant* | *Pounds per 2,700 sq. ft.* | *Average Fruit wt. (ounces)* | *Soluble Solids* |
|---|---|---|---|---|---|
| *Albion* | 11.21 A | 0.33 A | 9378 A | 0.48 A | 7.44 A |
| *San Andreas* | 10.71 A | 0.32 A | 9180 A | 0.47 A | 7.56 A |
| *LSD* | 1.52 | 0.04 | 996 | 0.02 | 1.89 |

**Treatment with the same letter are no significantly different.*

Table 11: Chroma Meter fruit color results.

| *Cultivar* | *L* | *A* | *B* |
|---|---|---|---|
| *Albion* | 23.57 | 23.3 | 7.28 |
| *Benecia* | 23.42 | 19.55 | 6.57 |
| *Berrielle* | 23.57 | 22.36 | 6.24 |
| *Cabrillo* | 27.64 | 25.15 | 8.24 |
| *Camarosa* | 23.77 | 22.36 | 7.1 |
| *Camino Real* | 23.87 | 12.72 | 6.24 |
| *Chandler* | 25.63 | 25.15 | 8.42 |
| *Festival* | 27.75 | 25.47 | 8.77 |
| *Flavor Fest* | 25.53 | 28.66 | 11.19 |
| *Fontiras* | 33.54 | 32.64 | 15.29 |
| *Lucia* | 23.57 | 23.3 | 7.28 |
| *Ruby June* | 25.53 | 28.66 | 11.19 |
| *Ruby Red* | 30.38 | 29.36 | 11.64 |
| *San Andreas* | 28.5 | 31.91 | 11.47 |
| *Scarlet* | 30.61 | 29.72 | 12.78 |
| *Sensation* | 30.38 | 29.36 | 11.64 |
| *Sweet Ann* | 27.75 | 25.47 | 8.77 |
| *Sweet Charlie* | 29.84 | 28.52 | 10.42 |
| *White Carolina* | 85.2 | 1.43 | 23.45 |
| *Jewel* | 91.06 | 0.35 | 5.1 |
| *Galletta* | 33.54 | 32.64 | 15.29 |
| *Sonata* | 25.53 | 28.66 | 11.19 |
| *Laurel* | 30.61 | 29.72 | 12.78 |
| *Rubicon* | 33.15 | 35.5 | 13.46 |
| *Earliglow* | 30.38 | 29.36 | 11.64 |
| *Mayflower* | 30.5 | 28.36 | 11.9 |

**Frozen Fruit Marketing Quality Analysis.**

| *Cultivar* | *Acidity as Citric* | *Brix* | *pH* |
|---|---|---|---|
| *Chandler* | 0.7 | 9.2 | 3.6 |
| *San Andreas* | 1.5 | 10.2 | 3.8 |
| *Camarosa* | 1.9 | 10.9 | 2.5 |
| *Mayflower* | 2 | 8.1 | 2.5 |
| *Camino Real* | 1.8 | 8.7 | 2.5 |
| *Sonata* | 1.3 | 9.1 | 2.8 |
| *Rubicon* | 1.5 | 9.9 | 2.5 |
| *Galletta* | 1.6 | 7.4 | 2.5 |
| *Earliglow* | 1.3 | 10.0 | 3.5 |
| *Laurel* | 1.3 | 7.8 | 2.5 |
| *Benecia* | 1.3 | 7.5 | 3.4 |
| *Albion* | 2.1 | 12.9 | <2.5 |
| *Jewel* | 1.6 | 7.7 | 3.2 |
| *Sweet Charlie* | 1.7 | 11.2 | 2.5 |
| *Festival* | 2 | 10.6 | 2.7 |
| *White Carolina* | 1.3 | 7.9 | 4.5 |
| *Ruby Red* | 1.2 | 8.4 | 2.9 |
| *Lucia* | 0.8 | 8.6 | 4.3 |
| *Flavor Fest* | 1.1 | 7.3 | 3.6 |
| *Fontiras* | 1.4 | 8.7 | 2.6 |
| *Ruby June* | 1.9 | 10.1 | 2.6 |
| *Sensation* | 1.9 | 11.1 | 3.0 |

# Design Protocol for Strawberry Plug Production

Thom Harker, Brad Bergefurd and Charissa Gardner – The Ohio State University

**Introduction**

For growers that are using the annual plasticulture system of strawberry production, the cost of plugs is a substantial recurring investment. By purchasing tips and producing their own plugs, approximately 50% of the plant costs can be saved relative to purchasing plugs. Producing plugs from runner tips is not difficult but like all horticultural enterprises requires attention to detail, good sanitation and timeliness.

The largest costs recurring cost in producing plugs aside from the runner tips, are soilless media and plug trays. Growers may be tempted to reuse plug trays but it is not advised as the potential savings are not worth the potential risks of diseases. Trays could be dipped in a dilute bleach solution to help clean them, but any potential savings will quickly be taken up by the labor involved in this. The largest one-

time expense could easily be for the timer unit, although if the grower is establishing a large plug production operation, there can be significant cost in the pipe, fittings, and nozzles.

The following illustrations and accompanying explanation should allow you to construct your own propagation system.

**List of Materials** for a single 6 ‘ system capable of producing 600 plugs in 50-celll trays.

Solenoid

1- 10 PSI pressure reducer

1- Intermatic C8815 Timer or equivalent capable of short intervals

CPVC tubing cutter

CPVC Cement and Primer

Teflon tape

2 – 8’ ½” CPVC Pipe (24’) total

2 - ½” T-fittings for risers

1- ½” end caps

2- ½” FIP CPVC  fitting

1- ½”CPVC x 3/4” hose adapter

Nozzle Assembly (mini wobblers or similar).  It is possible to use a fine misting nozzles, but if the flats are outside you are more likely to get evaporation than using a mini-wobbler type system that produces larger drops.

**Assembly** –

A) Cut one section of CPVC into 3 sections:

1- 3’ and 2-18” each. Using CPVC primer and solvent attach ½” T-fitting at either end of the 3’ sections. This is where the risers will be installed. Using the primer and solvent attaché the 18”sections into the T-fitting opposite the 3’ section.

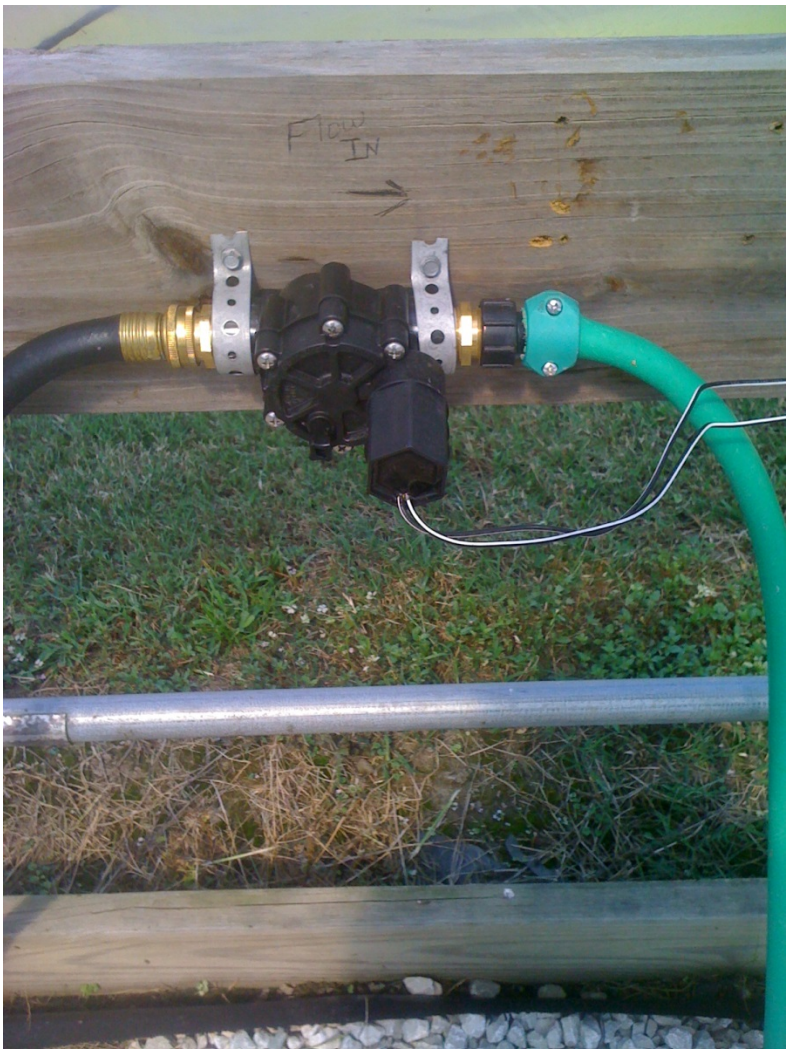
B) Using primer and solvent attach the ½”by ¾” hose adapter to the free end of one 18” section and the end cap to the other end. Additional units can be attached simply by replacing the end cap with another ½”x3/4” adapter. If this is done, it would be helpful to include a valve between sections so that the system can be turned off if the additional length is not needed.

c) The second section of CPVC should be cut into 2 -2’sections.

D) Using primer and solvent attach these 2’ sections into each T-fitting for a riser and then attach the ½” CPVC FIP fitting to the free end of the riser.

E) The nozzle assembly is then wrapped with Teflon tape and screwed into the risers.

F) Using ¾” garden hose attach this system to a hydrant that has a 20 PSI pressure reducer attached. This section is run to the solenoid which is wired to the time. (**Note – electricity and water can be fatal if not treated with respect. Connect timer to the electrical source away from the mist system and use a waterproof box.) When the timer opens the valve in the solenoid, water will flow from the hydrant through the pressure reducer to the solenoid and then on to the mist system.




This system will need to be staked to hold it erect. Rebar works well. It is also possible to construct legs to support this system using the extra CPVC and fittings, but we have found that by keeping the system two-dimensional it is easier to store flat along the wall or on a shelf.

Timing

Every year is different but we have found that for the first week it is probably best to run this mist system for 30 seconds on and two minutes off during daylight hours. As the runner tips begin to root and grow, the interval between run times increases and the duration can also slowly increase until the final week before planting the plugs should be watered 2 or 3 times per day for approximately 2 minutes.

# Strawberry plug plant propagation protocol

Thom Harker, Brad Bergefurd and Charissa Gardner – The Ohio State University

The goal is to keep the leaves moist until the tips start to create their own roots. Hot, sunny days will require extra mist, while cooler, cloudy days less mist.

Day 1: 20 seconds every 2 ½ min. from as soon as you start rooting in the early morning, and then keep running the mist until about 6:00 to 6:30 pm. If temperatures are mild you may find that a 3 minute cycle with 10-15 seconds is adequate the first day

Day 2: plugs should be standing up and turgid in the morning (not flopped over), and if the day is warm, I would continue with the more intensive misting cycle (20 seconds every 2 ½ min) for the 2nd day, from around 8 am until about 6:00 to 6:30 pm (DAY 2 and 3 are ultra critical, and you must have someone be responsible for monitoring the system very close).

Day 3: if warm/hot, stay with 20 seconds every 2 ½ min from 8 am until 6:00 to 6:30 pm

Days 4-5: I tend to be more conservative than some "pluggers" and I am inclined to go with 10-15 seconds every 5 minutes. This may result in too much misting? You do not want to saturate the soil media with water (you will know this if the trays are "heavy" to lift up). The idea is to make sure the leaves always have some droplets of water. Some propagators will go to a 10 seconds every 10 minutes for days 4-5.

Day 6-7: By the the 6th day you should be seeing some new rooting in the plug cell. At this stage you may be able to go with misting from 9 am to 6 pm for 10 seconds every 15 minutes. On day 6 the first watering of the day should be long enough to completely wet the soil.

The misting schedule after the first week must really be determined on the basis of well the plugs are rooting up until this point and weather conditions. In other words, the right misting schedule will vary depending on conditions. Some propagators have found success on days 8-10 by misting from 9 am to around 6 pm for 15 seconds every 30 minutes, and then they lengthen the interval each day. The actual misting period may stay at 15 seconds, but on days 11-13, you can consider misting from 10 am to 3 pm each hour. By day 14 the plugs should have an excellent root system, and from this point on, the practice is to sprinkle for 5 minutes at 1 pm, and then again in the late afternoon if temperatures are high.

## Successful Project Outcomes

This project generated much unbiased research based information and provided resources to help farms adopt new technologies to profit through adoption of strawberry management and season extension strategies. However, the best outcomes are from farmers themselves that have become educated and used the research based results to begin new enterprises and to profit for their family farms. Throughout the project several farmers have reported harvesting strawberries a month earlier and achieving yields up to 3x greater than their neighbors who grow a traditional matted row strawberry system. Numerous thanks and appreciation was showed by those who attended field days, workshops or trainings where this information was presented and demonstrated. One grower from Washington Courthouse, Ohio reported by adopting the techniques developed by this project he was able to harvest over $100,000 of strawberries from

his 2 acre planting 5x more than normal strawberry yields.

**Beneficiaries**
Over 627 clients participated in or requested information generated from this strawberry research and education project. Program participants included high school age students, traditional livestock and grain farmers looking to diversify farm enterprises, new and beginning farmers, urban farmers, socially disadvantaged farmers, high school teachers, Agricultural lenders, Extension Educators and University State Specialists.

**Lessons Learned**
Project staff learned that the new strawberry production techniques require a high level of management and requires lots of highly skilled stoop labor to be successful. As new techniques are researched there are new disease, insect pests and nutritional needs that have been identified from this project that need to be further researched and addressed. The production techniques developed from this project clearly provide growers opportunities to harvest strawberries up to 6 months a year however an economic analysis of these production methods and the available market potential should be considered for future research to understand the economic feasibility of the techniques. Production systems identified also require different planting materials. Plug plant nursery systems and protocols were developed by this project however in Ohio an unavailability of vegetative plant material (runner tips) during the majority of the year does not allow Ohio growers to extend planting windows for current plant material is only available for a three week period in August and this plant material is only available from California, Canadian and Nova Scotia nurseries. Future research to expand adoption of these production techniques should include the development of a certified virus and disease-free stock plant nursery production system which should include research into tissue culture planting material so that Ohio nurseries and producers are not as reliant on foreign and out-of-state nurseries for propagation material. Development of our own field mother plant production industry Ohio will have more control of vegetative planting stock availability for Ohio and will be able to expand production even more throughout the year.

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**Project Title: Container Production and Chemigation of Berries for Season Extension and Risk Mitigation**

**Project Summary**

The production protocols of blackberries, blueberries and raspberries in containers have been developed and optimized through three years of dedicated research by our project team members at OSU South Centers, diligent information gathering by us from nursery growers, researchers, technical support professionals in the US and other countries, and the strong financial support

and cooperation of USDA. We have met all of the projects goals and exceeded the goals of grower outreach and extension.

We were able to show that container blueberry production can be a highly effective method for growing blueberries in northwestern Ohio, where blueberry production was strongly discouraged or proven to be impossible in the past. For the remainder of the state, blueberry production in containers is also an excellent method to shorten the time it takes to get the blueberry planting established by at least 2-3 years and sustained for many years.

The 10-gallon pots (flatter ones better than tall round), pine bark media with our without peat moss, slow release fertilizers with micronutrients at the appropriate rates, and acidified water by injecting sulfuric acid are the winning combination for successful blueberry production in just about anywhere in Ohio. The large 10-gallon pots can also be "planted" in pre-dug holes in raised beds as a nearly permanent planting method. Container blackberry and raspberry production can be an excellent method of winter production for consistent production and season extension. At least 75 growers showed strong interests in adopting this system while 10 to 15 of them are planning to grow up to 50 acres of berry production in containers.

The "chemigation" for pest and disease management in berry plants has been demonstrated. Several growers are planning on adding the "chemigation" set up using micro-sprinklers on their farm. The planned acreage for "chemigation" installation could be up to 15 acres.

Direct grower support though workshops, presentations, research tours, and grower visits have resulted in more than 2,000 grower contacts. News releases, web pages, online videos, and social media efforts on the project have reached at least 500,000 contacts in Ohio and beyond.

The estimated impact on Ohio employment could be a creation of 25 jobs and 55 jobs retained. It is not that hard to imagine that 8,000 to 10,000 lbs of blackberries, blueberries, and raspberries will be produced from the system per acre since these pots can be placed quite close and when all of the parameters are optimized from the first year of planting. This is probably why that some farms in California have 15 to 200 acres of blueberries grown in containers. We have gone through first three years of "growing pains" during our trial from late 2015 to 2018 and will be able to offer good advice to all growers in Ohio now. Since the 10-gallon potted blueberry bushes can be "planted" in the raised beds for many years, this production system can be adopted by just about anyone in Ohio.

The main limitations of this system could be tighter labor market and trade tensions due to the new and evolving political climate. The production techniques have been well worked out. Only minor tweaks are needed by our growers now. Container blueberry production can also be a quicker way to transition into organic production since substrate is organic based. We definitely see bright future of this innovate production system.

**Project Approach**

## 1. Research Projects:

### 1.1. Container Production of Blueberries, Blackberries, and Raspberries

1.1.1. Information Gathering from the Experts in the Field:

Since there wasn't commercial container production of berries in Ohio or the Midwest for that matter, our project team members collected information from many experts in the fields of container production of fruit crops in California, Ohio, and Tennessee in US, and Legro (https://www.legro.nl/) in the Netherlands.

Here is a list of significant activities for information gathering from September 1, 2015 to September 30, 2018:

- Dr. Gary Gao communicated with a researcher with Legro (https://www.legro.nl/) in the Netherlands about potting mixes for blueberries since her group had done container blueberry production for about 7 years. He also met one of the sales managers of Legro and learned a lot about the innovative techniques overwintering blueberry bushes in containers in Australia and South Africa while attending the North American Bramble Growers Association's Annual Meeting in Ventura, California in 2018.
- Dr. Gao reached out to Dr. Dan Struve, a retired nursery professor at The Ohio State University and learned a lot about potting mixes.
- Dr. Gao and his team members visited with Dr. James Altland of USDA ARS in Wooster, Ohio, has a research program on container production of ornamental crops.
- Mr. Ryan Slaughter, a research assistant at OSU South Centers, attended the Great Lakes Expo in Grand Rapids, Michigan and ONLA CENTS show. He brought back valuable information.
- Dr. Gao attended the Annual Meeting of the American Society for Horticultural Science in 2017. He learned from one of the meeting attendees that there was one commercial blueberry farm with 200 acres of blueberries grown in containers for fruit production.
- Dr. Gao attended the 2018 Annual Meeting of the North American Bramble Growers Association in Ventura, California. During the Annual Meeting there, he toured one berry farm with 15 acres of blueberry production in containers and learned about their struggles during the first three years and successes during the recent years.
- Dr. Gao attended the 2018 Annual Meeting the National Association of County Agricultural Agents in Chattanooga, TN. He was able to exchange information from his extension colleagues from other states. More importantly, he was able to participate in an all-day tour of the commercial

nurseries in middle Tennessee. One of the stops on the tour was Freedom Tree Farms, which boasts 1.3 million budded fruit trees annually and 350,000 berry plants, which are sold bare-rooted or potted. He learned that Florikan® 4-5 months Micronutrient Blend Controlled Release Fertilizer and 30% peat moss with 70% pine bark were the winning combination for container production of blueberries at Freedom Tree Farms.

### 1.1.2. Container Fruit Production Research Trials

Our project team members continued site preparation, plant installation and maintenance for our container production from April to June, 2016. After several months of preparation, the container production plot was installed in May, 2016. We looked at three different fruit crops, which were blackberry, blueberry and raspberry. Each with them had its own unique challenge(s). The main challenge with blackberry was lack of cold hardiness. The main problem with blueberries is the strict requirement for acidic soil. The key challenges with raspberries are early spring stem dieback and root rot from poor soil drainage.

We started with bare-root plants for blackberry and raspberry and 2-year-old, one-gallon size blueberry bushes. All plants were transplanted into 10 gallon (G) containers. Our base media was Screened Southern Loblolly aged Pine Bark which has a natural pH of around 4.3. All containers were amended with 36 grams (g) of micronutrient, the general recommendation for Micromax micro-nutrients for a 10 (G) container.

**Blackberries:**

Containers for blackberries were top-dressed with 126 (g) of Osmocote 15-9-12, a 6-month slow-release macronutrient. These were also amended with 144 (g) of Dolomitic Lime per container to raise the pH up to around 6.8. There are four different winter protection treatments for these; they are: moving containers into a protected structure like a barn, moving containers into a four-season high tunnel, covering containers with two layers of 0.9 ounce row cover and covering containers with four layers of 0.9 ounce row cover. During the growing season, all containers were on landscape fabric in a nursery style setting. All containers were irrigated using 6.6 Gph spray stakes.

Figure 1. Blackberries bushes grown in container. Photo by Gary Gao, OSU.

**Raspberries:**

Containers for raspberries were top-dressed with four different treatments of Osmocote 15-9-12, a 6-month slow-release macronutrient. The treatments were 47 (g), 94 (g), 141 (g) and 188 (g). We also applied 144 (g) of Dolomitic Lime per container to the media to raise the pH up to around 6.8, which the desirable level for this crop.

Figure 2. Raspberries (middle) grown in containers in 2016. Photo by Gary Gao.

Figure 3. Excellent growth and fruiting were shown in raspberries in containers in 2017. Photo by Gary Gao, OSU South Centers.

**Blueberries:**

Containers for blueberries were then top-dressed with four different treatments of Topdress Special 17-3-6, a slow-release macronutrient source. Four treatments were 47 (g), 94 (g), 141 (g) and 188 (g).

Blueberry bushes performed very poorly in 2016. We were quite surprised by how much iron chlorosis in our blueberry bushes, since the pH (4.6) of the potting mix was ideal for blueberry plants. We then tested our irrigation water in August, 2016. It turns out that our water alkalinity was quite high and was 180 ppm. Hence, high alkalinity in our irrigation was the culprit. In 2017, we added an acid injector to supply sulfuric to our irrigation water for our blueberry bushes. In addition, we doubled the fertilizer rate. Our blueberry bushes turned green and grew a lot in 2017 and 2018!

Figure 4. An acid injector was added in blueberry production in containers in 2017. Photo by Gary Gao, OSU South Centers.

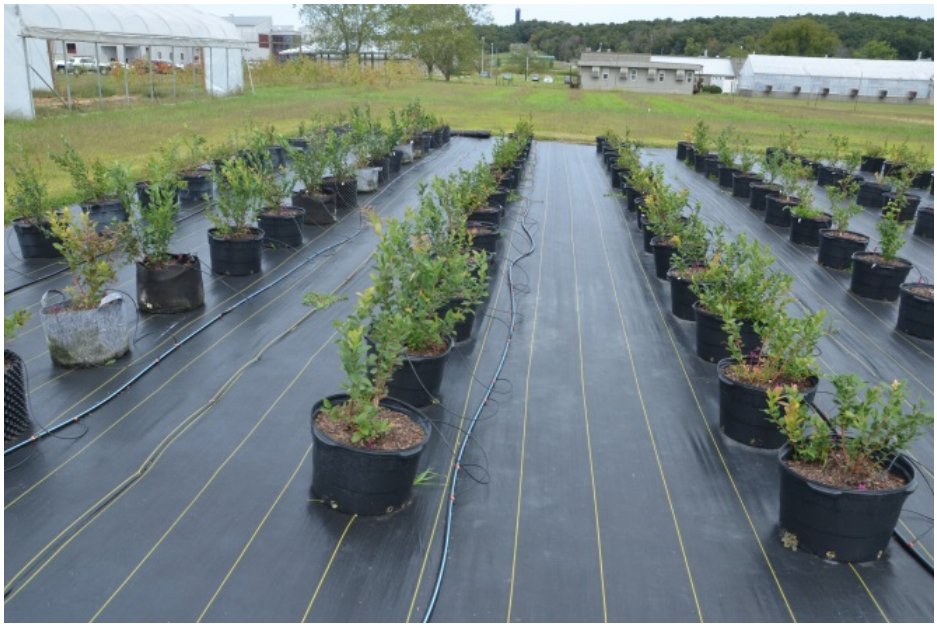

Figure 5. Much better growth and leaf colors were shown in many of our treated blueberry bushed in containers in 2017. Photo by Gary Gao, OSU South Centers.

Dr. Gary Gao attended the 2017 Annual meeting of American Society for Horticultural Science and presented some of our preliminary results on container fruit production in a poster. He was able to gather comments from other conference attendees. One attendee told Gary that one blueberry farm in

California had installed 200 acres of blueberry in containers. This was exciting news to our project team members since the concept of container fruit production is not that far from becoming a reality in Ohio.

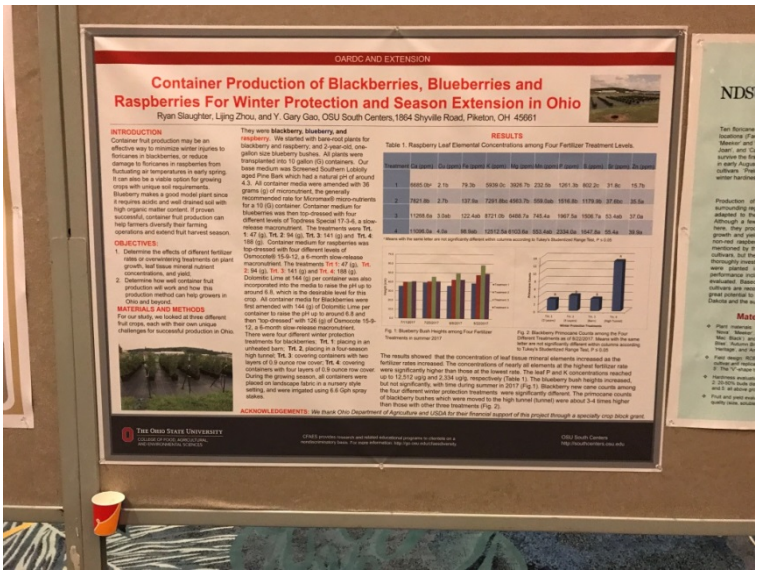


Figure 6. A poster presentation on container berry production was presented at the 2017 Annual Meeting of the American Society for Horticultural Science. Photo by Gary Gao, OSU South Centers.

## 1.2. Chemigation Research and Demonstration

Our project team members met with several experts in the areas of container production and "chemigation" from January to March, 2016. Mr. Michael Daniels, a college intern, collected information on mico sprinklers for our Chemigation research and demonstration. We have identified several container types, sizes, mixes, and fertilizer programs for our container production research. We have also identified and ordered various parts for setting up our "chemigation" demonstration research.

From July 1 to November 30, 2017, our project team members collected data from our container production yard, installed a chemigation demonstration unit in our mature blueberry plot, and organized a field night on “Container Fruit Production, Chemigation and Wine Grape.” Dr. Gary Gao also visited a few fruit growers and talked to them about container fruit production and chemigation. One of the large scale blueberry growers has agreed to install one acre worth of chemigation setup for a trial on his farm and possibly offers an onsite demonstration to other fruit growers in 2018.

Figure 7. Chemigation system was installed in our mature blueberry planting. Photo by Gary Gao, OSU South Centers. Photo by Gary Gao, OSU South Centers.

## 2. **Grower Outreach and Support**

### 2.1. Grower Workshops

- Title: "Ohio Super Berry, Container Production, and Wine Grape Workshop"
  Date: March 2016
  Attendances: 40

- Title: "Super Berry, Container Fruit Production and Wine Grape Field Night"
  Date: July 7, 2016
  Attendance: 32

- Title: "Ohio Blueberry and Bramble, Container Production, and Wine Grape Workshop"
  Date: March 2017
  Attendances: 35

- Title: "Ohio Blueberry, Bramble, Container Fruit Production and Wine Grape Field Night"
  Date: July 7, 2017
  Attendance: 36

- Title: "Ohio Blueberry, Bramble, Container Production, and Wine Grape Workshop"

Date: March 2018
Attendances: 38

- Title: "Ohio Blueberry, Bramble, Container Fruit Production and Wine Grape Field Night"
  Date: September, 2018
  Attendance: 34

**2.2. Presentations**

- Title: Container Fruit Production
  Program: Farm Science Review by OSU - CFAES
  Date: September 20, 2016
  Attendance: 50

- Titles: Container Fruit Production and Chemigation
  Program: Ohio Produce Growers and Marketers Association's Annual Congress
  Date: January, 2017
  Attendance: 38

- Title: Blackberry Production Systems
  Program: Horticulture and Crop Science Seminar Series
  January, 2017
  Attendance: 35

- Title: Container Berry Production
  Program: Berry and Chemigation Workshop
  Date: March, 2017
  Attendance: 28

- Title: Tree Fruit and Small Fruit Production
  Programs: Master Gardener Training
  Date: March, 2017
  Attendance: 45

- Titles: Blackberry, Blueberry, and Raspberry Production
  Program: 2017 Southwest Ohio Specialty Crop School.
  Date: February, 2017
  Attendance: 37

- Title: Container Fruit Production Research Update
  Webinar: Ask the Expert Training Program
  Date: March, 2017
  Attendance: 15

- Title: Blueberry and Bramble Container Fruit Production and Chemigation
  Program: Ohio Produce Growers and Marketers Association's Annual Congress
  Date: January, 2018
  Attendance: 51

- Title: Berry production: Blueberries and brambles
  Program: 2018 Ohio Conservation Tillage Conference
  Website:
  https://fabe.osu.edu/sites/fabe/files/imce/files/Documents/Program.2018.pdf
  Date: March, 2018
  Attendance: 98

- Title: Growing Blueberries, Blackberries, and Raspberries in Containers
  Program: Farm Science Review hosted by the College of Food, Agricultural and Biological Sciences of The Ohio State University.
  Date: September, 2018
  Attendance: 55

**2.3. Research Tours**

- Our research plots of container berry production and chemigation demonstration at OSU South Centers were the main focus of research tours by new and existing growers, researchers, extension professionals, students, OSU administrators, legislators, the 25 year celebration of OSU South Centers, and the Fruit Nutrition Day. Dr. Gary Gao and our research support team members offered 52 tours of research plots from May 2016 to late 2018 to approximately 1,378 people at OSU South Centers in Piketon.

**2.4. Farm Visits**

- Dr. Gary Gao made 46 visits to fruit farms that grew Blackberry, blueberries and raspberries from September 1, 2015 to September 30, 2018. These visits represented at least 800 acres of fruit production. He introduced container production and chemigation systems, provided production tips, diagnosed problems and research updates to new and existing growers.

**2.5. Social Media**

- Facebook Postings:
  Dr. Gary Gao has shared articles, program flyers, pictures, videos, and links to website with his 340 FaceBook “friends.”

- YouTube Videos:

  Opportunities for Berries & Grapes in Ohio

  Title: Opportunities for Berries & Grapes in Ohio
  Date: October, 2015
  Presenter: Ryan Slaughter, Research Assistant II, OSU South Centers
  Link: https://www.youtube.com/watch?v=2CO7sb-PkEc

  Title: Berries & Grapes in Ohio
  Date: November, 2016
  Presenter: Ryan Slaughter, Research Assistant II, OSU South Centers
  Link: https://www.youtube.com/watch?v=V-ZhETVXHQM

  Title: Blueberry, Bramble, and Wine Grape Field Night
  Date: September, 2018
  Presenter: Ryan Slaughter, Research Assistant II, OSU South Centers
  Link: https://www.youtube.com/watch?v=lBKVdJEejlg

- Twitter (Ryan Slaughter)
  https://twitter.com/rslaughter88
  Stats: 808 likes and 73 followers.

**2.6 Websites:**

Ohio Farm Bureau:
https://ofbf.org/events/ohio-cane-fruit-pruning-workshop/
Date: March, 2017

OSU South Centers:
Fruits: https://southcenters.osu.edu/horticulture/fruits

**Goals & Outcomes Achieved**

1. Expansion of the container berry production acreage:

More than 75 growers expressed strong interests in berry production in containers and more than 15 indicated that they would adopt berry production in containers as of November, 2018. Before the start of this project, there weren't any growers who grew blackberries, blueberries or raspberries in containers (pots) on a commercial scale in Ohio. One grower in Central Ohio has indicated that he wanted to put in about ten acres of blueberries in containers. Another grower in northwest Ohio indicated he wanted to put more at least one acre of blueberries. A grower in

southern Ohio has a small planting of blueberry container. One grain farmer in northeast Ohio expressed a strong interest in putting in 5-10 acres of berries in containers. However, the expansion has been put on hold by many fruit growers due to uncertainties in the market created by much tighter labor market from 2016 to the present and trade tensions.

2. The protocols of container berry production systems were well developed and optimized for adoption in Ohio based on three years of research. 'Draper' blueberry cultivar has turned out to be one of the most difficult blueberry cultivars to grow in Containers. After three years, we were able to grow 'Draper' very well and harvested fruits from 'Draper' in 2018. However, we were pleasantly surprised by how well 'Legacy' and 'Sweetheart' performed in containers. Our best treatment(s) for 'Draper' also worked very well for 'Legacy' and 'Sweetheart.'

Following are the pictures of 'Legacy' and 'Sweetheart' grew in containers.

Figure 8. 'Legacy' blueberry bushes grown for two years in containers in 2017 and 2018. The picture was taken in December, 2018 by Ryan Slaughter, OSU South Centers.

Figure 9. ‘Sweetheart’ blueberry bushes grown in containers in 2017 and 2018. The photo was taken in December, 2018 by Ryan Slaughter, OSU South Centers.

**Blueberry**

Table 1. Blueberry Marketable Yield among the Four Treatments on Each Harvest Date in 2018

| Trt | 21-Jun | 28-Jun | 5-Jul |
|---|---|---|---|
| 1 | 10.00a | 3.67a | 3.67a |
| 2 | 17.00a | 43.33a | 19.33a |
| 3 | 30.00a | 50.00a | 21.67a |
| 4 | 15.33a | 3.33a | 5.33a |

Means with the same letter in the same column are not significantly different according to Tukey's Studentized Range Test, $P \leq 0.05$

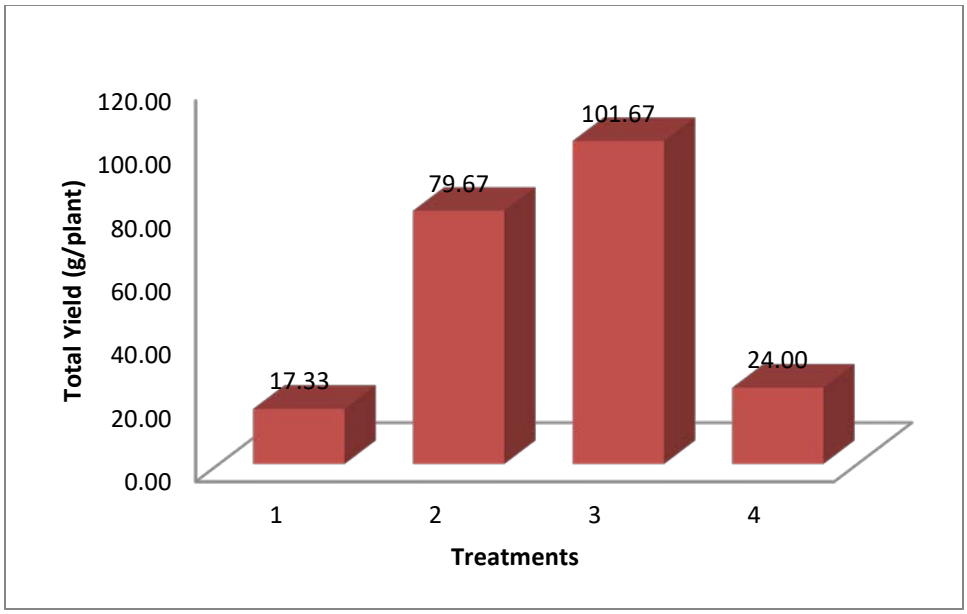


Figure 10. Blueberry total seasonal yields (g/plant) among the four fertilizer treatments in 2018. Containers for blueberries were top-dressed with four different treatments of Topdress Special 17-3-6, a slow-release macronutrient. The treatments were treatment 1: 104 (g), treatment 2: 139 (g), treatment 3: 174 (g) and treatment 4: 210 (g), respectively.

**Blackberry**

Table 2. Blackberry yield (g/plant) among the four treatments on three harvest dates in 2018.

| Trt | 27-Jun | 29-Jun | 2-Jul |
|---|---|---|---|
| **1** | 44.67ab | 16.78b | 23.22a |
| **2** | 68.89a | 58.67a | 32.22a |
| **3** | 5.00b | 1.56b | 4.56a |
| **4** | 6.11b | 3.89b | 3.00a |

Means with the same letter in the same column are not significantly different according to Tukey's Studentized Range Test, $P \leq 0.05$

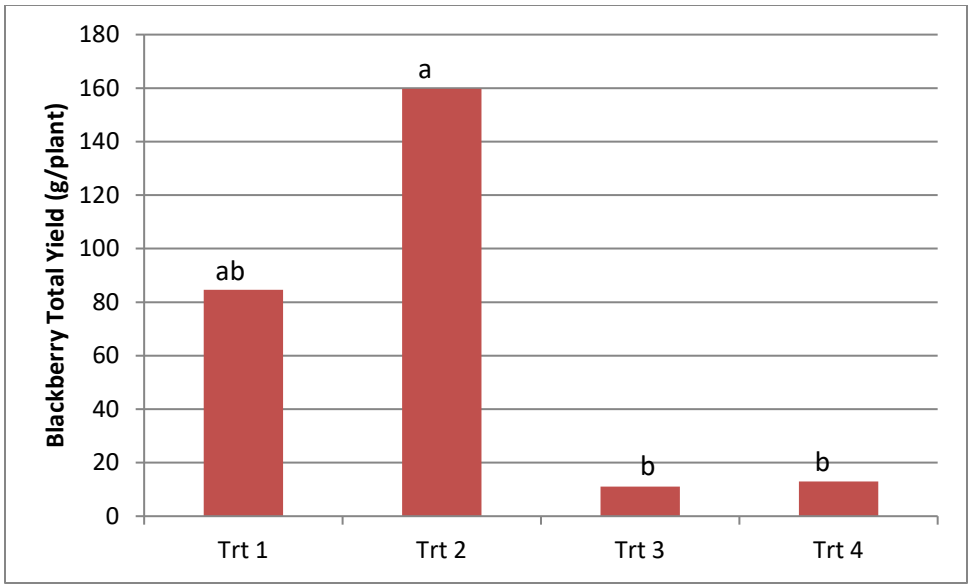


Figure 11. Blackberry total seasonal yields (g/plant) among the four treatments in 2018. Means with the same letter are not significantly different according to Tukey's Studentized Range Test, P ≤ 0.05. There were four different winter protection treatments for the blackberries: 1). Covering containers with two layers of 0.9 ounce row cover; and 2). Covering containers with four layers of 0.9 ounce row cover. 3). Moving containers into a protected structure like a barn; 4). Moving containers into a four-season high tunnel.

**Raspberry**

Table 3. Raspberry Marketable Yield (g/plant) among the Four Treatments on Each Harvest Date in 2018

| Trt | 6/1/2018 | 6/4/2018 | 6/6/2018 | 6/8/2018 | 6/11/2018 | 6/13/2018 | 6/15/2018 |
|---|---|---|---|---|---|---|---|
| **1** | 18.67a | 27.33a | 23.33a | 25.33a | 24.33a | 23.00a | 19.33a |
| **2** | 15.33a | 18.67a | 24.67a | 18.00a | 29.33a | 46.33a | 14.00a |
| **3** | 7.33a | 20.00a | 32.67a | 39.33a | 19.67a | 39.00a | 16.33a |
| **4** | 12.00a | 24.67a | 21.33a | 17.33a | 36.00a | 37.33a | 18.00a |
| **Trt** | **6/18/2018** | **6/20/2018** | **6/22/2018** | **6/25/2018** | **6/27/2018** | **6/29/2018** | |
| **1** | 18.33a | 29.00a | 27.00a | 51.67a | 11.67a | 9.00a | |
| **2** | 16.00a | 13.33a | 26.33a | 35.00a | 9.00a | 5.00a | |
| **3** | 29.33a | 18.33a | 30.33a | 46.67a | 31.67a | 13.33a | |
| **4** | 12.00a | 5.67a | 23.33a | 44.33a | 25.67a | 6.33a | |

Means with the same letter in the same column are not significantly different according to Tukey's Studentized Range Test, P ≤ 0.05. Containers for raspberries were top-dressed with four different treatments of Osmocote 15-9-12, a 6-month slow-release macronutrient. The treatments were treatment 1: 86 (g), treatment 2: 133 (g), treatment 3:180 (g) and treatment 4: 228 (g).

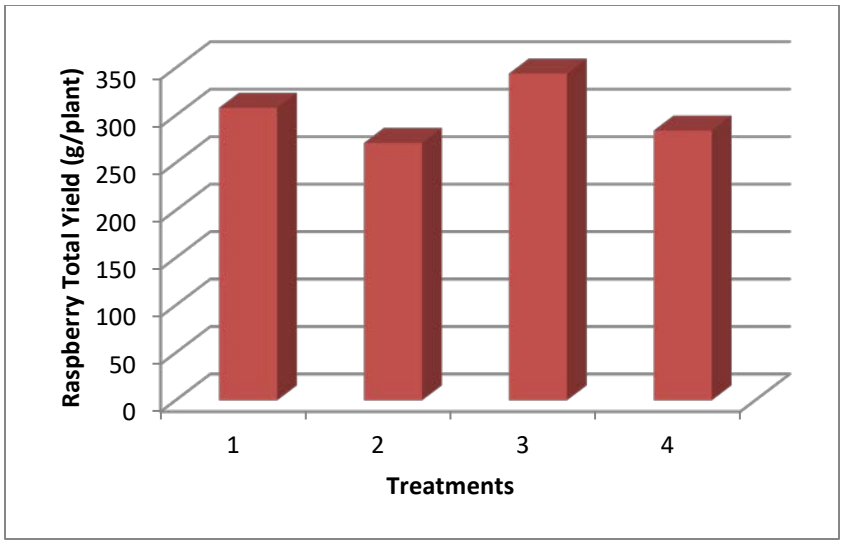


Figure 12. Raspberry total seasonal yields (g/plant) among the four fertilizer treatments in 2018. Containers for raspberries were top-dressed with four different treatments of Osmocote 15-9-12, a 6-month slow-release macronutrient. The treatments were treatment 1: 86 (g), treatment 2: 133 (g), treatment 3:180 (g) and treatment 4: 228 (g).

**Fruit size**

Table 4. Raspberry Fruit Size (g/berry) among the Four Treatments on Each Data Collection Date in 2018.

| Trt | 6/1/2018 | 6/4/2018 | 6/6/2018 | 6/8/2018 | 6/11/2018 | 6/13/2018 | 6/15/2018 |
|---|---|---|---|---|---|---|---|
| **1** | 1.42a | 2.11a | 1.77a | 1.70a | 1.45a | 1.62a | 1.66a |
| **2** | 2.34a | 2.41a | 1.38a | 1.82a | 1.29a | 1.91a | 2.04a |
| **3** | 1.91a | 2.63a | 2.08a | 2.04a | 2.17a | 2.25a | 2.09a |
| **4** | 1.19a | 1.06a | 1.99a | 1.93a | 2.03a | 1.93a | 3.03a |
| **Trt** | **6/18/2018** | **6/20/2018** | **6/22/2018** | **6/25/2018** | **6/27/2018** | **6/29/2018** | |
| **1** | 1.46a | 1.44a | 1.78a | 3.15a | 1.34a | 1.01a | |
| **2** | 1.01a | 1.29a | 3.67a | 3.02a | 2.44a | 1.33a | |
| **3** | 1.49a | 1.76a | 2.58a | 3.82a | 2.03a | 1.62a | |
| **4** | 1.56a | 1.29a | 2.47a | 3.05a | 2.27a | 1.28a | |

Means with the same letter in the same column are not significantly different according to Tukey's Studentized Range Test, $P \leq 0.05$

Table 5. Blueberry Fruit Size (g/berry) among the Four Treatments on Each Data Collection Date in 2018.

| Trt | 21-Jun | 28-Jun | 5-Jul |
|---|---|---|---|
| **1** | 0.47a | 1.43a | 1.27a |
| **2** | 1.03a | 1.13a | 0.83a |
| **3** | 0.87a | 1.30a | 1.13a |

| | | | |
|---|---|---|---|
| **4** | 1.07a | 0.80a | 0.97a |

Means with the same letter in the same column are not significantly different according to Tukey's Studentized Range Test, $P \leq 0.05$

Table 6. Blackberry Average Fruit Size (g/berry) among the Four Treatments on Each Data Collection Date in 2018.

| Trt | 27-Jun | 29-Jun | 2-Jul |
|---|---|---|---|
| **1** | 2.70ab | 2.84a | 3.26a |
| **2** | 3.42a | 2.91a | 2.80ab |
| **3** | 0.50b | 0.49b | 1.21b |
| **4** | 0.74ab | 0.61b | 1.03b |

Means with the same letter in the same column are not significantly different according to Tukey's Studentized Range Test, $P \leq 0.05$

Types of potting mixes (100% pine bark), plastic pot sizes (10 gallon), berry crop cultivars, fertilization regimes, pest management programs, temperatures of plant storage, timing of plant transfers from storage to field, time of fruit maturation, total yield, fruit quality (chemical and physical), and costs of materials and labor will all recorded and will be turned into three peer reviewed journal article. Extension fact sheets will also be written for commercial growers.

3. The total yields of berry production in containers (pots) over open field production were definitely increased by at least 25% in blackberries, 15% blueberries and 15% in raspberries.

With blackberries, we were able to get a full crop, when we covered the bushes in containers with two or four layers of rover covers. Either two or four layers worked very well. With row covers, the yield could have been zero two to three out of five years. This system definitely worked on blackberries.

With blueberries, the container production works beautifully, even with relatively high alkalinity in irrigation water. In most parts of Ohio, the soil pH is too high for blueberry production. This production system solved a huge problem for growers. In western Ohio, blueberry production (using the container production) will be a viable production system for the first time in history! The yield differences between container production system and open field production in amended native soil will be as high as 100%. This is because the blueberry bushes will die out in 4-5 years, if they ever live that long to begin with in the amended soil.

With raspberries, the container production system solved two big problems for grower, root rot and floricane dieback in spring. These two issues could cause up to 90% to 100% yield loss in many parts of Ohio. With the container production system for raspberries, we were able to grow beautiful “Kweli®” raspberries.

4. We were able to extend the harvest season of blackberry, blueberry and raspberry by 2-3 weeks. Berry crops in pots were stored in high tunnels, unheated barns, or covered in row covers in the field. These container-grown plants were moved to open field at different times. We were able to achieve this goal by placing the potted plants out in the field either early or late. The plants can be even moved into protected structures when there is a danger of frost.

5. We were definitely able to increase the awareness of container berry production technology among growers and consumers. We published more than five press releases on berry production in containers. We reached at least 250,000 consumers through newspaper articles. Three regional workshops were offered each year during the two years of the project. More than 100 attendees were reached through these regional workshops. We reached more than 1,000 through our presentations, research tours, and workshops. One fact sheet on container production of blueberries, blackberries and raspberries was originally planned. However, a more comprehensive PowerPoint presentation was developed in its place. Since there is too much data cover in a one pay fact, a bulletin and three research papers are being developed for publication.

6. We were able to demonstrate the effective use of chemigation in our mature blueberry planting at OSU South Centers in Piketon. The labor savings could be at least 50%. One of the biggest savings was reduction on potential fruit loss since driving a tractor with a sprayer through a blueberry planting before harvest would have knocked off 10-20% of the fruits. One of our biggest blueberry growers in Ohio has decided to install chemigation system in his late ripening blueberry field. More growers will likely follow.

7. We provided very strong direct support of new and existing berry growers to help create and retain jobs during the three years of project. We reached more than 2,000 growers through presentations at the Ohio Farm Science Review, Ohio Produce Growers and Marketers Association Congress, and OSU Extension County programs. We solved at least 250 production problems from 2015-2018. The estimated number of jobs with created or retained could be at least 80.

**Beneficiaries**

We were able to develop a highly viable berry production system for all 2,500 existing fruit growers and thousands new growers and many thousands more grain farmers who may want to diversify their farming operations. The anticipated berry production in containers could reach 50 to 100 acres in Ohio, if not more.

Our comprehensive Extension outreach programs helped growers reduce crop loss from cold injuries, poor soil conditions, poor water quality, improper pruning techniques, poor cultivar selection or planting techniques, excessive or under-application of fertilizers, damaging insects, diseases, and nuisance wildlife, and competition from weeds. Our educational efforts on best management practices, season extension methods, and innovative production systems definitely helped 1,200 berry farmers stay competitive and could help Ohio's 2,500 fruit growers diversify

their operations. The results from research trials and grower support programs helped create at least 25 jobs and retain 55 existing jobs from 2015 to 2018 and beyond. Last, but not least, all Ohioans, approximately ten million strong, will benefit from the nutritious, locally grown, and possibly organic blackberries, blueberries, and raspberries produced in containers.

**Lessons Learned**

Container fruit production system is a highly specialized production system since fertilizer, water, growing media, trellis support, and winter storage all have to be worked out and optimized. Since we were more used to field production in native soils or amended native soils, the project took longer than we had anticipated. We select the right sized pots, tweaked nutrient levels and injected acid to improve our irrigation water. Up to 95% of the container production issues were solved in three years. We needed more time to see how well the potted plants will do after they are planted in raised beds.

Another issue is negative effects of the mild winter temperatures on flower development in various berry crops. Most fruit plants do not like mild winter temperatures since they may not get enough chilling hours for proper flower bud development and subsequent fruit set and production. The mild winter temperatures did hurt our plants quite a bit. Some of the blackberry bushes in a high tunnel sustained heat stress, cane and flower bud damage, and then total fruit loss for the year in 2016/2017 season. Blueberry bushes did not grow very well as we had hoped.

Tight labor market due to new policies on immigration and trade tensions between US and other countries also created a lot of anxiety and uncertainties in the agriculture sector. Many growers decided not to invest in new technology.

Dr. Gary Gao asked Ms. Lori Panda of Ohio Department of Agriculture for a one-year "no cost" extension in June 2017. Our request was granted. We definitely appreciate the excellent support from USDA and Ohio Department of Agriculture for their strong over the years. We have learned a lot and hope to have optimized the production protocols for all existing fruit growers and new fruit growers.

**Additional Information**

**Press releases:**

1. News: Study Examines Potential of Containers for Commercial Berry Production (Nov. 4, 2015) http://cfaes.osu.edu/news/articles/study-examines-potential-containers-for-commercial-berry-production
2. Container Fruit Production May Have Good Potential in Ohio (Connections Newsletter 2016 Summer Edition) https://southcenters.osu.edu/newsletter/connections-newsletter-2016-summer-edition/container-fruit-production-may-have-good

3. Researcher Studying Benefits Of Growing Berries In Containers (November 10, 2015) http://www.growingproduce.com/fruits/berries/researcher-studying-benefits-of-growing-berries-in-containers/
4. News: 2017 Ohio Cane Fruit Pruning Workshop, March 16, 2017. https://ofbf.org/events/ohio-cane-fruit-pruning-workshop/
5. Ohio Blueberry, Bramble, & Wine Grape Field Night, August 24, 2017. https://agnr.osu.edu/sites/agnr/files/BrambleFlyer.pdf

**Abstract**

1. Container Production of Blackberries, Blueberries, and Raspberries for Farm Diversification, Season Extension, and Winter Protection in Ohio
   https://ashs.confex.com/ashs/2017/webprogramarchives/Paper25994.html
   https://ashs.confex.com/ashs/2017/webprogramarchives/Session8615.html
   Proceedings of the 2017 Annual Meeting of American Society for Horticultural Science. The trip was funded by The Ohio State University for Dr. Gary Gao's professional development, not by this SCBG.

**Selected Program Flyers**

1. 2016 Farm Science Review Schedule:
   http://fsr.osu.edu/sites/fsr/files/imce/Web%20program%20schedule.pdf
2. 2018 Farm Science Review Schedule:
   https://fsr.osu.edu/2018-farm-science-review-event-schedule
3. 2018 Ohio Conservation Tillage Conference
   https://fabe.osu.edu/sites/fabe/files/imce/files/Documents/Program.2018.pdf
4. Blueberry, Bramble, Container Fruit, and Wine Grape Field Night
   https://southcenters.osu.edu/sites/southc/files/Container%20Fruit%20Field%20Night.pdf

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**Project Title: OSU – Implementing New On-Farm Produce Safety Education Models**

**Project Summary**

Food safety has been a continuous to the public and has had an adverse economic impact on growers, packers, processors and shippers of fresh produce. Since its inception in 2007, The Ohio State University Fruit and Vegetable Safety Team (OSU FVST) has aspired to provide produce safety educational outreach services to Ohio's estimated 3600 produce growers on on-farm produce safety. Educational curriculum closely follows content within the FDA Food Safety Modernization Act (FSMA) Produce Safety Rule. To enhance the existing produce safety program and extend educational opportunities to stakeholders in post-harvest produce production chain, the OSU FVST 1) developed a virtual Good Agricultural Practices (GAPs) course (GAPS online course) 2) created educational specialized classes tailored to a specific produce growing audience 3) maintain traditional GAPs program for growers seeking the 3-hour, in person class 4) delivered two produce safety symposia covering the FDA FSMA Produce Safety and Preventive Controls standards at the Ohio Produce Growers and Marketers Association (OPGMA) Congress 5) delivered FSMA food safety training and 6) delivered post-harvest produce handling workshops.

The previously developed GAPs program content was in high demand but its content required updates to reflect the new food safety regulation. We aligned the 3-hour GAP training with FSMA requirements and updated the content to reflect the latest evidence. Also we expanded the course delivery modes in order to reach growers that are in remote location, have limited mobility or time constraints. An online GAPs education course identical to the 3-hour core class was developed. We developed specialized classes will be developed for previous core class attendees who seek advanced education. Specifically, a class on minimizing the risks from post-harvest contamination and flooding were developed and delivered. Post-harvest class is available to interested OSU Extension Educators to present on needs bases. We continued to deliver GAPs core class across Ohio. Plain grower version was created by adjusting the content and using culturally appropriate examples to be offered to accommodate those who do not use technology, such as the Plain Community. FSMA PSA trainings for growers were delivered.

**Project Approach**

In two years of this project, the Ohio State University's Fruit and Vegetable Safety Team taught 1024 fresh produce growers (370, 607 in 2016 and 47 in Nov/Dec 2015) about Good Agricultural Practices in the following counties in Ohio: Mahoning, Franklin, Lucas, Trumbull, Mahoning, Cuyahoga, Knox, Morrow, Guernsey, Clermont, Summit, Montgomery, Holmes and Wayne. Each GAPs class was approximately three hours long; dedicated to best practices to ensure on-farm food safety including water quality, soil amendments, equipment sanitation, waste management, worker health and hygiene, and transportation and storage. The science behind the best practice recommendations were communicated and the growers were guided in developing food safety plans and standard operating procedures (SOPs). The course content and binder components closely followed the FSMA produce safety rule standards. Workbooks included materials that growers will need to developed their own food safety plans. We scheduled and delivered 34 core GAP classes over two years. Feedback on the quality and content of the training was collected from growers using surveys. The surveys were developed and deemed exempt through The Ohio State University Institutional Review Board (IRB). After the class 97.8% thought that the course was useful to them, 84.3% thought the course will help them improve their food safety practices and 73.4% of the participants felt ready to develop a food safety plan on their own. In 2016, we developed the first draft of a kit for 3rd party audits,

and we incorporated these kits into the new updated version of the GAPs training. In January 2016, we organized a two-day food safety workshops for Ohio fresh produce growers delivered at the Ohio Produce Grower Marketing Association (OPGMA) annual congress in Sandusky Ohio. Approximately 270 growers participated in nine sessions. Experts in the field of food safety from the state and nationally held sessions on topics including FSMA Produce Rule update, preventive controls, sanitation and disinfectants, consumer insights, post-harvest water quality, produce food safety and soil, regulatory issues and inspection, food safety in protected environments and GAPs. In 2017, we organized another series of two-day food safety sessions for Ohio fresh produce growers that were delivered again at the OPGMA annual congress in Sandusky Ohio. We developed and delivered classes on post-harvest contamination, food safety of produce during flooding and risk communication for growers. We presented growers with emerging topics in food safety of fresh produce including antimicrobial resistance. Approximately 140 growers attended the sessions. Selected food safety sessions were ranked in the top 5 to 10 by growers among all congress sessions. We also completed the GAPs online course, which will be offered through the College of Food, Agricultural, and Environmental Sciences beginning in the spring 2018 semester.

**Goals and Outcomes Achieved**

The Ohio State University Fruit and Vegetable Safety Team developed and delivered numerous food safety education sessions:

1) Core GAPs 3-hour program was aligned with FSMA, updated with new science based recommendations and audit kits. We delivered GAPS training 34 times (1024 growers reached) of which four were for Plain Growers.
2) Two, 2-day produce safety symposia were delivered covering the FDA FSMA Produce Safety and Preventive Controls standards and science based recommendations of how to achieve the standards at the Ohio Produce Growers and Marketers Association (OPGMA 2016 and 2017, approximately 310 growers reached).
3) Two Produce Safety Alliance Grower Training courses were organized and delivered (50 growers reached).
4) Two Minimizing Postharvest Contamination of Fresh Produce 1-hour training in preventing cross-contamination of human pathogens from contaminated equipment, biofilms and zones was developed and delivered (120 growers reached).
5) Two Food Safety Modernization Act Education workshops were delivered to educators, food hubs and regulators (55 participants reached).
6) An OSU educational in-service was conducted in 2017 to train OSU Extension Educators on the revised GAPs training and to train them on FSMA-Fresh Produce Rule regulations (16 Educators reached).
7) Good Agricultural Practices (GAPs) course (GAPS online course) ready to launch in January 2018. The course is designed in the OSU Canvas online platform and includes the following seven modules:

    - *Introduction to the Course:* Describe what the team does, an overview of the course, expected goals, a brief explanation about being a voluntary program and not a certification program, and FSMA vs GAPs.
    - *Introduction to Produce Safety:* Who is responsible for ensuring safe produce, cost, causes and outcomes of foodborne illnesses, National GAPs Program,

USDA Group GAPs Food Safety Program, the importance of a Farm Food Safety Plan and Land Use Risk Assessment.

- *Water:* Human pathogens and pests associated with water, on-farm water usage, factors that influence produce contamination by water, pre- and post-harvest water, and four step cleaning and sanitizing procedure.
- *Waste:* Soil Amendments as a source of foodborne pathogens, types of biological soil amendments, best practices for using raw animal manure, and methods for producing compost.
- *Wildlife:* Wildlife and domestic animals, best practices for using domestic working animals, domestic non-working animals, best practices to handle and to deter animal intrusions.
- *Workers:* Worker health, hygiene and training, best practices for worker hygiene, worker clothing guidelines, importance of hand washing, restroom facility guidelines, and signs and symptoms of illness.
- *Traceability:* Produce storage guidelines, produce transport guidelines, documentation guidelines for traceability and methods for keeping track of produce.

Each module is designed to have a short description of the topics, a set of interactive slides made in Adobe Captivate, a wrap-up/summary of the module and a graded quiz. Some of the interactive slides have some ungraded questions that are used as knowledge checks. The water module is delivered using videos for pre- and post-harvest water sections.

A video about putting together a low-cost hand washing station is currently in production and will be added to the workers module. We are finalizing the quizzes after each module and are currently in the review phase.

The following resources were developed and published in this project:

Lewis Ivey, M.L. and Ilic, S. 2017. *Fresh Produce Safety Rule-Is My Farm Exempt?* Infographic Series 1.2. Ohio State University Extension, Columbus, OH.

Lewis Ivey, M.L. and Penate, A. 2017. *Food Safety-The Facts* (Spanish), Infographic Series 1.1S. Ohio State University Extension, Columbus, OH.

Lewis Ivey, M.L. 2016. *Food Safety-The Facts*. Infographic Series 1.1. Ohio State University Extension, Columbus, OH.

Lewis Ivey, M.L. and Ilic, S. 2016. Food Safety and Garden Flooding. HGY-1154, Departments of Human Sciences, Human Nutrition and Plant Pathology, Ohio State University Extension, Columbus, OH.

Ilic, S. and Lewis Ivey, M.L. 2016. Food Safety in Gardens. HGY-1153, Departments of Human Sciences, Human Nutrition and Plant Pathology, Ohio State University Extension, Columbus, OH.

Lewis Ivey, M.L. 2016. Pictographs for Plain Grower Good Agricultural Practices Trainings: Water, Waste, Workers and Wildlife. Ohio State University Extension, Columbus, OH.

**Beneficiaries**

We trained approximately 1,600 growers over the past two years in various classes and workshops pertaining to fresh produce food safety and specifically related to new FSMA requirement, using six new on-farm produce safety education models. The new GAPs course is available and will continue to be scheduled across Ohio. The new 1-hour Minimizing Post–harvest Contamination of Fresh Produce class is available on an "as-needed" bases. On-line GAPs course is available for growers who cannot attend in-person lessons. After attending the classes and workshop developed in this project growers gained skills required to understand food safety risks in the fresh produce production both pre- and post-harvest. They also gained knowledge of control measures and best practices necessary to ensure safety of produce and also keep their market share. These skills will contribute to increase in grower's self-efficacy to meet the food safety requirement both imposed by growers and those required through new FSMA regulation. These skills allow the growers to expand their markets to buyers who require compliance, thus creating a potential for increased profits.

**Lessons Learned**

At the beginning of the project, our goal was to deliver HACCP training session for growers and packers of fresh produce. In the meantime, the Preventive Control Rule was finalized in Dec 2015, and Preventive Control training took the place of HACCP training. To accommodate the changes project PIs Ilic and LeJeune took the training, however the Lead Trainer courses were largely unavailable until fall of 2017. In addition, the produce safety grower's urgent needs were to receive the PSA training. To meet the growers' requests, we adjusted the goals of this project to organize and deliver PSA trainings instead.

While GAPs surveys showed very good response of audience to the training, we did not include pre- and post-knowledge tests for all workshops. In 2017, we collected participant consents and will be able to send follow up surveys to better measure long term knowledge intake by the participants. These are scheduled to be sent out 12 months post training. In addition, we have worked with the North Central Regional Center for Food Safety Education to implement nationally standardized surveys that will measure long term knowledge and behavior change among recipients of PSA training.

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Additional Information:
Website links, pictures, anything you feel necessary to report.
https://producesafety.osu.edu/resources-0

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**Project Title: The Foodbank -- Increasing Access to Specialty Crops for Underserved Families in the Miami Valley**

**Project Summary**
The Foodbank's tri-county service territory of Montgomery, Greene, and Preble counties of Ohio represent one of the hungriest areas in the Nation. At the time of the start of The Foodbank's Increasing Access to Specialty Crops for Underserved Families in the Miami Valley, 130,200 residents identified as food insecure. Access to fresh produce for these residents is severely limited, many live in food deserts and those who don't cannot afford fresh produce from the local grocer. The Foodbank's USDA SCBG funded project grew over 1,000 pounds of specialty crops in its first year. At the close of our second year of growing, over 7,000 pounds of specialty crops were harvested and distributed among the food insecure in our community.

Nearly three years later, local food insecurity numbers have declined to 123,910 and families served by The Foodbank report increased access to and consumption of specialty crops. The survey results included in The Foodbank's closing report reflect such.

USDA SCBG funding was used to develop 44 raised bed gardens to grow and harvest locally grown fresh produce for food insecure residents of the Miami Valley who lack access to fresh food. The funded project is not built on a previously funded project.

**Project Approach**
Project partners include:

University of Dayton, who developed and conducted all studies for this project, which are included in the final report.

Alexandra Klug, who served as The Foodbank's Horticulturist Manager in year one. Her, and a team of volunteers, built all garden beds. Her efforts resulted in just over 1,000 pounds of harvested specialty crops in year one.

James Hoffer, served as The Foodbank's Horticulturist Manager in year two and beyond. He has redesigned and rebuilt all garden beds along with furthering The Foodbank's efforts to harvest specialty crops. His efforts resulted in over 7,000 pounds of harvested produce in year two. Additionally, Mr. Hoffer has developed a program to source excess specialty crops from local gardeners and farms in the area. All harvested and gleaned specialty crops were distributed

among the community's food insecure families through The Foodbank's Mobile Farmer's Markets and network of member agencies.

Victor Smith, Mr. Smith assisted in designing and building The Foodbank's garden beds in year one (funded under this project). His expertise as an agronomist and hobby farmer contributed greatly to the design and build of the first garden beds.

Below is a summary of the approved work plan with significant accomplishments, conclusions, and recommendations.

September, 2015-Februrary, 2016: The Foodbank hired a full-time Horticulturist Manager and began preparing the property for gardening. The blacktop was repaired using a cold-patch which proved to be unsuccessful as the patch created a further un-level space to build the beds upon. A mixture of sand and gravel that was already on the lot was a more successful approach to leveling the ground. Additionally, proposed repairs to the fence were delayed and eventually made in 2017 using other funding.

During this time The Foodbank worked with the University of Dayton to develop a survey to assess client's willingness to consume fresh produce. The survey was created by University of Dayton engineering students and was conducted in August 2016. A copy of survey results can be found below along with post-program survey results that were collected in 2017.

March-November, 2016: Year one of planting took place. In total, 1,012 pounds of produce, including tomatoes, bell peppers, beets, jalapenos, various herbs, okra, lettuces, and onion were harvested. Additionally, clients were surveyed to identify willingness to consume fresh produce and eating habits. Survey results can be found attached to this document.

December, 2016-March, 2017: All raised beds were planted with a cover crop. During this time, Alexandra Klug, Horticulturist Manager left The Foodbank. Her replacement, James Hoffer, was hired in February 2017 and immensely improved The Foodbank's gardening program. During this time, a replicable model guide was also developed that details year one of growing. The model is included as an attachment to this report.

The Foodbank's first year of gardening to increase access to fresh produce was successful, yet full of trial and error. Each lesson learned helped to guide year two of growing.

**Goals and Outcomes Achieved**
There were three defined goals approved for this project.

Goal 1: Increase sourced specialty crops for distribution to Foodbank clients. The benchmark for this goal was 100 pounds. At the conclusion of year one of growing, we harvested 1,012 pounds of fresh produce that was distributed to those in need. This goal was met.

**Goal 1: Increase sourced specialty crops for distribution to Foodbank clients. The established goal for this project was 100 pounds. At the conclusion of year one of growing,**

**we harvested 1,012 pounds of fresh produce that was distributed to those in need. This goal was met.**

Goal 2: Establish and fill a full-time Horticulturist Manager position. The Horticulturist Manager was hired in September 2015 and completed year one of growing. Her departure in December 2016 was unexpected, yet the position was again filled in February 2017, thus ensuring success of the garden and meeting this goal.

**Goal 2: Establish and fill a full-time Horticulturist Manager position. The Horticulturist Manager was hired in September 2015 and completed year one of growing. Her departure in December 2016 was unexpected, yet the position was again filled in February 2017, thus ensuring success of the garden and meeting this goal.**

Goal 3: Develop a replicable growing model for distribution to other nonprofits and foodbanks looking to start a garden. This goal was met. A model has been created and is included as an attachment to this report. It is continually updated and includes lessons learned and successes for year one and two of gardening along with garden educational initiatives funded by NCR-SARE.

**Goal 3: Develop a replicable growing model for distribution to other nonprofits and foodbanks looking to start a garden. This goal was met. A model has been created and is included as an attachment to this report. It is continually updated and includes lessons learned and successes for year one and two of gardening along with garden educational initiatives funded by NCR-SARE.**

**Beneficiaries**

The produce harvested through The Foodbank's 40 raised beds benefitted food insecure residents living in Montgomery, Greene, and Preble counties of Ohio. In total, 747,208 clients were served by The Foodbank's programs in fiscal year 2016 (calendar year 2015). Produce harvested through The Foodbank's garden was distributed through 30 Mobile Farmer's Markets in underserved communities across our tri-county service territory.

**Lessons Learned**

The Foodbank's first year of growing included many lessons. Below is a summary of such.

Inability to use low-level offenders to work in the garden and the need for additional manpower: Originally proposed was the use of low-level offenders as manpower in the garden. However, upon further investigation, it was deemed that the use of offenders in the garden during normal operating hours was not feasible due to the possibility that they would come into contact with volunteering youth. This, in turn, resulted in a lack of manpower to help water, maintain, and harvest from the garden. Though volunteer help was useful, it was often unreliable and as the summer months grew hot, many volunteers did not want to garden. From this experience, we enlisted the help of a full-time University of Dayton student intern who helped manage the garden in year two of growing.

Length of time spent watering: One of the largest hindrances experienced in our first year of growing was the length of time the Horticulturist Manager had to spend watering the beds. Without an irrigation system, much time was wasted which ultimately hindered harvest. In year two, The Foodbank purchased an irrigation system that watered all beds, and was able to be set on a timer to water the beds during the weekend when staffing was limited.

Garden bed design: Although the garden beds that were built in year one were beautiful, they were impracticable. The design of the beds made harvesting difficult and increased the chance of blight on many plants due to a lack of sunlight in the middle-most part of each bed. The beds were removed and rebuilt by engineers in year two of growing. This alone greatly increased overall harvest records in year two.

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Additional Information:
Please find The Foodbank's project model attached.

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**Project Title: The Refugee Response – Expending the market for locally grown ethnic specialty crops**

**Project Summary**
Recognizing a market opportunity we are exploring the viability of production and ultimately increasing the availability of ethnic varieties of specialty crops in the Ohio marketplace. The primary goals are to 1) identify and cultivate profitable crops, 2) expand the market for these crops while 3) increasing employment opportunities for the refugees we serve through expanding markets. We will conduct research to determine production characteristics, crop marketability and profitability, necessary investments in infrastructure to support cultivation, and education and marketing to consumers. Success will be measured by the number of local food consumers and institutions exposed to ethnic food crops as well as by the growth in sales of these crops at the conclusion of the 2016 and 2017 growing seasons.

**Project Approach**
While there is rapidly growing interest and availability of local foods in Ohio, there is a lack of culturally appropriate, locally-grown ethnic foods. Mintel estimates that between 2012 and 2017 sales of ethnic foods in grocery stores will grow more than 20 percent, which mirror similar demands upon farmer's markets. Despite this, there is a lack of production data and marketing information available for Ohio farmers interested in taking advantage of this growing market segment. The Refugee Response is well positioned to test this market opportunity with a strong CSA registration (120 members), restaurant partnerships (15 on contract) and on-site retail directly adjacent to the West Side Market. We also maintain a significant network of businesses,

institutions and other organizations that are interested in exploring ways to expand our partnerships that include specialty crops. These agencies have been significant partners for the Refugee Response and the Ohio City Farm in relation to the SCBG project, OSU Extension, Cuyahoga Municipal Housing Authority (CMHA), Ohio City Inc, (OCI), Great Lakes Brewing Company (GLBC), Cuyahoga Metropolitan School District (CMSD) and 20 independent restaurants in Greater Cleveland, Ohio.

OSU Extension provided the technical support and the generation of content in relation to the specialty crops. CMHA provided the administration of the Ohio City Farm and approved the continuation of the existing lease for the cultivation of the Ohio City Farm by the Refugee Response. OCI provided the promotion of the Ohio City Farm and highlighted our project and the SCBG crops on their website, through their newsletters and at the Ohio City Street Festival. GLBC has been a long term partner of the Ohio City Farm and was the largest purchaser of specialty crops for use in their restaurant. They are also the largest single restaurant purchaser from the Ohio City Farm. CMSD worked in partnership with the Refugee Response to bring over 400 school children to the Ohio City Farm to learn about cultivation techniques and to learn about food of the world. Twenty Independent Restaurants were provided with samples of the specialty crops and were also customers.

Most importantly, we have the collective expertise of our refugee trainees who have experience growing these crops and are part of the communities where they are used as part of a traditional diet.

Project objectives include increasing consumer awareness and access to locally grown ethnic varieties; growing the profitability of our program; creating the opportunity for increased employment opportunities for refugees through season extension; as well as potentially employing additional trainees as a result of increased sales demands. This project has not been submitted to any other funders and is pivotal to our ability to remain competitive while also filling a gap in the local food market. One hundred percent of our crops are specialty crops; there is no risk that funds will be used for non-specialty crops.

Through the implementation of the project it was determined that the overall success was in the ability to grow the specialty crops, however there was little sales to show for the production. This was in part due to the unfamiliarity of the crops and the lack of resources to conduct robust marketing.

**Goals and Outcomes Achieved**

**GOAL #1 Identify profitable crops through market research and outreach.**

An objective for ODA grant AGR-SCG-15-07 is to conduct a market feasibility study for the production and sales of a selected group of ethnic specialty crops. Ten ethnic specialty crops were selected. A survey instrument was developed for three distinctive audiences:

1) Person who already or are likely to purchase Asian specialty crops
2) Restaurants who already purchase Asian specialty crops
3) Refugees and immigrants from Asian countries

1) PEOPLE WHO ALREADY OR ARE LIKELY TO PURCHASE ASIAN SPECIALTY CROPS

A six-question survey was developed and distributed via a Survey Monkey link shared through the Ohio State University Summer Sprouts list serve (n= 1100) and The Refugee Response CSA list. The survey was opened on Oct. 25, 2015 and was open for three weeks. The survey was completed by 26 respondents.

2) RESTURANTS THAT CURRENTLY PURCHASE PRODUCE FOR THE REFUGEE RESSPONSE

A survey instrument was created in order to gather information from restaurants that currently purchase produce from The Refugee Response in order to determine which of the selected specialty crops they would be most likely to purchase. The survey was administered by Maggie Fitzpatrick, Manager of Agricultural Empowerment while performing regular produce drop-offs. Fifteen restaurants participated.

3) REFUGEES AND IMMIGRANTS FROM ASIAN COUNTRIES

A survey instrument was created in order to gather information from recently arrived immigrants and refugees from Asia countries regarding the types of ethnic produce that they currently purchase, where they purchase, and what they would purchase if it were available. The survey (along with a set of associated photos) was piloted with current REAP (Refugee Empowerment Agricultural Program) participants. Based on comments received the survey was modified to include clearer definitions. The survey instrument and associated photos were distributed to two resettlement agencies, Catholic Charities and US Together, Inc., who assisted in completing the survey. Twenty-five (25) persons participated in this survey.

Based on the results of these outreach efforts the following crops were selected for production: Okra, roselle, Asian long beans, bittermelon, sweet potato vine, pumpkin vine, amaranth, culantro, Thai eggplant and chili pepper.

**GOAL #2 Increase consumer awareness of locally grown ethnic specialty crops to allow for market expansion.**

Pre-assessments of restaurant clients, CSA members, and members of the refugee community regarding their interest and knowledge of and interest in select specialty ethnic crops (see GOAL #2) was accomplished in 2016. In 2017, TRR continued to offer samples to interested restaurants, promoted ethnic specialty crops via social media, and provided recipe cards in CSA bags.

**GOAL #3 Increase availability of access to locally grown ethnic foods in Cleveland, OH.**

In 2016, TRR sold ethnic produce to 24 restaurants, 127 CSA members, and 1127 farm stand customers. The number of restaurants purchasing ethnic crops increased dramatically, the number of CSA members increased slightly, and the number of farm stand customers decreased dramatically. However, overall, sales of ethnic crops at the farm stand doubled. Although there were fewer customers; they were purchasing more. In 2017, TRR placed a higher focus on restaurant sales. In order to do so, they closed the farm stand one day a week (halving the amount of time they were open for sales) which led to lower foot traffic and sales. They also

strategically lowered the number of CSA shares available for the same reason. The number of restaurants that TTR sells to grew by 8 (to 32) in 2017.

**GOAL #4 Identify profitable crops through market research and outreach.**
Within the targeted crop selection, crops that were familiar to consumers such as Asian Long beans, Thai basil, and Asian-type eggplant seemed to garner greater consumer acceptance. Although initial market research indicated that there was interest in purchase of bitter melon and amaranth, they did not prove to be popular items and production of these vegetables by TRR will likely cease or be significantly decreased in the future.

**GOAL #5 Increase consumer awareness of locally grown ethnic specialty crops to allow for market expansion.**
In 2016 samples were provided to fifteen restaurant partners. Follow up and feedback will occur in late December. Social media, via Facebook (approximately 2,000 likes) was used to increase awareness of the availability the selected ethnic specialty crops. By the end of 2017, TRR increased the number of Facebook followers to 2,859 and added an Instagram account which currently has 800 followers. In 2017, samples were provided to several more restaurants which led to sales outlets and future opportunities.

**GOAL #6 Increase the availability and access to locally grown ethnic foods in Cleveland, OH**
The goal was to triple the pounds of ethnic specialty crops sold. In 2016, the amount of ethnic specialty crops sold almost doubled. Although the target goal wasn't met, almost twice as much ethnic specialty crop produce was sold by TRR in 2016 than in 2015. Due to production issues (see Lessons Learned), produce availability led to sharply decreased sales of several popular items in 2017.

| CROP | 2015 (lbs. sold) | 2016 (lbs. sold) | 2017 (lbs. sold) |
|---|---|---|---|
| Pepper | 56 | 88.2 | 6 |
| Long Beans | 456.62 | 654.25 | 307 |
| Okra | 138.14 | 309 | 60 |
| Roselle | 22 | 27.7 | 0 |
| Thai Basil | 11.5 | 41.55 | 157 |
| Amaranth | 0 | 38 | 0 |
| Bitter melon | 0 | 58 | 12 |
| Pumpkin leaves | 0 | 13 | 0 |
| Sweet potato leaves | 0 | 21 | 64 |
| Thai Eggplant | 0 | 34 | 80 |
| | 684.26 | 1284.7 | 686 |

**GOAL #7 Increase employment and training opportunities for the resettled refugees we serve through expanded ethnic specialty crops and season extension related to growing those crops.**

The TRR was able to increase employment opportunities in 2017 to include 10 trainees, 3 seasonal farmer managers, and 1 full-time site manager. While only partially related to increased ethnic specialty crop production, the increase in employment opportunities indicates that there is room for growth in employment opportunities within niche markets.

**GOAL #8 Continue to create niche, profitable markets in order for The Refugee Response to remain a top provider of quality, local produce.**

In 2016, sales of the selected ethnic specialty crops increased by $711.50 at TRR farm stand. The target was to increase sales by $1000 in 2016. However, overall sales of the selected crops rose from $2942.35 in 2015 to $6295.15 in 2016. As described in GOAL #3, the farm stand decreased the number of hours open during the 2017 growing season, therefore farm stand sales were down dramatically.

| CROP | 2015 ($) | Farm Stand Only ($) | 2016 ($) | Farm Stand Only ($) | 2017 ($) | Farm Stand Only |
|---|---|---|---|---|---|---|
| Thai Chili Pepper | 238 | 86 | 373 | 113.4 | 24 | 0 |
| Long Beans | 2122.35 | 313.6 | 3271.25 | 832.5 | 1842 | 200 |
| Okra | 458 | 286.6 | 939 | 308 | 120 | N/A |
| Roselle | 90 | 22.5 | 470 | 22 | 0 | 0 |
| Thai Basil | 34 | 23 | 547 | 23 | 2041 | 91 |
| Amaranth | 0 | 0 | 177 | 0 | 0 | 0 |
| Bitter melon | 0 | 0 | 115.9 | 64 | 24 | 24 |
| Pumpkin | 0 | 0 | 39 | 0 | 0 | 0 |
| Sweet Potato | 0 | 0 | 273 | 16.3 | 256 | 8 |
| Thai Eggplant | 0 | 0 | 90 | 64 | 160 | 0 |
| | 2942.35 | 731.7 | 6295.15 | 1443.2 | 3466 | 323 |

**GOAL #9: Empower our refugee trainees by harnessing their pre-existing agriculture knowledge of ethnic specialty crops to cultivate ethnic varieties that have strong market interest and profit potential while increasing their level of interest and engagement in agriculture and as a means of their long-term financial self-sufficiency.**

After several years as a farm manager, TRR has been able to promote Hsar Lar Doe (refugee from Burma) into the site manager position. While this promotion is only partially due to ethnic specialty crop production, it indicates that there has been in increase in opportunities available in agriculture to refugee farmers.

**Beneficiaries**

The beneficiaries of this project are the consumers of ethnic specialty crops particular restaurateurs who purchase from TRR who now have a source of several ethnic special crops. The number of restaurants that TRR sells to has almost doubled in the last two years. TRR response has benefitted by increased interest and future potential sales of the crops. Sales of ethnic specialty crops were doubled from $2,942 in 2015 to $6,295 in 2016. Regional growers of ethnic specialty crops have benefitted by increased production knowledge of the crops via presentations at OEFFA and the Growing Green (Franklin Park Conservatory) conference in 2016.

**Lessons Learned**

In 2017, there were several crop failures/delays particularly within the warm season plants that need long growing seasons. Eggplant, Thai pepper, and okra transplants were not received and planted until the end of June. This dramatically affected the amount of produce available for sale. Transplants were produced by a commercial greenhouse for free but ended up costing valuable production time and sales in the end. The lesson learned is that "free" comes may come with a steep opportunity cost. Sorrel seed did not germinate and wasn't available for the 2017 growing season. One challenge when growing unusual crops is that it hard to find seeds through traditional, reputable sources. Therefore if saving seed perform germination tests regularly while in storage and if purchasing seed complete a germination test prior to planting.
There were several crops that did not gain the interest that TRR hoped but several that did.

As the TRR continues to grow, focus on the most profitable ethnic specialty crops will continue. At this stage in our 2018 farm planning we have identified three crops that will continue to grow. A significant part of our success in farming will depend on the financial sustainability of the farm. In 2017 TRR received no state, federal or city funding apart from small funding for materials from the USDA. Being unsuccessful in the next SCBG grants means that resources are not available to market these specialty crops further than existing pathways, even though we showed great success in being able to grow these varieties.

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