

**FY 2014 SPECIALTY CROP BLOCK GRANT PROGRAM – FARM BILL**

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## **PROJECT #1**

**Project Title:** Seeking Critical Hop MRLs in New and Growing Asia-Pacific Export Markets

**Partner Organization:** Washington Hop Commission

### **PROJECT SUMMARY**

Over fifty percent of the Washington hop crop is exported. As a result, compliance with foreign regulations remains a high priority for the Washington hop industry. Additionally, the expansion of the craft brewing industry around the world is resulting in Washington hops being exported to new markets. Around the world, more and more markets are focusing on pesticide residues and maximum residue standards. Countries are establishing their own standards that can differ from US standards. The combination of additional exports to new markets where hop MRL standards had not yet been established put Washington hop exports at risk. The goal of this block grant was to establish new hop pesticide maximum residue levels (MRLs) in five new and growing hop export markets: Australia, Taiwan, Hong Kong, China, and South Korea. Having such standards in place would remove concerns of residue violations in the receiving market.

Hop exports to the markets in question have grown by 30% since this start of the project. Exports to the five markets are now worth \$33 million annually and are up another 13% in the first quarter of 2017. This trend is expected to continue, therefore the MRL gaps in each market needed to be addressed. Additionally, each of the markets is in the process of establishing MRLs, so the timing of the grant was excellent. The grant allowed for a dedicated effort to seek MRLs at a time of transition in all five markets, when it would be easier to obtain MRLs. Pursing MRLs after this period will be more formalized and resource intensive.

This project did not build on a previously funded SCBGP project.

#### ***The Accepted State Plan (final proposal) included the following information:***

“The 2014 funding priority addressed by this project is enhancing international trade. Current hop exports to Australia amount to \$3.6 million, to Korea are \$4.9 million, to Hong Kong are \$3 million, to China are \$14 million, and to Taiwan are zero, for a total of \$25.5 million (just over 6 million pounds of hops). By comparison exports to the EU, Japan and Canada amount to \$87 million and have been as high as \$120 million three years ago. The countries targeted by this grant proposal accounted for over 30% of the world’s beer production in 2013, but represented only 11% of US hop exports. There are significant opportunities to expand these markets, but to do so, the hop industry must establish a strong foundation by obtaining the needed MRLs. As MRLs are established, exports will grow. With the new MRLs in place, the industry believes that exports to the new markets could double to a total of \$50 million in five years. Without MRLs, the probability of rejection and limitations on use of products will mean limited or no increases in exports.”

### **PROJECT APPROACH**

The efforts undertaken in each market were unique due to the differing regulatory circumstances. Efforts in each market are briefly described below.

**Australia:** When the project started, Australia had 10 hop MRLs in place. Australia is a growing market for the craft brewing industry and hop exports from Washington have grown significantly. Australia has made establishing additional MRLs a priority and set up an established system for seeking import tolerances. USHIPPC took advantage of this system and submitted requests for all priority MRL needs

over the course of the grant. The Australia system allows for annual submissions. USHIPPC divided its submissions into its highest priorities the first year, and second highest the second, and the remaining priorities the third. This seemed logical as opposed to asking for around 50 MRLs at once. After the highest priorities had been submitted, USHIPPC officials traveled to Canberra to meet with Food Safety Australia New Zealand (FSANZ) to discuss the submission and address concerns. FSANZ thanked USHIPPC for taking a three-year approach to the effort. As a result of USHIPPC's work under the block grant, there are now 56 hop MRLs established in Australia, 46 of which are new. Another 23 are expected once the third priority list is finalized in the second half of 2017. This will lead to a total of 69 new hop MRLs in Australia as a result of the grant.

**Taiwan:** When the block grant started there were NO hop MRLs in Taiwan. Taiwan had never considered hop MRLs despite focusing on MRLs in general for the last 15 years. Although the hop industry was flying below the Taiwan authorities' radar screen, the industry decided to pursue Taiwan MRLs as a proactive and long-term solution for the market.

USHIPPC worked with USDA and the American Institute in Taiwan (AIT) – the US Embassy, to approach the Taiwan government about hop MRLs. The Taiwan government surprised the industry by stating because hops were part of alcohol, MRLs would be handled by the alcohol office in the Department of the Treasury (!). Recognizing that the Department of the Treasury would not have the technical background for establishing hop MRLs, it was agreed that technical work would be completed by local university officials with more background. USHIPPC submitted its priority needs and additional background through AIT. After review, **Taiwan agreed to establish 33 new hop MRLs. This is the first time Taiwan has ever established hop MRLs, and it was the result of the grant and USHIPPC efforts.**

**Hong Kong:** Hong Kong established its positive MRL list on August 1, 2014, just before the block grant went into effect. USHIPPC had been able to obtain 50 hop MRLs on that list, but hoped to finish up the needs in Hong Kong by submitting the remaining six hop priorities. Unfortunately, this was not able to occur, but due to much larger issues than hop MRLs. Hong Kong has established NO MRLs since its original list in August 2014 due to politics surrounding MRLs in general. Hong Kong MRLs must be approved by the Hong Kong legislature, and concerns about Chinese produce and Chinese MRL needs have tied the issue up for the last two and a half years.

As part of the grant, USHIPPC contractors met with Hong Kong authorities three times to discuss the situation (twice in Hong Kong and once in Geneva). USHIPPC learned that while MRLs were being delayed, Hong Kong could meet the needs and importantly said, they are only testing against existing MRLs. This was huge news for the industry as it let them know that they could ship to the market without concern. The new MRLs in 2014 were at acceptable levels, and the missing MRLs were not being tested for. Exports therefore have proceeded without concern. USHIPPC is disappointed its final remaining MRLs were not established during this period, but was pleased to learn of Hong Kong's current policies and can provide the priority needs once the Hong Kong system opens up again. The work from the Block Grant has the industry well prepared for the next steps while current shipments are continuing with confidence.

**China:** When the block grant began, China also had no hop MRLs established. At the end of the grant, 13 MRLs are now in place in China that correspond to US MRLs. These have not been easy to come by, but progress is being made. China is a growing market for US hops. China has also committed to establishing 10,000 MRLs by the year 2020. Unfortunately, China has not yet established a system for seeking import tolerances. Instead, full registration for use in China is needed, which means field trials must be conducted in China. Despite this hurdle, several registrants were dedicated enough to undertake this effort and obtain the MRLs. USHIPPC appreciates these efforts.

In addition to seeking these MRLs, USHIPPC contractors met with the US Embassy and Chinese officials in Beijing during the grant to discuss the need for a simpler import tolerance system. USHIPPC learned that such a system is being considered and is slowly making its way through the Chinese regulatory system. Several years will be needed before it is finalized, but once it is, numerous additional hop MRLs will be sought.

**South Korea:** South Korea is an important and growing market for hop exports. South Korea is also completely overhauling its MRL system. By January 1, 2019, national Korean MRLs must be in place or product will be rejected. At the start of the block grant, six Korean MRLs existed. USHIPPC needed approximately 60 additional MRLs. At the end of the block grant, 12 Korean MRLs exist that correspond to US MRLs, but USHIPPC is optimistic that dozens more are on their way. As part of the grant, USHIPPC approached 15 chemical registrants with the industry's MRL needs in Korea. USHIPPC provided background and requested that submissions be made to the Korean government seeking the MRLs. Data packages are due to the Korean government by the end of 2017, so the submissions are being prepared. Additionally, USHIPPC officials met with the Korean government three times on the need for hop MRLs, and presented to the Korean Brewer's Association in Seoul, who agreed to approach the Korean government on this issue. USHIPPC is convinced the efforts taken during the block grant will lead to the needed Korean MRLs by the 2019 deadline.

USHIPPC contracted with Bryant Christie Inc. (BCI) in Seattle to assist with this project. BCI proved invaluable in pursuing these MRLs. They organized the hop MRL priority setting and briefed the industry continually on progress. They met with Australian, Korea, Hong Kong, Taiwan, and Chinese officials. They traveled to all markets except to Taiwan in pursuit of the MRLs. They also met with 15 pesticide registrants to stress hop MRL needs in key markets around the world. USHIPPC and its members are pleased with their efforts.

In addition, USHIPPC representatives held discussions with representatives of other hop producing countries during meetings of the International Hop Growers' Convention, informing those officials regarding efforts and challenges in the Asia Pacific region. This effort has resulted in a collaborative approach that will continue harmonization efforts in the region after the completion of the grant.

This project only benefited hops. What was learned in Hong Kong about testing policies was shared with the greater agriculture community as a whole, which was appreciated. This information would not have been known without this Block Grant and USHIPPC efforts.

### **Goals and Outcomes Achieved**

- USHIPPC determined its MRL priorities in each market by working with the industry and reported progress to the hop industry throughout the course of the grant.
- USHIPPC representatives traveled to Australia, China, and Hong Kong (twice), and South Korea (three times) in pursuit of the MRLs needed. They met with government officials during each meeting stressing hop MRLs.
- USHIPPC met with Taiwan officials twice in San Francisco regarding hop MRL needs.
- In Korea a relationship with the Korean Brewer's Association was forged to seek hop MRLs.
- USHIPPC representatives met with 15 registrants over the course of the grant and provided hop MRL needs in the market so submissions could be made.

The expected measurable outcomes are both immediate and long term. USHIPPC achieved 104 new hop MRLs in the target markets, but scores more are expected, especially in Korea, China, and Taiwan. The

efforts are currently underway for submissions to Korea that will result in new MRLs in the next year and a half. That information will also be used in Taiwan and China, which will take a little longer. Once all the regulatory courses are completed, USHIPPC expects over 200 new hop MRLs in these markets.

	<b>Number of Hop MRLs at Start of Grant</b>	<b>Number of Hop in Market MRLs now</b>	<b>Target Goal of New Hop MRLs at Start of Grant</b>	<b>New Hop MRLs Established during the Block Grant</b>
<b>Australia</b>	10	56	15	46 (23 more expected by end of 2017)
<b>Taiwan</b>	0	33	15	33
<b>Hong Kong</b>	50	50	6	0
<b>China</b>	0	13	10	13 (more expected)
<b>South Korea</b>	6	12	15	12 (50 more expected by January 1, 2019)

The chart above tells the story clearly. The project had huge success in Australia and Taiwan. The goal in China was met. The goal for Korea fell short, but within a matter of months will be greatly exceeded with new packages going in to the Korean government. This is just a matter of timing. The goal in Hong Kong was not met, but there were simply NO MRLs established during the period of the grant for anyone. Hong Kong is essentially closed on setting new MRLs for the time being. This was not a hop issue, it was a system issue, but important intelligence was learned in the meetings in Taiwan, which allow exports to the market to proceed.

The following chart compares benchmark figures for 2013 hop exports from Washington State with 2016 figures at the conclusion of the grant:

<b>International Market</b>	<b>Amount (2013 figures)</b>	<b>Amount (2016 figures)</b>	<b>Explanation</b>
<b>Australia</b>	\$3.6 million	\$7.2 million	Explosion in growth. New MRLs making big difference in confidence in shipping.
<b>Korea</b>	\$4.9 million	\$3.8 million	Market is down 22%, but will recover. MRLs are mandatory by 2019, so not an option not to pursue
<b>Hong Kong</b>	\$3 million	\$5.8 million	Good growth in this market since new MRLs in place.
<b>China</b>	\$14 million	\$14.7 million	Exports were as high as \$17 million in 2015. Market continues to grow. New MRLs are

			helping to encourage confidence in shipping.
<b>Taiwan</b>	\$0	\$60,000	With new MRLs, shippers are feeling safer to export to Taiwan. Market is just developing.

Source: FAS/US Census Bureau

### **BENEFICIARIES**

Hop growers and merchants are the direct beneficiaries of efforts from this project. This can be seen in the rise in exports to the markets in question over the course of the project by 30%. As a result of the block grant, shippers can export with greater certainty their shipments will not be rejected for a pesticide residue violation

While there is lag-time in compiling export data, the most recent USDA-FAS Global Agricultural Trade System Online (GATS) figures available for 2016-17 (crop year 2016) indicated the following levels for the countries referenced above, which are compared to 2013 totals for the US (note, Washington state represents approximately 74% of the US crop):

Australia – increased from 1,070,344 to 1,349,009 pounds (+26%)

Korea – increased from 1,173,961 to 2,089,982 pounds (+78%)

Hong Kong – increased from 1,046,755 to 1,200,637 pounds (+14.7%)

China – increased from 2,862,702 to 3,458,171 pounds (+20.8%)

Taiwan – increased from zero to 14,330 pounds (+14,330%)

Total increase in export volume for these countries: from 6,153,762 to 8,112,129 pounds (+31.8%).

Total increase in export value for these countries: from \$25.5 million to \$33.5 million (\$7,846,084 or +30.6%).

As a result, the benefit of this project to Washington state hop growers and processors utilizing the most recent year of export data available through GATS (2016 crop) would be 74% of \$7,846,084, or \$5.8 million. However, benefits are expected to continue to grow over the next several years, as the available export figures do not include a full year for the most recent crop, and much work remains to be done in several countries due to challenging regulatory systems and changing requirements.

104 new hop MRLs established, with more to come. Exports to the markets in question are up 30%.

### **LESSONS LEARNED**

Lessons learned from this project are as follows:

- The Australian system for seeking import tolerances is fantastic and should be used by other markets to seek MRLs.
- MRLs are a growing concern among many commodities and a proactive approach is needed to address the issue.
- Contacts with registrants are needed in order to solve these issues.
- Sometimes circumstances totally unrelated to your efforts can affect the desired outcome. The Hong Kong situation had nothing to do with hops, but stymied the industry to obtain the additional MRLs it was seeking.

- More is accomplished if you travel to the markets and meet with individuals as opposed to just sending emails.
- Although 104 new MRLs is an impressive achievement, more will be obtained in the future as a result of this effort, so the ultimate benefit of this project has yet to be finalized.

There were several twists in the road. Hong Kong's refusal to issue any MRLs as described above and China's lack of a system to simply seek a MRL without going through a full registration process was challenging. Having to work through Taiwan's Treasury Department was also challenging. Still significant progress was made in the grant despite these challenges.

The hop MRL challenges were unique. The Hong Kong situation was the only real insurmountable one and that will need to be resolved eventually through political compromise in the Hong Kong legislature. USHIPPC became experts of the Hong Kong situation and has informed other groups of what was learned.

**Additional Information**

In-kind matching support from the Washington Hop Commission: \$46,500.00.

Cash matching support from the US Hop Industry Plant Protection Committee included:

-\$15,500 for MRL database maintenance and support

-\$7,861.33 for Misc. Expenses and Review Fees (\$861.33 over the pledged amount)

-\$14,101.18 for Contractor and Staff Travel (\$898.82 under the pledged amount)

Total matching contributions (cash and in-kind): \$83,962.51 (\$37.49 under the pledged amount).



Matt Lantz, Bryant Christie Inc. at Food Safety Australia New Zealand in Canberra Australia speaking about hop MRL needs in Australia, July 2015



Bryant Christie Inc. meeting with officials from the Hong Kong Centre for Food Safety, August 2015



Matt Lantz, BCI, meeting with MRL experts from Korea's Ministry of Food and Drug Safety (MFDS) about Hop MRLs, February 2017

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## **PROJECT #2**

**Project Title:** Washington Apple Consumer Website

**Partner Organization:** Washington Apple Commission

### **PROJECT SUMMARY**

Consumers today rely on digital sources of information - internet, smart phone, and tablet - more than any other format, even TV. In research conducted in spring 2013 by Rose Research, over 75% of consumers in Asia cited those sources as the consumers' primary means of gaining information on recipes, health and beauty. Websites, especially those that are mobile device-enabled, are critical for engaging with consumers, and communicating product information. The Washington Apple website, [www.bestapples.com](http://www.bestapples.com), accessible to both the US and foreign consumers, was outdated and available only in English. The WAC applied for WSDA Specialty Crop Block grant funds to update the website, make it mobile device-enabled, highlight the connection between Washington apples and a healthy lifestyle and translate the site into 8 key foreign market languages - Spanish, traditional Chinese (Taiwan), simplified Chinese (China), Bahasa Indonesia, Russian, Thai, Arabic and Vietnamese.

Reaching consumers with relevant information to help them make purchasing decisions is critical in today's digitally connected world. In many of the Washington Apple Commission's target markets, smart phones are the preferred method of obtaining product information, and the ability to communicate information in an appealing way can make or break a brand's market presence. SCBGP funds allowed the Commission to update the outdated website to make it accessible by mobile phone users, as well as providing information in 8 key languages (including English). With Washington apple production increasing, and a relatively stable US market, export markets provide an increasingly important outlet for this additional production and help keep US domestic pricing firm.

This project was no built on a previously funded SCBGP project.

### **PROJECT APPROACH**

The Washington Apple Commission signed the Interagency Grant Agreement in October 2014. Initial efforts to contract through the state procurement system were unsuccessful and WAC subsequently conducted a RFP in December 2014. After reviewing over 25 proposals, and interviewing the top 5, WAC selected the Fiction Tribe, a design company based out of Portland, OR. The Fiction Tribe was contracted to conduct a platform-up redesign of the Washington Apple Commission's website, [www.bestapples.com](http://www.bestapples.com). Wordpress was identified as the most versatile, cost-effective, and easy-to-use content management system upon which to build the new website. WAC met with the Fiction Tribe in February 2015 for a discovery meeting during which features, aesthetic preference, goals, and priorities were discussed. With that information in hand, the contractor developed a sitemap for WAC's feedback. Content was then analyzed and categorized, and a finalized sitemap for the redesigned site was created. This sitemap informed the development of the wireframes – which are essentially blueprints to display the architecture of the site. At the same time, copywriting and content development began.

During the second quarter of 2015, the project moved into the design and development phases. The design process began by identifying the optimal user experience for the new website based on the site goals. An initial set of wireframes was developed for the main content sections of the site: Home Page, Apple Variety Page, and Site Navigation Menu. With the WAC team's feedback, the wireframe designs underwent edits, and additional wireframes were developed for other key content sections, including the Primary Navigation/Category Landing Page, Single Post Page, and E-commerce Home Page. After a third round of review, the wireframes were finalized and approved, and then the design phase kicked off. The Fiction Tribe developed and presented two unique sets of design comps for WAC's review. Each design followed

the architecture laid out in the wireframes, and each had its own look and feel. WAC chose one design for further refinement, and after two rounds of review and edit, the site design was finalized and approved.

In the period between July 1 and September 30, The Fiction Tribe completed the majority of the programming and development of the website. The last part of September and the first part of October were dedicated to BETA review and testing the site on multiple operating systems, browsers, and devices, and any programming and development updates that were warranted were made in that timeframe. This process ensures that the website will be viewed at the highest quality across all of the most common web user scenarios.

Although the initial proposal called for key site information to be translated into eight key foreign market languages – Spanish, traditional Chinese (Taiwan), simplified Chinese (China), Bahasa Indonesia, Russian, Thai, Arabic and Vietnamese, the closure of the Russian market to US agricultural goods in August 2014 meant that the WAC program in that country was put on hold. The elimination of translation into Russian allowed additional content to be translated into the remaining seven languages and created a more robust and informative site.

WordPress training was conducted with Washington Apple Commission staff in August 2015, which enabled the staff to begin making edits to the site prior to launch during the BETA review phase. Staff has full control of site content on an ongoing basis with the WordPress content management system. A duplicate ‘sandbox’ site was also created to provide staff with a place to test edits in a WordPress environment before making edits in the real, public-facing site.

Www.bestapples.com is hosted in the US, however due to restrictions on access to foreign-hosted websites in China, WAC had to host the site on a Chinese-based platform in order to ensure Chinese consumer access, and can be accessed at [www.bestapples.com.cn](http://www.bestapples.com.cn).

The official site launch with all seven languages occurred at the end of November 2015, four months ahead of the original workplan schedule. Since the contractor was able to conduct translations simultaneously it eliminated the need for the staggered language launch as originally planned. Press releases were used to alert both the trade and consumers to the availability of the site, and WAC points of sales materials highlighted the web address.

As noted above, after a competitive bid process in which over 25 proposals were reviewed, WAC chose to partner with the Fiction Tribe out of Portland, Oregon to design and implement the site. The majority of the design and development work was done by the Fiction Tribe, with input and oversight by WAC staff. Translated copy was reviewed for accuracy by the WAC foreign market representatives in Mexico (Spanish), Taiwan (Traditional Chinese), China (Simplified Chinese), the Middle East (Arabic), Thailand (Thai), Indonesia (Bahasa Indonesia) and Vietnam (Vietnamese).

The project does not benefit non-specialty crops.

#### **GOALS AND OUTCOMES ACHIEVED**

As this was a specific project, all activities conducted to develop the new website as listed above were completed to achieve the performance goals and outcomes. Third party research conducted by Rose Research as part of annual country program evaluations has been used to obtain measurements for consumer purchase behavior and awareness. Google Analytics is the source of website statistics information. There were no long term Expected Measureable Outcomes.

The activities and goals established for the project are in line with the actual accomplishments. This was a specific project to update the Washington Apple Commission website to be mobile friendly and available in key target market languages. To date, approximately 44% of the visits are coming from mobile phones

and tablets, a relatively large number that shows the importance of the redesigned site in reaching consumers in these markets. The previous website design was optimized only for desktop, so the new site design is serving both desktop and mobile audiences well.

A secondary goal was to create a site that could easily be updated by WAC staff – this would allow maximum flexibility/response to information and reduce costs through in-house updates.

The first goal was:

Increase target consumer (women between ages of 25 – 50) awareness in three key markets Mexico, Indonesia and Thailand of the health benefits, varieties and uses of Washington apples.

Target: 20% increase in consumers who say they are “more likely” to purchase WA apples due to information provided on the website in their language.

Performance Measure: Percent of consumers in third party consumer surveys in Mexico, Indonesia and Thailand who say they have increased or made purchase of Washington apples due to information provided on the website in their language.

Results: In research conducted in March 2013, 35.2% of target consumers in Mexico were able to recall that Washington Apples can help gain health if adopted as part of a healthy lifestyle. That number increased to 40% when again measured in March of 2014, and subsequently jumped 15% to 55% in March 2015, after the launch of the website in Spanish. In Indonesia, the number of consumers who were aware of at least one health benefit increased from 33 to 35%; this number is lower probably because the survey was taken on the islands of Bali, Kalimantan and Sulawesi, where internet and smart phone use is lower.

Goal: Improve access for consumers from key international Washington apple export markets of Mexico, Indonesia and Thailand.

Target: 15% increase among consumers accessing the website during the three months following launch.

Country	Visits in June 2014	Average Mo. Visits since launch	% increase	Visitor Profile
Mexico	697	729	5%	80% new
Thailand	100	166	66%	85% new
Indonesia	43	54	26%	85% new

The highest increase in site visits is coming from Thailand with a 66% increase. What is interesting is that this trend is increasing, with the past three months (May – July) averaging 268 visits. The second highest increase is in Indonesia, although the base is still low and further emphasis on the site availability will be placed during the 2016-17 promotional season. Mexico did not meet the target increase of 15%, which could be reflective of the general lower importance of electronic communication in that culture, although it still has the greatest number of site visits outside of the US.

### **BENEFICIARIES**

There are 1,550 apple growers located primarily in 10 counties in Central and Southeastern Washington State: Okanogan, Chelan, Douglas, Grant, Kittitas, Yakima, Benton, Franklin, Walla Walla and Adams. Approximately one-third of the crop is exported, and that percentage will need to increase by 25% to keep pace with production increases over the next 5 years. In order to maintain and grow the export presence, communicating to target consumers the high quality, healthy and versatile benefits of Washington apples versus the competition (other origin apples, fruits and snack foods) is critical.

Exports of Washington apples generated a total of \$804 million FOB value for the growers and shippers of Washington apples in the 14-15 crop year (September 1, 2014 – August 31, 2015). In a soon to be published econometrics study by a team led by Harry M Kaiser, Ph.D. from Cornell University, the overall combined marginal benefit-cost ratio is 3.81 in the short-run and 4.11 in the long-run for joint export promotions using both Washington apples industry funds and USDA Foreign Agricultural Service Market Access Program funding. That is, for every additional dollar in export promotion funding (such as the website), industry profits increase by \$3.81 in the short-term and \$4.11 in the long-term.

Although the grant addresses the consumer information benefits, the site also includes enhanced Washington apple shipper contact information, and is the fourth most-visited page, with 11,686 page views since the new site went up in November 2015. This is important information in terms of increasing the ability of potential foreign buyers to access Washington apple suppliers directly to obtain quotes and develop new business opportunities. WAC does not have the tools or resources to track which website contacts to individual shippers have resulted in sales.

### **LESSONS LEARNED**

All in all the project went smoothly and yielded better than expected results in terms of site redesign quality and favorable feedback from industry. Project staff gained additional experience in website design platform terminology, using an editable site content management system (WordPress) and website analytic tools.

The original budget request was not sufficient to obtain the desired site functionality and look, and the amount of industry contribution was increased by \$18,450 to a total of \$24,450 from the original match of \$6,000.

When formulating the original performance measures, the plan called for using a pop-up query tool to obtain site feedback. However, after thoroughly costing the site redesign and translation, the cost to implement that feedback system was beyond the scope of the budget. Therefore sources such as Google Analytics for site metric information has been relied on.

### **ADDITIONAL INFORMATION**

As mentioned above, the current total cash investment of Washington Apple Commission industry funds is \$24,450. It was combined with grant monies to fund the site design, development and translations.

The URLs for the translated websites are:

Spanish: <http://es.bestapples.com>  
Traditional Chinese: <http://cn.bestapples.com>  
Simplified Chinese: <http://cn1.bestapples.com>  
Indonesian: <http://id.bestapples.com>  
Thai: <http://th.bestapples.com>  
Arabic: <http://arabic.bestapples.com>  
Vietnamese: <http://vn.bestapples.com>

### **CONTACT INFORMATION**

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## **PROJECT #3**

**Project Title:** Washington State Wine Promotions in Canada

**Partner Organization:** Washington Wine Commission

### **PROJECT SUMMARY**

Canada's high rate of consumer income and limited level of domestic wine production make it an attractive export market for wine-producing regions around the world. Several factors, including the close proximity between Canada and Washington State, have made Canada the top export market for Washington State wine. In spite of this, wine exports to Canada from Washington only accounted for 0.5% of total Washington wine production at the start of the project (65,214 cases valued at \$5 million in 2012/13). The principal issues in the Canadian market that have limited the growth of Washington wine exports are a lack of consumer and trade awareness of Washington wines and limited availability on store shelves. This project sought to increase the awareness and sales availability of Washington State wine in Canada.

As an industry, Washington State wine has seen significant growth in production in the past 15 years. The number of wineries in the state grew from 170 in 2001 to 850 in 2014 (the number of wineries has continued to rise to more than 900 since the project began), and wine grape production more than doubled in that same period. While encouraging, this level of growth will realistically be difficult to maintain without continued exploration and development of export markets. Canada was the sixth largest wine-importing market in the world at the project's outset. Canada was already an important export market for Washington State wines at the outset of this project, but exports to Canada accounted for only a small portion (0.5%) of Washington wine production and therefore significant opportunity for growth remained. These factors all combined to make Canada the clear choice for Washington State wine to pursue as a target market in this project.

### **PROJECT APPROACH**

The Washington State Wine Commission (WSWC) collaborated with the Liquor Control Board of Ontario (LCBO) and Société des Alcools de Québec (SAQ) to promote Washington State wine in alcohol monopoly retail stores in both provinces. Ontario and Quebec contain over 60% of the population in Canada, making them ideal province-level target markets that can help grow consumer and trade awareness within these provinces and more broadly across the country. In the first year of programming, WSWC and LCBO conducted an in-store tasting program featuring eight Washington wines, performed two educational seminars on Washington wine for 30 LCBO product consultants, hosted a Washington wine and food pairing dinner for six leading wine journalists in Ontario, and conducted trade and consumer tastings which drew in 206 and 325 attendees respectively. These events were complemented by a feature on Washington wine in the official LCBO magazine *Vintages*, which is circulated in French and English. The strong level of engagement seen at the events was encouraging to both groups. Before the program year had finished, LCBO made clear their intent to send LCBO buyers on a visit to Washington State, and to continue the in-store tastings of Washington wines in the following year. Both of these plans were completed in the 2015-16 program year.

The second year of programming saw WSWC begin its activities in Quebec with SAQ, following a similar pattern in programming as the year prior in Ontario. WSWC-led activities with SAQ began with a Washington wine feature in SAQ's official *Cellier* magazine, 46 in-store displays, 92 in-store tastings, and a release of several new Washington wine products in SAQ stores that coincided with the promotions. In all, the promotions featured six Washington wine brands already available in SAQ stores, and five new

releases. Promoted wines saw sales increases between 62.1% and 94.6% during the promotions. This impressive rise in sales led SAQ to offer WSWC the opportunity to perform another round of in-store tastings three months later, which WSWC accepted. After the promotions were completed, SAQ informed WSWC of their decision to expand the range of Washington wines sold in SAQ stores, and that they planned to send SAQ buyers to visit Washington in October 2016 to determine which new wines to include. During the second program year in Ontario, WSWC continued its promotional activities from the first year, by running two rounds of in-store tasting events in LCBO stores.

2016-17 marked the final year of the project. WSWC returned to Ontario and coordinated with LCBO to conduct a total of 140 in-store tastings throughout the year. LCBO had previously developed a thematic display to be used in in-store promotions, and agreed to use it for the WSWC activities. WSWC supplied generic end-cap displays, signage, neck-hangers, and other point-of-sale materials to be used during the promotions. A total of 2,623 bottles of Washington wine were purchased during the in-store tastings themselves, and an estimated 9,513 customers had the opportunity to try Washington wine firsthand. As reported by the buyer for *Vintages* (one of two LCBO sales channels and the one that most Washington State wines are sold through), the Q1 sales of Washington wine through this channel totaled \$7,696,437. This marked an increase of 26.3% over the previous year, nearly doubling the LCBO's projected increase of 13.6%. The substantial rise in sales and sustained interest in Washington wine from the province's consumers and trade is encouraging, and LCBO continued to expand its portfolio of Washington wines through the rest of the year. The same has happened with the SAQ. Between 2015-16 and 2016-17 alone, sales through SAQ stores rose 75%. With more Washington State wines on store shelves than ever before, prospects for continued growth in both markets are very positive.

Key contributors to this project included Washington State wineries, United States Department of Agriculture overseas staff, and the WSWC's in-market representatives, Nantel & Associates. Throughout the program, wineries and their Canadian agents have assisted in arranging and supplying the wine for in-store tastings at LCBO and SAQ stores. Several wineries also hosted trade delegations in Washington that included buyers from LCBO and SAQ. It is important to note that these inbound visits were not directly supported with SCBG grant funds but were a vital step in continuing the in-market promotional activities, and securing new store listings for Washington wines. WSWC also received significant assistance from USDA offices in the provinces as they helped identify promotional opportunities and suitable members of trade to involve in the programming. Lastly, Nantel & Associates oversaw the implementation of the program and maintained communications with LCBO and SAQ. The project did not benefit any non-specialty crops.

### **GOALS AND OUTCOMES ACHIEVED**

The activities completed during the program included in-store tastings in LCBO and SAQ monopoly stores, in-store displays promoting Washington wine, media features on Washington wine in the official LCBO and SAQ magazines *Vintages* and *Cellier*, new in-province product releases, educational seminars for monopoly product consultants, trade and consumer tasting events, and media outreach in the form of a food and wine pairing dinner. Nearly all activities were performed in conjunction with LCBO or SAQ as their cooperation allowed the program to most directly reach Canadian wine trade and consumers.

Gains are expected to continue for all Expected Measurable Outcomes in the long-term, but WSWC is able to report on current progress below.

The goals for this program were to increase the number of Washington wineries exporting to Ontario and Quebec, and to increase the overall sales of Washington wine in each province. Thanks to a wide array of activities targeting the leading sales channel in both provinces (LCBO and SAQ stores, respectively), significant accomplishments were seen. The number of wineries with wines available through Canadian

monopoly retailers is at an all-time high. During the lifespan of the project, success was most evident in Ontario with eight new wineries exporting and the volume of sales nearly tripling. However, the project may actually position Washington State for even more success in Quebec over the long-haul. Gains in Quebec were primarily made over the last year, when sales rose 75% and the number of wineries exporting rose back to 21 after dipping in 2015/16. Washington State wines are now widely available in SAQ stores through both the specialty/*Cellier* program and through the general list. This latter form of availability—combined with growing recognition for Washington State as a winegrowing region—is critical for significant volume increases as it means that wines are available in most stores throughout the province.

The expected measurable outcomes for the project were: 1) an increase of at least five new Washington State wineries exporting to Ontario from a 2014 baseline of 15 wineries, 2) an increase of at least 5 new wineries exporting to Quebec from a 2014 baseline of 21, 3) a sales increase in Ontario of 5,000 cases or approximately \$330,000 from a 2014 baseline of 22,643 cases, and 4) a sales increase in Quebec of 4,000 cases or approximately \$420,000 from a 2014 baseline of 13,951 cases. See the actual outcomes at completion of the project in the table below:

<b>Description</b>	<b>Baseline</b>	<b>Goal</b>	<b>Outcome</b>
Number of Washington wineries exporting to Ontario	15	20	23
Number of Washington wineries exporting to Quebec	21	26	21
Sales of Washington wine in Ontario (cases)	22,643	27,643	58,369
Sales of Washington wine in Quebec (cases)	13,951	17,951	23,820

The data above was collected through the annual industry export survey for WSWC, and supplemented through a review of data provided directly by the LCBO and SAQ. Three of the four measures were exceeded by wide margin, with only the number of Washington wineries exporting to Quebec being unmet. However, as mentioned above, the number of wineries exporting to Quebec has accelerated over the last year after dipping in 2015/16. In all likelihood, the original goal for this measure will be surpassed in the coming year.

### **BENEFICIARIES**

Most directly, export-oriented Washington State wineries have benefitted from the completion of this project. Those that were already in the market when the project began benefitted from the project’s promotional activities and from the resultant expansion of demand. In addition, at least eight new-to-market wineries benefitted from the opportunity to export their wines to Ontario and/or Quebec. With the volume of sales nearly tripling in Ontario and nearly doubling in Quebec over the three-year project period, success was seen by most wineries engaged in exporting to Canada.

More generally, the project has benefitted all wineries in Washington State by furthering the presence of the state’s wine-regions in one of the top wine-importing markets in the world. Having seen the marketability of Washington wine in the Canadian market, it is probable that monopoly buyers in Canada will look to other wineries to further expand their portfolios. On the margin, even wineries that are not looking to export will see growth in the number of wine tourists from Canada.

The LCBO and SAQ also benefitted from the project as they were able to grow their sales figures and expand their available product lines.

### **LESSONS LEARNED**

In implementing this program, project staff were able to conclude the effectiveness of direct-to-consumer sampling opportunities for new and previously available wine products. When complemented by media exposure in the monopolies’ magazine publications, allowing the Canadian consumer to try Washington

wines firsthand in monopoly stores helped to show them the combination of quality and price-point that make Washington wines attractive options for purchase. Furthermore, working directly with the provinces' monopolies allowed WSWC to illustrate the sales feasibility of Washington wine to those supplying the market, thereby promoting Washington wine to consumer and supplier alike.

The only unexpected difficulties encountered during this project were occasional scheduling delays from LCBO and SAQ, which forced certain programming to be implemented later than initially planned. Given that the monopolies are the only retailers in their respective markets, WSWC had to be flexible with these delays. Fortunately, the overall quality of the promotions did not suffer as a result, and the majority of the programming was implemented. One positive result of these delays was that WSWC's flexibility and understanding regarding the scheduling changes served to demonstrate to the monopolies WSWC's commitment to its goals for the markets of Ontario and Quebec.

The target number of exporting wineries was not met in Quebec, likely as a result of structural changes at the SAQ in 2015/16. The number of suppliers was thus impacted but not the volume. One surprising outcome was that the strength of the U.S. dollar did not appear to impact the project negatively. This stability shows the seriousness with which consumers in Ontario and Quebec now view wines from Washington State, thanks largely to the opportunities provided by this SCBG project.

#### **ADDITIONAL INFORMATION**

The total level of matching donations for the program was \$40,809. This consists of \$11,700 in cash contributions, provided in the form of payments to WSWC's international program consultant (5% of the consultant's retainer contract with WSWC, for each of the three years of the project). The international program consultant assisted WSWC with the overall strategy and administration of the project including oversight of the in-market representative that coordinated day-to-day implementation of the project and coordination with the SAQ and LCBO. In-kind contributions consisted of \$29,109 in personnel and benefit costs to WSWC staff members involved on the project (1% of WSWC's personnel and benefits costs in 2015/16 and 2016/17). Staff from WSWC were primarily involved in the strategy, oversight, travel, SAQ/LCBO engagement, and administrative elements of the project. These contributions were only applicable to this specific grant project—they have not been covered by any other source of grant funds or considered contributions for any other grant projects or programs.

Attached with this report are:

- (1) Washington State wine advertisement in October 2014 *Cellier* magazine (back page)
- (2) Washington State wine advertisement and article in Spring-Summer 2017 issue of SAQ magazine
- (3) Photo of LCBO buyer visiting Wahluke Wine Co. and of SAQ buyer visiting a vineyard at Goose Ridge (their visits to Washington State—and the subsequent growth in the number of wineries with listings in Ontario and Quebec—was the result of engaged promotional support from WSWC)
- (4) Photo of 2015 trade tasting with the LCBO
- (5) Example photos of in-store tastings and displays

#### **CONTACT INFORMATION**

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**See Attachment A– 2014 SCBGP-FB**

## **PROJECT #4**

**Project Title:** Putting Pears on the Menu: Increasing the Use of Pears by National Restaurants

**Partner Organization:** Pear Bureau Northwest

### **PROJECT SUMMARY**

The "Putting Pears on the Menu" project is designed to enhance domestic markets and domestic market sales, which is one of the 2014 Funding Priorities. Through this grant, Washington and Oregon pear growers and shippers will have the opportunity to introduce national chain restaurant decision-makers to pear production, seasonality, varieties, quality, storage and ripening education. There is also a perceived limited use and seasonality of pears among this group that hinders year-round usage and sales into major foodservice operations.

The Pacific Northwest, home to 84% of the US fresh pear crop has had two record-breaking crop yields within the past five years. Thus, increasing foodservice usage of pears is critical in helping demand keep pace with supply. The ultimate goal is to get more pears on national multi-unit restaurant menus, thereby increasing pear sales.

### **PROJECT APPROACH**

The first phase of this project was to complete a qualitative research study, to be conducted by Harvest PR & Marketing. A targeted list of chefs/corporate menu planners were interviewed by phone for insights on the planner's use of (or decision not to use) fresh pears. This exercise addressed the current barriers to use of pears, and perceptions and topics to address through the education and communication. As pear harvest began, Pear Bureau Northwest conducted a three day event featuring classroom time with a leading post-harvest ripening and handling expert, orchard tours with local growers, and visits to packing and shipping facilities, providing foodservice chefs with an unforgettable experience and closer look at the Pacific Northwest.

The project goal was to recruit 8+ key culinary/foodservice chefs/executives, representing high volume restaurant companies with 50+ units, for example, The Cheesecake Factory, Panera, Freshii, Ruby Tuesday, and Olive Garden. Twelve chefs accepted the invitation, (see Attachment B) yet six dropped out within the last weeks of the event due to unusually high workload in the restaurant industry during the event timeframe. Final attendees included research chefs from Panera Bread, Cheesecake Factory, Sizzler, Tavistock Restaurants, Brio Bravo, and Brickhouse Tavern and Tap.

National menu labeling laws took effect in December 2015 following the 2015 event date. As a result of the labeling requirement, national chain restaurants aggressively reformulated many items on their broad menus to better reflect consumer demands for healthier nutritional portfolios. This was likely the single largest menu development event, or even crisis, to happen in the foodservice industry, preventing many from attending the tour.

Following the tour, Pear Bureau Northwest planned to continue to foster relationships with these decision-makers, supporting menu ideation process by supplying fresh pears (by request for R&D), providing internal pear usage training materials for multi-unit operators, and offering the services of a post-harvest ripening expert for customized support. Outreach occurred four times since the October event. One chef has provided details of their pear formulation changes, including improving pear ripening for salad at Cheesecake Factory, and

two chefs provided feedback on their goals, with Sizzler seeking value-added pear slices and Abe & Louie's continuing to feature pears seasonally.

Pear Bureau Northwest (PBNW) team managed the project and provided key connections with industry for the contractor, Harvest PR. PBNW attended the tour and presented key components in the training program, like unique varieties, usage ideas, consumer insights and preferences. In addition, PBNW's ripening specialists provided education about ordering, ripening and handling, the key barrier to menuing pears. PBNW also completed all the reporting for the project and contributed in-kind and cash contributions to the matching requirements.

HARVEST PR developed the target chain account list, created the invitation and connection with the chef leaders, arranged for flights and travel as well as created the educational schedule and materials.

GROWERS and SHIPPERS supported the project with orchard tours in Hood River (Ray Sato Orchard and Kiyokawa Orchard) and a pear production facility tour (Duckwall-Pooley Fruit Co.), helping to educate chefs about the supply chain for pears – including hand picking and hand packing pears for distribution.

The project did not benefit any non-specialty crops. The benefit was solely to pears.

## **GOALS AND OUTCOMES ACHIEVED**

### Activities Performed

- Develop target list of 25 chefs and corporate menu planners
  - The target list is attached to the report, and includes target chain accounts for pear menuing collected from internet search, contractors database and national culinary events that were attended – NRA and WOHF/CIA.
- Qualitative research study was planned to support event planning.
  - Phone calls were conducted and chefs were interviewed face to face when possible.
- Recruit chefs at national gatherings and events:
  - Six chefs attended the event after more than 30 chefs were invited. The invitations began 8 months before the event and twelve final attendees were firmed up in the last months before the tour, but only six attended.
- Final invites to chefs and travel arrangements
  - Hotel and transportation was arranged for each chef, as well as group transportation to and from the orchards in Hood River, Oregon.
- Tour itinerary planning and industry involvement
  - A copy of the dossier from the event is found under Attachment C, showing the event and education materials delivered to attendees.
- Tour conducted in Oregon and Washington
  - Tours were conducted per above itinerary in Oregon. Given the limited time spent with the chefs, the tour was only conducted in Hood River and the additional 4 hour drive to reach Yakima Valley was not put into the schedule. The tour included a drive along the Columbia River between Hood River and Portland, Oregon and orchards were pointed out.
  - Video and still photos are provided to show the activities conducted at the tour.
- Chef follow up to support menu development
  - The hardest and weakest part of the project has been continuing follow-up with

the chef attendees. PBNW has reached out three to four times with each chef. Results have been summarized in Attachment B.

- Developing relationships with chain accounts is a long-term process with the average menu development cycle being 18 months or more. Continued interaction with the development chefs will be required to encourage development of new items. For new fiscal planning, outreach to these targets will be included in the planning.

Comparison of the activities and goals established.

- Develop target list of 25 chefs and corporate menu planners
  - The target list is attached to the report, and includes a strong list of target chain accounts for pear menuing. This portion of the project was performed above expectation.
- Qualitative research study
  - The qualitative research study was not possible before the event planning, as chefs were not making themselves available to answer questions. It was determined that some directional feedback from face-to-face interviews and former research interviews to build the tour plans was necessary.
- Recruit chefs at national gatherings and events
  - Two events were scheduled with the hope of interacting, interviewing and inviting attendees. There great interest from the two events but no one accepted an invitation. To improve the process, better pre-event screening and post-event follow-up may have garnered more chef attention and acceptance to the tour.
- Final invites to chefs and travel arrangements
  - The final number of attendees was 6 development chefs, with two of the chefs being entry level staff without as high of decision making power as desired. A significant barrier to attendance was the timing for the event, as described above. Many chefs that accepted the invitation later cancelled or sent a junior developer in their place because of the looming nutrition labeling regulations in the industry.
- Tour itinerary planning and industry involvement
  - Planning and involvement with the pear industry was successful. A key speaker from Sysco Fresh Point pear buyer, a key distributor in the foodservice market, cancelled his attendance at the last minute and could not provide a replacement. The buyer's attendance was not part of the initial plan, but added as an opportunity by the planning team.
- Tour conducted in Oregon and Washington
  - The event was exceptional, both in content and execution. The orchard visits and pear luncheon were informative and impactful on the attendees – with a first-hand opportunity to meet the grower, tour the orchard and further understand the value of fresh produce. Unanimously, the chefs felt this was the best part of the entire event.
  - Given the limited time spent with the chefs, the tour was only conducted in Hood River and the additional 4 hour drive to reach Yakima Valley was not put into the schedule. The tour included a drive along the Columbia River between Hood River and Portland, Oregon and orchards were pointed out. Chefs left the event with a very clear understanding about availability and role of Washington shippers and growers in the pear fresh market.
  - Video and still photos are provided to show the activities conducted at the tour.
  - A copy of the dossier from the event is attached to the report, showing the event and education materials delivered to attendees.

- Chef follow up to support menu development
  - Follow-up included annual connection via mail and email.
- GOAL: Provide northwest pear growers and shippers with a qualitative understanding of the opportunities and barriers for putting northwest pears on the menus of national, multi-unit restaurants.
  - The dossier provided the key educational content that the team believes chain restaurants need to understand to expand pears on the menu and was shared with the shippers through a dedicated member's only site.
  - Three Fresh News updates were sent during the program period updating shippers and growers and directing them to the team for more information.
  - The tour was summarized and shared with the grower community in the quarterly Outreach newsletter delivered to each of 1600 growers in Washington and Oregon.
  - The content and learnings were used to build the foodservice website.
- GOAL: Increase overall northwest pear sales by increasing foodservice sales to national, multi-unit restaurants. TARGET: Increase pear purchases by the high-volume national restaurant companies participating in outreach by an average of 25% by fall 2016; aim for season-long pear usage or menu items with at least a 3-month promotional duration.
  - The Mintel report showing restaurant menuing incidence was purchased at the beginning of the project and is attached. A key challenge to purchasing a follow-up report was identified and the report was not purchased. The follow-up study was not included in the budget and new managing director refutes the value of the study and procedures. During the period, internet searches were conducted to identify menu incidents and a report is attached.
  - Incidence on the menu is in no way a predictor of pear sales and volume. A key challenge in foodservice produce distribution is tracking sales.
  - A complete review of each restaurant progress is found in Attachment B.

### **BENEFICIARIES**

1600 growers and 50 pear handlers in Washington and Oregon directly benefited from the program. Quantifying pear sales lifts as a result of menuing pears is virtually impossible given the lack of industry shipment data and the private data collection by restaurants.

Longer term, the information learned from working with chefs first hand led to the development of the foodservice website for chefs and the video production showing the harvest tour and learnings for future chefs.

A complete list of activities accomplished by each restaurant is found in Attachment B. No pear sales volume is possible within the foodservice distribution

### **LESSONS LEARNED**

The leading challenge to the project was the timing of the execution during the year restaurant chains were aggressively reformulating their menus to meet mandatory nutrition labeling requirements.

The effectiveness of the harvest/orchard tours is limited by the reach of the invitees. Current management will work closely to set strong expectations for orchard tours events. Though is a common and useful activity for produce industry organizations, it is also expensive and resource heavy.

The development team was surprised to only have six development chefs attend the event. Additionally, grower orchard and farm tours are a common way to attract top development chefs to produce industry – used by other key commodity boards and market orders.

The development team was surprised at how difficult it was to get chefs to answer a few qualitative questions. Later it was determined that the extreme stress and demand of achieving the menu nutrition labeling was affecting chef time availability.

Former project manager over-estimated the strength of Mintel Data in determining success and measurable outcomes.

#### **ADDITIONAL INFORMATION**

Total PBNW contributions are attached in Attachment D, and includes \$20,678 in matching funds from the organization. The contributions covered travel expenses and other event costs to reach chef targets.

The attachment includes printed materials used for the event.

A DROPBOX link can be accessed to review testimonial videos of the chef attendees and photographs of the event. [https://www.dropbox.com/sh/4ahfmys09z41e3c/AACzBIVLItmA-RWL\\_6ZzvYYFa?dl=0](https://www.dropbox.com/sh/4ahfmys09z41e3c/AACzBIVLItmA-RWL_6ZzvYYFa?dl=0)

Contributions and learnings from the event were used to develop the USA Pears Foodservice website and Foodservice training course. [www.foodservices.usapears.org](http://www.foodservices.usapears.org)

#### **CONTACT INFORMATION**

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**See Attachment B– 2014 SCBGP-FB**

## **PROJECT #5**

**Project Title:** Improving Postharvest Needle Retention on Cut Christmas Trees

**Partner Organization:** Washington State University – Gary Chastagner

### **PROJECT SUMMARY**

Washington and Oregon Christmas tree growers supply approximately 40% of the total number of Christmas trees sold in the U.S. About 90% of these trees are shipped outside of the Pacific Northwest (PNW) to markets throughout the U.S. and exported to a number of foreign countries. Industry surveys have shown that needle loss is one of the top reasons consumers cite for dissatisfaction with fresh Christmas trees. Needle loss is a common problem with most species of conifers, including PNW-grown Douglas-fir (Figure 1) that are grown as Christmas trees. Considerable research has been conducted to identify factors that predispose cut trees to shed needles. As expected, early harvest and allowing trees to dry afterward increases needle loss problems. While delaying harvest helps reduce needle loss, this is difficult to do when growers must ship trees to retailers in other states who typically want to open their lots on Thanksgiving weekend.

Recent research on balsam fir Christmas trees in eastern Canada has shown that exposure to concentrations as low as 10 ppm of ethylene will significantly accelerate postharvest abscission of balsam fir needles. Ethylene is a simple, unsaturated hydrocarbon which regulates many diverse metabolic and developmental processes in plants. The most studied process related to ethylene is its role in senescence and abscission of various plant tissues. Typically, ethylene is thought to increase prior to abscission and stimulate the activity of several enzymes, such as cellulase and pectinase. The enzymes have a variety of roles, which include weakening of cell walls, dissolution of middle lamella, and swelling of cells in the abscission zone.

It is unclear what role ethylene plays in the loss of needles from other conifer species, such as Douglas-fir, that are more widely grown in the PNW. It is also unclear how effective treatments, such as 1-methylcyclopropene (1-MCP), that are commonly used to inhibit the effects of ethylene on other crops would be on reducing needle loss and improving tree quality. During this project, a series of clonally-propagated balsam fir, Douglas-fir, Nordmann fir, Turkish fir, and Canaan fir trees that are currently maintained at WSU Puyallup were used to determine the role of ethylene in needle loss on these four additional species of trees. Tests also determined the potential of reducing needle loss and improving tree quality by investigating the effectiveness of 1-MCP in reducing the loss of needle on these species.

Industry statistics consistently illustrate the magnitude of the problems associated with needle loss. In 2011, the National Christmas Tree Association (NCTA) estimated that 30.8 million real Christmas trees were sold in the United States. While the number varies from year-to-year, the actual number of trees sold today is very similar to 40 years ago. Given that since 1970, the number of households has nearly doubled from 64 million to 116 million in 2012, it is obvious that the Christmas tree industry has not been able to maintain the market share it had 40 years ago. While the total use of Christmas trees, real and artificial, has increased, real trees have lost market share to artificial trees.

Consumer surveys have consistently shown the importance needle retention issues have on their use of real trees. For example, in 2007 the NCTA surveyed consumers in an effort to understand factors that affected their purchasing patterns. Messiness/needle loss was cited by 46% of respondents as the reason they did not use a real tree. This was second only to the percentage of respondents that indicated that they did not use a real tree because they had already purchased an artificial tree. Currently, there are no known effective

treatments to reduce needle loss on cut PNW-grown Christmas trees. This project benefits growers in the PNW by providing them with a better understanding the role that ethylene plays in the loss of needles on PNW-grown trees and determination of the potential benefit of using commercially available treatments to block the effect of ethylene on Christmas trees. The development of effective treatments to reduce needle loss enhances the quality and consumer acceptance of cut Christmas trees, which potentially enhances domestic and export markets.

This project built on a previously funded 2010 WSDA SCBGP project to identify sources of Nordmann and Turkish fir with superior needle retention characteristics that are regionally adapted to production conditions in the PNW. Depending on harvest date and display conditions, poor needle retention was a significant problem with some sources of these species. If exposure to ethylene is shown to increase needle loss and if treatments with 1-MCP are shown to block the effects of ethylene, growers will be able to improve the consistency of needle retention of Christmas tree species grown in the PNW.

### **PROJECT APPROACH**

All of the testing was done using branches harvested from clonally-propagated Douglas-fir, Canaan fir, balsam fir, Nordmann fir and Turkish fir that were maintained in a 2-acre holding block at WSU Puyallup during this project (Figure 2). The material in the holding blocks represents a unique collection of tested trees that have been acquired from populations in Oregon, Washington, Ohio, Michigan and Pennsylvania over the past 20 years. Phenotypes of individual clones of each species are genetically predisposed to exhibit either good or bad needle retention in a standard 7 to 14-day-long detached-branch needle loss test.

*Determine the effect acute and chronic exposure to ethylene has on needle retention* - Yearly, experiments were conducted to determine the effect acute (24hr) and chronic (7 day) exposure to ethylene had on needle loss. In each experiment, branches from 5 clones of Douglas-fir, Canaan fir, balsam fir, Nordmann fir and Turkish fir that have been previously evaluated for their needle loss characteristics were collected from clonal holding blocks at WSU Puyallup. Branches were harvested and stored outside in crates in a cool, shaded area. The branches were then sorted into “Ethylene Incubation Chambers” (EIC) which were constructed from 7 gallon sealable buckets equipped with a septum to allow for injecting ethylene, a small fan to circulate air, and an airtight lid (Figure 3). One set of buckets was used to assess acute ethylene exposure and another set was used to assess chronic impacts of ethylene exposure on needle abscission. The branches were exposed to 6 concentrations of exogenous ethylene (0, 1, 10, 100, 500, and 1000 ppm). Each treatment was replicated five times and there was a single branch from each phenotype in each EIC. Ethylene was injected into each EIC with a syringe and monitored to confirm treatment concentrations. Air samples from buckets were collected daily and stored in pre-vacuumed 12 ml vials. In the acute trial, samples were taken from every bucket 30 minutes after injecting the ethylene treatments and again 24 hours later. In the chronic trial, samples were collected from every bucket daily. In this trial the buckets were opened, branches were lifted out and lightly fanned, placed back in the bucket, and tightly sealed. Treatments were re-injected, and air samples were collected 30 minutes later. Upon completion of the exposure period, branches from all the buckets were displayed in a postharvest room maintained at 20°C and the effect of the treatments on needle retention was assessed over a 2 week period of time. Needle loss was rated on a 0 to 7 scale where 0= none, 1 = <1%, 2= 1-5%, 3= 6-15%, 4 =16-33%, 5=34-66%, 6=67-90%, and 7=91-100% of needles shed. All the air sample vials were taken to the USDA, ARS Tree Fruit Research Laboratory in Wenatchee, WA and the concentration of ethylene was determined by gas chromatography.

With the exception of the Nordmann and Turkish fir, results of these trials were similar from year-to-year. As expected, needle loss ratings were higher for branches that came from clones with bad needle retention characteristics vs. clones with good needle retention characteristics. The 2016 tests, which were conducted in November, indicate that acute exposure to exogenous ethylene had virtually no effect on needle loss by

branches from either phenotype of Canaan fir and Douglas-fir (Figure 5). Acute exposure of balsam fir branches from phenotypes with bad needle retention to ethylene actually tended to have reduced needle loss (Figure 5). This suggests that short periods of exposure to ethylene are not likely to increase needle loss from cut Christmas trees.

However, chronic exposure of branches from phenotypes of balsam, Canaan, and Douglas-fir that are predisposed to shed needles, to ethylene increased the severity of needle loss ratings (Figure 6). Although there was a slight increase in needle loss from phenotypes of Douglas-fir that have good needle retention characteristics, chronic exposure did not increase needle loss on branches from phenotypes of balsam and Canaan fir that are genetically predisposed to retain needles. Increased needle loss was most evident at the lower concentrations of ethylene tested. Exposing branches to higher concentration of ethylene did not result in higher levels of needle loss. The sensitivity of Nordmann and Turkish firs to ethylene is still unclear. Responses of branches from individual clones of the phenotypes of these species were highly variable from test to test (data not shown), which may be the results of labeling issues of the trees in the holding blocks.

*Determine the effectiveness of 1-MCP treatments in reducing ethylene-induced needle loss* - During the second and third year of this project, experiments were done to determine whether blocking ethylene receptors using 1-MCP will reduce needle loss when branches are exposed to ethylene. In each experiment, branches from 5 clones of Douglas-fir, Canaan fir, balsam fir, Nordmann fir and Turkish fir that have been previously evaluated for their needle loss characteristics were collected from clonal holding blocks at WSU Puyallup. The branches were harvested at the same time as the above mentioned ethylene trials. The branches were placed in chambers constructed from large 4.75 cu. ft. plastic bins and exposed to the ethylene blocking compound 1-MCP "Blocker" at concentrations of 0,1,10, and 100 ppm for 24 hours prior to exposure of branches to 10 ppm exogenous ethylene (Figure 3). These bins were equipped with a septum to allow for air sampling during the 24 hour exposure period. The following day, the branches were transferred to EICs described in the ethylene trials. These branches were then exposed to concentrations of either 0 or 10 ppm exogenous ethylene for 7 days to determine the impacts of ethylene exposure on needle abscission after pretreatment with 1-MCP. In this trial, treatments were replicated five times and there was a single branch from each phenotype in each EIC chamber. Ethylene was injected into each EIC with a syringe and monitored to confirm treatment concentrations. The buckets were opened daily, branches were lifted out and lightly fanned, placed back in the bucket, and tightly sealed. Treatments were re-injected, and air samples were collected 30 minutes later. Upon completion of the exposure period, branches were displayed in a postharvest room maintained at 20C and the effect of the treatments on needle retention was assessed over a 2 week period of time. Needle loss was rated on a 0 to 7 scale where 0= none, 1 = <1%, 2= 1-5%, 3= 6-15%, 4 =16-33%, 5=34-66%, 6=67-90%, and 7=91-100% of needles shed.

The needle loss data from this trial indicates that pretreatment of branches from balsam fir, Canaan fir, and Douglas-fir with 1-MCP prior to a 7-day chronic exposure to 10 ppm ethylene significantly reduced needle loss during display (Figure 7). The effectiveness of the 1-MCP treatment was not correlated to the concentration of 1-MCP the branches were exposed to (data not shown). Based on a t-test analysis, exposure of the balsam fir, Canaan fir and Douglas-fir branches from clones with poor needle retention characteristics significantly reduced the needle loss from the branches that were exposed to 10 ppm ethylene (Figure 7). Similar variability issues, as those noted above, were observed with the Nordmann and Turkish firs in the 1-MCP tests (data not shown).

*Analyze data, prepare quarterly and annual reports* – All of the data have been analyzed and all quarterly and annual reports were submitted on time.

*Prepare an article on project for industry publications* – An article summarizing the results of this project will be published in the Winter issue of the PNWCTA Christmas Tree Lookout magazine.

*Present project updates to industry at grower meeting* – During the project, updates on this project were presented to growers at the following meetings:

- 200 growers at the 2017 Pacific Northwest Christmas Tree Association (PNWCTA) Short Course
- 20 growers at the 2017 IECTA Spring Meeting
- 200 growers at the 2016 PNWCTA Short Course
- 200 growers at the 2016 PNWCTA Tree Fair
- 200 growers at the 2015 PNWCTA Short Course
- 200 growers at the PNWCTA Summer Meeting/Tour

The results from this project were also presented to attendees at the 2017 IUFRO International Christmas Tree Research and Extension Conference in Iceland. <http://www.skogur.is/rannsoknir-og-verkefni/radstefnur/radstefnur-2017/ctre-2017/home/presentations-.pdf-versions/>

*Prepare final report and manuscripts for publication* – This report completes the first part of this activity. A manuscript detailing the findings from this project is being prepared and will be submitted to the open access forestry journal, “Forests”.

Dr. Mattheis at the USDA, ARS Tree Fruit Research Laboratory in Wenatchee, WA provided guidance on the design of the ethylene exposure trials and alternate sources of key supplies required for the ethylene, detached -branch tests. He also provided access to gas chromatography equipment in his laboratory that was used to monitor the concentration of ethylene in the exposure chambers used in the project studies. Nate Reed from AgroFresh provided the 1-MCP, and he and Dr. Mattheis provided recommendations on the concentrations of 1-MCP used. Mr. Reed also provided small fans to circulate the gas in the MCPICs. In addition, he measured the air samples that were collected from MCPICs to verify the 1-MCP concentrations in each chamber. Washington Christmas tree grower Ken Scholz, who chairs the PNWCTA Advanced Research Program Committee provided advice relating to this project.

This project only benefits the Christmas tree and bough production industries. No non-specialty crops are affected.

### **GOALS AND OUTCOMES ACHIEVED**

*Goal: To expand the understanding of the role of ethylene on the loss of needles in Christmas trees from the current understanding with balsam fir. Target: to four species that are grown in the PNW. Benchmark: no current benchmark exist, Performance Measure: as measured by the publication of a ranking of the effects of ethylene on the postharvest needle retention of PNW-grown species.*

As indicated in the Project Approach section of this report above, three trials were completed to understand the effect exposure to ethylene has on the loss of needles by PNW-grown Christmas trees. Although data were obtained for only two species (Canaan fir and Douglas-fir) in addition to balsam fir, and not the targeted four species, the results indicate that increased needle loss associated with the exposure to ethylene is influenced by the duration of the exposure (acute vs. chronic), genetic propensity of branches to shed needles, and the concentration of ethylene to which the branches are exposed. Information on the effects of ethylene on needle retention on balsam fir, Canaan fir, and Douglas-fir will be published in a paper that is being submitted to the journal “Forests” and an article in the PNWCTA Christmas Tree Lookout magazine.

*Goal: To reduce the risk of postharvest needle loss on cut PNW-grown Christmas trees by testing and developing a protocol to use at least Target: one product, such as treatment with 1-Methylcyclopropene (1-MCP) to inhibit ethylene-induced needle loss. Benchmark: there are currently no known effective ethylene inhibitors, Performance Measure: as measured by the publication of two publications and*

*presentation of project results at a total of four grower meetings. The number of growers that the project results reach will be based on the attendance of growers at the grower meeting. The number of growers who receive copies of industry publications with the project results will be estimated based on the circulation data for the publications.*

As indicated in the Project Approach section of this report above, the pre-treatment of balsam, Canaan, and Douglas firs to 1-MCP "Blocker" was shown to be effective in reducing the loss of needles from phenotypes of these species that are predisposed to shed needles. Presentations were made to an estimated 1,020 growers at six industry meetings and 33 Christmas tree research and extension participants at a scientific conference during the course of this project. An article summarizing the results of this project will be published in the upcoming Winter issue of the PNWCTA Christmas Tree Lookout magazine.

Although, none of the expected measurable outcomes were long term, additional research is needed to develop practical and economical means of treating cut trees with 1-MCP as well as determining if this treatment has any unexpected effects on the postharvest quality of cut trees that are displayed in water.

All of the activities proposed for this project were completed. The goal of expanding knowledge of the role of ethylene on needle loss in Christmas trees from the current balsam fir, to four PNW-grown species was only partially completed.

There was no baseline data available for the two goals established for this project. The achievement on the targets is detailed above and in the Project Approach section of this report.

### **BENEFICIARIES**

This project will benefit the state's approximately 250 Christmas tree growers who produce this specialty crop. Reducing needle loss on cut trees will also benefit retailers and consumers. This crop represents approximately \$42 million in farm income, and WA is the fifth largest producer of cut trees in the U.S. Growers range from small choose-and-cut farms to large wholesale operations. Most of these growers are located in western Washington, but there is also significant production in the Inland Empire region of the state. In addition to benefiting Christmas tree growers in WA, this project has the potential to benefit growers in Idaho, Oregon and other major production regions in the U.S.

While it is difficult to place an economic value on improved needle retention, some industry statistics are available to illustrate the magnitude of the problems associated with needle loss. In 2011, the NCTA estimated that 30.8 million real Christmas trees were sold in the United States. While the number of trees sold varies from year-to-year, the actual number of trees that are sold today is very similar to the number that was sold 40 years ago. When you consider that since 1970, the number of households has nearly doubled from 64 million to 116 million in 2012, it is obvious that the Christmas tree industry has not been able to maintain the market share it had 40 years ago. While the total use of Christmas trees, real and artificial, has increased, real trees have lost market share to artificial trees.

In 2007, the National Christmas Tree Association (NCTA) surveyed consumers in an effort to understand factors that affected their purchasing patterns. Messiness/needle loss was cited by 46% of respondents as the reason they did not use a real tree. This was second only to the percentage of respondents that indicated that they did not use a real tree because they had already purchased an artificial tree. Currently, there are no known effective treatments to reduce needle loss on cut PNW-grown Christmas trees. This information clearly shows both the potential benefit of understanding the role that ethylene plays in the loss of needles and what commercially-available treatments may block the effect of ethylene on Christmas trees. The development of effective treatments to reduce needle loss will enhance the quality and consumer acceptance of cut Christmas trees, which potentially will enhance domestic and export markets.

## **LESSONS LEARNED**

Collaboration with Dr. Mattheis at the USDA, ARS Tree Fruit Research Laboratory in Wenatchee, WA, who provided guidance and access to gas chromatography equipment in his laboratory that was used to monitor the concentration of ethylene in the EICs; and Nate Reed from AgroFresh, who provided the 1-MCP “Blocker” product used in project tests. Both were critical to the success of this project. Also critical was the ability to collect and store air samples from the EICs in pre-vacuumed 12 ml vials until they could be processed in Wenatchee. Unexpected needle loss patterns from some of the clones of Nordmann and Turkish fir caused a problem resulting in too much variation in the data, eliminating the ability to assess the effects of ethylene on these species. This illustrates the importance of having genetically-uniform plant material for testing.

Conclusions for this project include:

- Acute (24hr) exposure to ethylene had virtually no effect on needle loss by branches from either phenotype of Canaan fir and Douglas-fir. This suggests that short periods of exposure to ethylene are not likely to increase needle loss from these species of Christmas trees.
- Chronic (7-day) exposure of branches from phenotypes of balsam, Canaan, and Douglas-fir that are predisposed to shed needles increased the severity of needle loss. However, chronic exposure did not increase needle loss on branches from phenotypes of balsam and Canaan fir that are genetically predisposed to retain needles. This suggests that the identification of phenotypes of these and possibly other species of Christmas trees that are genetically predisposed to retain needle is a potential long term solution to mitigating the effects of ethylene needle loss by cut trees.
- Pretreatment of balsam fir, Canaan fir, and Douglas-fir with 1-MCP was an effective way to reduce needle loss associated with chronic exposure to ethylene. Based on this, additional tests are needed to determine the potential benefit of treating cut trees with 1-MCP.
- A better understanding of the risk that cut trees are being exposed to ethylene during marketing and display is needed to fully assess the role this plant hormone plays in needle loss on cut trees.

The fact that the chronic exposure did not increase needle loss on branches from phenotypes of balsam and Canaan fir that are genetically predisposed to retain needles was unexpected. As indicated above, this suggests that the identification of phenotypes of these and possibly other species of Christmas trees that are genetically predisposed to retain needles is a potential long term solution for mitigating the effects of ethylene needle loss on cut trees.

As indicated in the Project Approach and Goals and Outcomes Achieved sections of this report, the goal of expanding the understanding of the role of ethylene on the loss of needles in Christmas trees from the current understanding with balsam fir to four species that are grown in the PNW was only partially completed. The needle loss from branches from clones of the different needle loss phenotypes of the Nordmann and Turkish fir used was inconsistent, which made it impossible to understand the effects of ethylene on these species. This problem appears to be related to labeling issues of the source trees in the field. A potential approach to avoiding this type of problem would be to conduct a needle loss pretest with branches from trees prior to running the actual tests.

## **ADDITIONAL INFORMATION**

*Cash match:*

During the course of this project, the Pacific Northwest Christmas Tree Associations provided a total of \$30,480 in support of the WSU Puyallup Christmas tree research program. Of this, \$5,000 plus \$10,000 from the WSDA Christmas Tree License program was used to support this project. These funds were used to help cover some of the initial startup cost for supplies, staff time, travel, and cold storage upgrades.

*In-kind match:*

Washington Christmas tree grower Ken Scholz, who chairs the PNWCTA Advanced Research Program Committee, provided advice relating to this project. The value of the unrecovered WSU Indirect – 51% MTDC on Campus Research, which was capped at 20%, was \$12,533.

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## **PROJECT #6**

**Project Title:** Strategically Deploying Data to Enhance Local and Direct Markets for Washington Specialty Crops

**Partner Organization:** Washington State University Small Farms Program

### **PROJECT SUMMARY**

The initial purpose of this project was to create peer reviewed data-driven communication and marketing tools to increase sales of specialty crops at Washington State farmers markets. Market advocates know that attracting and educating core shoppers is one of the most critical challenges that farmers markets and specialty crop farmers face. Farmers markets have extremely limited budgets for everyday operations, let alone sufficient funds to work with communication professionals to educate consumers on specialty crops and promote their specialty crop farmers' products. As a result, much of the consumer education and promotional materials are very general and claims tend to be speculative rather than evidence-based. The challenge is how to get the right data and effectively communicate it in ways that excite and capture the attention of core shoppers and market organizers, as well as inform agricultural educators, state agencies, policy makers, and other service providers about the benefits of buying specialty crops directly from farmers.

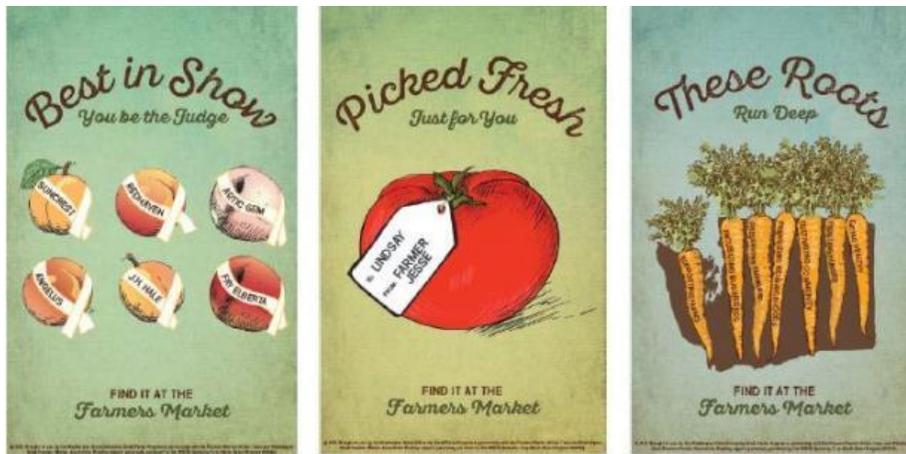
This project was motivated by a combination of factors, including the relatively recent original farmers market research projects at WSU and new data that was available about farmers markets and specialty crop farmers. In addition, the partnership with the Washington State Farmers Market Association (WFMA) was critical in confirming market managers' needs for more marketing tools as well as partnering in project outreach, distribution, and evaluation. The relationships formed through a Farmers Market Action Team (FMAT) led by the WSU Small Farms Program provided a timely and strategic team to work on this project.

In addition, the larger context is that shoppers who seek out "local" specialty crops ostensibly have more retail options than ever. Produce from familiar farms is available at many major grocery store chains and a growing variety of delivery services (e.g., Amazon Fresh, Blue Apron, Full Circle) in addition to food co-ops, independent grocers, CSAs, and buying clubs. Research is documenting how today's proliferation of options may be "reducing the ways in which consumers perceive farmers markets as different from other food-purchasing venues" (Gao, Swisher and Zhao 2012). As a result, farmers markets and their vendors face unprecedented competition for the "local foods" or "farmers market shopper."

This project was not previously funded.

### **PROJECT APPROACH**

Colleen Donovan organized an initial conference call with the Farmers Market Action Team (FMAT) to work on this project. A subcommittee comprised of seven farmers market managers and three partners, coordinated by Donovan, emerged and met frequently to agree on a concept; hire a consultant (Milepost Consulting); review the academic, original, and market research data compiled by Donovan; guide the creative process with the consultants; review drafts, finalize the products; print post cards with the graphics; and distribute promotional graphics to farmers markets and specialty crop farmers. Donovan and Karen Kinney of the WSFMA also conducted two evaluations of the graphics in conjunction with WSFMA promotions.



As detailed in previous reports, the three graphics were created based on themes that research indicates are important to core farmers market shoppers and showcase specialty crops: “flavor variety,” “picked fresh,” and “deep-rooted” benefits. The graphics were translated into Spanish and both sets of graphics were available with and without a background color. PDF and JPEG files of the graphics were emailed to market managers and farmers at their request via DropBox link (their stated preferred mode of distribution). In addition, Donovan created “Find it at the Farmers Market,” a 22-page PDF that shared project goals, core shopper research, graphics themes and thinking, as well as outreach ideas, and a request to track results.

To raise awareness about the graphics, postcard-sized cards were printed with the images and sent to every market in the state with a request to share them with specialty crop farmers, shoppers, and other market supporters. Evaluations confirmed that the most frequent use of the specialty crop cards was as thank you cards; markets also used them to recruit local farmers, showcase farmers markets, and one market used the theme “picked fresh for you” at its harvest celebration (where Donovan was the keynote speaker and talked about this project).



In addition, the graphics (in English and Spanish) were used in a variety of promotional materials and displayed/distributed at the 2016 WSFMA conference which had over 250 participants, representing farmers markets and specialty crop farms. The display included large banners, mugs, magnets, rack cards, greeting and thank you cards, note pads, and yard signs. With each item was its price and vendor where purchased so that market managers and farmers could see how affordable these marketing materials were to print once the art was provided.



*Rep Bruce Chandler being recognized for his support of the WSFMA and WA farmers*

Throughout the project, Colleen Donovan used the shopper and market data collected as well as the graphics in various presentations: “Find it at the Farmers Market” (July 2015, King Co. FM Managers Meeting);

“Know Your Shopper, Know Your Food” (Feb. 2016, WSFMA conference, over 100 people; evaluation available; and Feb. 2016, San Juan Island Ag Summit); and 2016 Tilth conference in Wenatchee (with Laura Raymond, WSDA).

In the fall of 2016, Donovan conducted a second project evaluation in partnership with the WSFMA and its member markets. Twice as many markets responded this year compared to last year. Almost three-fourths reported receiving the graphics and of these respondents, 87% said they used them. Most reported using the graphics online (via social media and websites); and displaying; distributing the postcards with the graphics at their information booth; and promoting with specialty crop farmers. Examples of comments included:

- "I used the carrot one as a newsletter photo but didn't realize until much later that these were customizable graphics! May still get some use from them yet.
- We have downloaded them to use as needed. Love Them! Social media, website, etc.
- We used the cards for display at farmers markets and events, gave them away in gift baskets, and used them as postcards.
- We would use the images in newsletters or to promote community days at the market. They are well received since they are so unique and well designed.
- As market manager, I used the postcards as thank you notes or for other means of written communication. I loved them!
- Gave them out as "Prizes" for kids or adults participating in an activity during a special event, as we did not have that many.
- Did test run for these graphics at market level, eight out of ten vendors gave their feedback: drawings are good - however, graphics do not render a modern look particularly to younger (25-45) audiences, they fit more to an older age group (50-70). Consumers: younger audience preferred a modern look. We did not post them online. As a new market enjoying a good response to own social network postings, the followers and Facebook "Likes" might have decreased based on those responses by presenting them with hard copies to judge their input.

This project benefited immensely from the contributions and key roles of the partners.

- Kelly Lindsay, Zack Cook, James Cornell, Leigh Newman-Bell of Pike Place Market Farm Program. Project leadership, hosting meetings, consultation, Spanish translation support, and graphics. Kelly Lindsay was the single most important project partner and generously shared her marketing expertise, especially in working with the communications consultants.
- Karen Kinney, Washington State Farmers Market Association. Project support, outreach to specialty farmers and markets, promotions at the WSFMA conference and with membership, expertise regarding shoppers.
- Lindsay Nessel and Melissa Borsting, SnoValley Tilth and the Carnation Farmers Market; Chris Curtis and Claire Leamy of the Neighborhood Farmers Markets; and Judy Kirkhuff, Seattle Farmers Markets all participated in the project committee and generously consulted on many aspects of the data and graphics development. They also modeled how to use the graphics at markets and how to use them with their specialty crop farmers.
- Candace Jagel, WSU and San Juan Island Farmers Market; Michele Catalano, Tilth Producers of Washington; and Mary Embleton, Cascade Harvest Coalition participated in the Farmers Market Action Team and provided outreach to specialty crop farmers.
- Steve Evans, King County Agriculture Program, offered a quarterly venue and listserv to keep markers up to date and get their feedback.

- Roberto Matus and Sarahi Bravo, Transformation Sunnyside. Translated the graphics into Spanish and promoted them among Latino specialty crop farmers in Yakima.

All graphics and promotions featured specialty crops and specialty crop farmers at the markets.

## **GOALS AND OUTCOMES ACHIEVED**

*1. Goal: To increase the sales of direct marketing, specialty crop farmers in Washington through five new, professional and creative "infographics" that are distributed to 160 farmers markets and used in local marketing campaigns throughout the 2015 market season.*

Three graphics featuring specialty crops and targeting core farmers market shoppers were distributed to 160 farmers markets via emails, mailings, and in-person presentations. In the most recent evaluation, 74% of respondents reported receiving the graphics and 87% reported using them.

When asked if the market respondent noticed an increase in shoppers after receiving the farmers market promotions, 16% said "yes"; 39% said "no"; and 45% said they were "not sure or N/A."

When asked if the market respondent noticed an increase in the sales of farms with specialty crops after receiving the farmers market promotions, 16% said "yes"; 45% said "no"; and 39% said they were "not sure or N/A." Some noted that it was difficult to sort out the effects of the various promotions and other event that were happening simultaneously.

An online google forms survey was sent to all the markets belonging to the Washington State Farmers Market Association on October 27, 2016 with a reminder notice on Nov. 10, 2016. It looks like 114 markets were successfully contacted. Responses from 31 markets, resulting in a response rate of 27% (31/114).

*2. Goal: To make educational materials on marketing specialty crops available to farmers markets.*

A new section was added to the online "WA Farmers Market Management Toolkit" to provide easy access to the specialty crop promotions and templates developed in this project. Based on the results of our pilot program, these materials summarize best practices on how to use the marketing tools we researched to promote specialty crops. Suggestions for how to evaluate the effectiveness of such promotions on the sales of specialty crops through direct markets were also incorporated into these materials and promoted. This section of the Toolkit can be found at:

<http://www.wafarmersmarkettoolkit.org/chapter-8/farmers-market-graphics/>

The special section on using the new graphics for promotions can be downloaded at: [FindIt@theFM Promotional Kit 2015 \(PDF\)](#)

In addition, these materials were emailed to market managers, the Washington State Farmers Market Action Team, Extension personnel belonging to the WSU Small Farms Team, and agency and non-profit partners who work with specialty crop farmers. All materials were shared at the 2016 Washington State Farmers Market conference on February 4 through a tabletop exhibit and a workshop presentation "Know your Shopper: Farmers Market Shopper Trend and Marketing Strategies." The workshop evaluations (attached) were filled out by 77 attendees. 95% or 73/77 said that the information presented was good or excellent. Around 94% said that they increased their knowledge on the topic. The project was also presented at the Tilth Producers 2016 annual conference on Sunday, Nov. 13, 2016 in workshop titled

“Direct Marketing Strategies: Finding a Successful Market”. The project results presented at the conference workshops are summarized in this section of the toolkit:

<http://www.wafarmersmarkettoolkit.org/chapter-8/know-your-farmers-market-shopper/>

The Washington Farmers Market Management Toolkit can be found at:

<http://www.wafarmersmarkettoolkit.org>

If any Expected Measurable Outcomes were long term, summarize the progress that has been made towards their achievement.

Expected Measurable Outcomes did not have a long term expectation.

Activities Planned	Actual Accomplishments
<b>1. Create promotional materials: five visually appealing, research-based “infographics” on posters that promote buying WA specialty crops directly from producers.</b>	<b>Created three graphics in two formats and two languages promoting specialty crops sold at farmers markets.</b>
1A. Convene Farmers Market Action Team to provide input on overall strategy, what messages about specialty crops to feature and what data about specialty crops to highlight.	FMAT was convened and a sub-working group participated actively throughout the project.
1B. Contract with communication firm (e.g., Milepost Consulting).	Contracted with Milepost Consulting.
1C. Develop creative plan and provide direct marketed, specialty crop data.	Creative plan was developed with Milepost and based on data provided by Donovan.
1D. Finalize five “infographics” and have available as PDFs.	Finalized and made available as PDFs and JPEGs, in two formats.
1E. Roll out “infographics” at the WSFMA conference, “how to” tips on promotions, and measurement metrics to track.	Rolled out as planned.
1F. Translate infographics into Spanish.	Translated as planned.
1G. Post “infographics” online in new section of the “WA Farmers Market Management Toolkit” with link to WSU Small Farms Program and WSFMA websites.	Posted online: <a href="http://www.wafarmersmarkettoolkit.org/chapter-8/farmers-market-graphics/">http://www.wafarmersmarkettoolkit.org/chapter-8/farmers-market-graphics/</a> .
<b>2. Using the five new infographics, develop five prototypes of marketing materials (e.g., weather-proof banners, fixed posters, sandwich boards, postcards, rack cards, etc.) for markets and farmers to field test in combination with social media tactics (Facebook, Twitter, Instagram).</b>	<b>Changed approach. Opted to create model materials and display them with cost and sourcing information at the 2016 WSFMA conference.</b>
2A. Convene Farmers Market Action Team to provide input on what types of marketing materials work best (including print materials, banners and other weather-proof signage) for promoting specialty crops.	Project partners provided input individually (not in a formal meeting).
2B. Research vendors for materials and produce prototypes.	Created summary sheet with list of online vendors and key features; distributed with other outreach.

2C. Select 3 markets and 3 farmers to field test new marketing materials. Develop testing protocols and evaluation tools.	Changed approach to online evaluation (see 4B).
2D. Field test new marketing materials at farmers markets and by specialty crop farmers.	Changed approach to online evaluation (see 4B).
2E. Compile results of field tests and share with WSFMA member markets, farmer members of Tilth Producers, the WSU small farms team, and post on WSU website and in “WA Farmers Market Management Toolkit.”	N/A
<b>3. Develop four infographic-based fact sheets to complement promotional “posters” (#1 above).</b>	<b>Initial outlines developed and data identified.</b>
3A. With the help of FMAT team, WSU SF will select the most significant findings about direct marketed specialty crops from the research profile to feature in four one-page highlights using professionally-designed infographics and layout.	Selected four themes for fact sheets: specialty crop shoppers; direct marketing specialty crop farmers; farmers markets and specialty crops; and farmers market impacts.
3B. Draft fact sheets convene FMAT to review drafts and provide input.	In process for submission and distribution through WSU Extension Publications system.
3C. Finalize, post to WSU Small Farms Program website, share with farmers, partners, markets, Ag professionals.	In process. Final versions will be posted through WSU Extension publications website and Small Farms Program Website.
<b>4. Evaluate and report on project.</b>	<b>Two evaluations completed.</b>
4A. In partnership with the WSFMA and DOH, design and survey 580 specialty crop farmers who are authorized by the Farmers Market Nutrition Program.	Changed approach.
4B. Design and administer online survey of farmers markets to evaluate impact of the infographics at their markets and also the impact of the WSFMA Farmers Market Week promotions. Share results in the final quarterly report.	Conducted in November 2015 and 2016.

The target for the first goal was that 30% or 55 farmers markets will actively use the infographics at markets and, of these markets, at least 50% will report increased sales of specialty crops by their farm vendors. In addition, WSU expected that at least 115 or 20% of farmers on the FMNP list of authorized specialty crop market vendors will report an "increase" or "significant increase" of sales in 2015.

With 87% of markets that received the graphics reported using them, the target of 30% was exceeded. However, among these markets, only 16% reported an increase of sales of specialty crops by their farm vendors.

The target for the second goal (to make educational materials on marketing specialty crops available to farmers markets) was achieved by not just posting a new section of the Toolkit online, but also through email outreach and in-person presentations. The Google analytics were not set up in time to collect user data to date, but are now operational and can easily be compiled for 2017.

## **BENEFICIARIES**

WSFMA and non-WSFMA member farmers markets and the specialty crop farmers that sell at their markets. WSFMA staff and other ag professionals.

There are currently 114 member markets of the WSFMA that have been part of this project. In addition, Donovan has identified an additional 55 farmers markets and included them in all outreach. Each of these markets has anywhere from 5 to 55 specialty crop farm vendors that they work with at the markets. A forthcoming fact sheet on specialty crop farmers will provide additional data on these beneficiaries and the economic impacts.

## **LESSONS LEARNED**

There were many lessons learned through this project both in terms of the final products, how they were used, and, perhaps more importantly, the larger lessons about working with outside agencies and what farmers markets and specialty crop farmers need to be successful marketers.

The project affirmed that farmers markets need, appreciate, and will find creative ways to use marketing materials to promote their markets and farmers. Of the three designs, the “Roots” graphic with the carrots and map of Washington State was the most popular.

Distributing both electronic versions and print examples of the graphics greatly helped raise awareness of their availability and “promote the promotions.” A handful of markets didn’t realize the graphics were free or that they could customize them to their market. In hindsight, this message should have been made more explicitly as that was the intention. Other markets wanted to use the graphics on materials that could be sold, such as t-shirts, and whether or not this was allowable was unclear due to the copyright of the original artwork and being grant funded. One of the most common uses of the postcards was as thank you cards. It makes sense that there is a demand for farm-related thank you cards by farmers markets that rely on donations, volunteers, and community cooperation.

As previously reported, another important lesson was in timing. For markets and farms to use new graphics in their promotions, they should receive them during the off-season when they have time to think about marketing materials. And, it is also true that reminders throughout the season are helpful to make sure they remember that they are available to use.

The project relied on market organizers and key partners that work with farmers to distribute the graphics. This strategy needs to be augmented with some sort of direct contact with farmers so that the project has confidence that all information is being conveyed and received by farmers.

Early in the process, the project adjusted the products from “infographics” that presented farmers market/specialty crop data in visually appealing ways to more of a graphic informed by the data. This was a good decision as there is a real question about the degree to which core farmers market farmers are motivated and change their buying behavior based on data. The shopper data available identifies values they care about, such as social impacts and caring for the environment. And while data has a role in affirming such values and potential impacts; it is very possible that even core shopper behavior is led more by emotion than intellectual decision making. Unfortunately, that level of consumer research is not currently funded. For now, the key take-away is to not assume that farmers market customers are going to be motivated by data alone. Furthermore, the ways in which data are being broadcast in today’s media environment do not lend themselves to even the most visually appealing reasoning and footnotes. While peer-reviewed data and evidence based messaging is more important than ever, how it is communicated needs to adapt to the diverse and fragmented ways people consume information today. This is not to say

new media should replace the reliable sandwich boards and banners; but that marketing efforts will be more successful with a “both/and” approach.

The opportunity to collect and aggregate shopper data about farmers market shoppers has been extremely helpful, especially in terms of building the capacity of farmers market leaders to think about their shopper segments. The information directly informed the graphics and has become part of the internal discussions/capacity building about how best to reach customers.

In hindsight, one of the key lessons about developing the graphics themselves is that it would have been better to start the conversation with the actual execution and what types of materials they were to be used on instead of how best to communicate data. In other words, the initial focus was too narrow and had the entire lifecycle of the project been scoped with a full 360 perspective, actually putting them into use would have been easier.

Perhaps one of the more far-reaching lessons from this project has to do with working with outside agencies such as Milepost Consulting, a professional communication firm. As is often the case with small organizations used to shoestring budgets, there is an expectation that the “expert” will be able to step in and have “the answer.” In this project, Milepost provided much needed expertise and help. However, the project should have been scoped in a more realistic way; Milepost’s contribution and ability to understand the farmers market farmers and shoppers, as well as what the project needed was significantly overestimated. Educating their team to this niche area and unique context took considerable time. In hindsight, more back and forth at the beginning of the project may have reduced the amount of time it ultimately took to get to the final products. The other side of this lesson is that the team underestimated its own expertise in this area. The project team had to step up and push the consultants on the final content and designs, exposing its own skills and raising its confidence in the process. Given that there are so many markets and farmers struggling with the same challenges, it may be helpful to create a tip sheet on how best to work with outside communications consultants and manage creative projects so that they can be more successful.

The final key lesson (re)learned is the critical need to build farmers markets’ (and all direct markets’) and specialty crop farmers’ marketing savvy. Far too often, marketing follows a product, business, or desire to open a market without first knowing who the customers are, what they need, and how to talk to them. This is a real challenge given how time-strapped these entrepreneurs are and the amount of time, treasure, and talent invested in simply getting to market. As such, there is still a compelling opportunity to create tools and products that can be easily deployed. In addition, there is a clear and compelling need to focus even more energy on building farmers’ and markets’ understanding of marketing fundamentals. It will be interesting to monitor the ways the publicly available graphics will be utilized for market promotion into the future. Number of downloads will be tracked.

As mentioned above, it is important to better understand what changes consumer behavior; plan to educate outside consultants and budget time accordingly; and to invest in building the foundational marketing skills and capacities of both markets and farmers.

#### **ADDITIONAL INFORMATION**

Pike Place Market was extremely generous in providing meeting space, staff time and expertise, and a platform to share the graphics. Their exact donation was not tracked, unfortunately.

Milestone Consulting reported a “discount” of \$14,706 on their final invoice. They apparently spent more time on this project than anticipated.

Reference Cited: Gao, Z., Swisher, M., & Zhao, X. (2012). A new look at farmers’ markets: consumer knowledge and loyalty. *HortScience*, 47(8), 1102-1107.

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## **PROJECT #7**

**Project Title:** Leveraging Farmers Markets to Increase Specialty Crop Farm Sales

**Partner Organization:** WA State Farmers Market Association

### **PROJECT SUMMARY**

The purpose of this project was to enhance the Washington State market for and local distribution of a wide variety of fruits, vegetables, herbs, nursery, and nut crops that are grown and direct marketed by Washington State farmers, including women farmers, immigrant farmers, limited resource farmers, and beginning farmers. Farmers markets have long been recognized for playing a variety of important roles: building meaningful connections between the public and local farmers; creating a direct sales outlet for local products; and contributing to community vigor and vitality. Despite this success, market organizers and many of their farmers continue to have difficulty developing the capacity and skills to adapt to an increasingly competitive market place as more retailers try to entice the "farmers market shopper" to their stores. Farmers markets on their own lack the capacity to develop sophisticated, wide-reaching marketing campaigns. Many smaller markets operate on shoestring budgets, struggling to grow their vendor sales and shopper base. Larger, more established markets, struggle to secure their market locations, juggle permitting and licenses, expand the shopper base, as well as stabilizing ongoing funding.

Direct marketing specialty crop farmers in WA have ample opportunities to learn about production. Far fewer opportunities exist to receive training in marketing skills and the specifics of how to be competitive at farmers markets and leverage their farmers market presence into other sales opportunities. This lack of training is especially acute for beginning farmers, those that are new to direct marketing and farms located outside of the Puget Sound region where there is less farm education available for direct marketing specialty crop operations.

As more shoppers demand more local specialty crops and more grocers are responding with "farmers market" like merchandising, both farmers and markets have recognized the need for more training to adapt to this new marketplace. An increasing number of farmers rely on farmers markets as their primary marketing channel, which means the WSFMA has a critical role to play in leveraging farmers markets to increase specialty crop farm sales.

Over the last four years, the WSFMA has worked to build educational opportunities for markets and farmers alike. With WSDA SCBGP support, it has a) reinvigorated the farmer workshop track at its annual conference to focus on the needs of specialty crop farmers who want to direct market their crops, and b) created a new farm member category to better serve the needs of specialty crop farmers. Both activities have led to significant increases in farmer participation at the conference and a renewed connection with WSFMA. This project is different from the previous project in that it planned to specifically target farmers who participate in the WIC/Senior Farmers Market Nutrition Program (FMNP) who are all, by definition, specialty crop farmers, as well as farmers new to selling at farmers markets. Because the FMNP farmers are a defined group, the expectation was that it would make outreach and evaluation easier to implement than in previous years. Because of the new targeted group of farmers and the new conference locations (in year two Olympia, in year three: Blaine), it was expected many of the farmers attending would be new to the conference.

**PROJECT APPROACH**

1. **Build Marketing Capacity of Direct Market Specialty Crop Farmers.** The WSFMA continued to contract with an events management contractor (Proper Planning) to take care of base logistics so that staff and board could focus on programming and meeting mission goals. The primary training was at the annual WSFMA statewide conference which included a marketing training track that included 21 workshops targeting specialty crop farmers at the three annual WSFMA conferences. WSFMA also led two workshops and tabled at the Tilth Conferences to reach over 100 additional specialty crop farmers. Specialty crop producer participation in conferences increased from 36 in 2014 to 50 in 2016, a 40% increase. Survey feedback from participants in all three WSFMA conferences was overwhelming positive.

2015 Farmer Track	<ul style="list-style-type: none"> <li>• <b>Display and Hands On Training:</b> Led by two specialty crop farmers known for beautiful displays and strong sales.</li> <li>• <b>Farmers Market Nutrition Program (FMNP) training:</b> Led by staff from the Dept of Health.</li> <li>• <b>Navigating the Farmscape:</b> Federal, State and Local Regulations. Led by a former WSDA staff.</li> <li>• <b>Pricing Pressure:</b> Staying Profitable with shrinking margins. Led by staff from WSDA and the Attorney General’s office.</li> <li>• <b>Choosing Farmers Markets that Work for Farmers:</b> This was a panel of four successful diverse specialty crop farmers from both sides of the mountains moderated by a farmers market manager.</li> <li>• <b>Newsletters and Blogs-How to Optimize Social Media Presence:</b> Led by the social media manager from a large market organization.</li> <li>• <b>Increasing Sales through Customer Engagement:</b> Led by the Keynote Speaker.</li> </ul>
2016 Farmer Track	<ul style="list-style-type: none"> <li>• <b>Food Safety Communications:</b> Proactive Communications Before, During and After a Food Borne Illness Outbreak at Your Market. Led by staff from WSDA and a former GreenMarkets staff who worked on communications at NYC farmers markets before and during a food borne illness outbreak at a market.</li> <li>• <b>From Fresh Bucks to the Power of Produce:</b> Are Incentive Programs Right for your Market? Led by the director of the Tacoma Farmers Market and a panel of market managers from across the state.</li> <li>• <b>What’s new in Produce Safety:</b> Led by staff from WSDA.</li> <li>• <b>Specialty Crop Producer Tours:</b> Three tours to one specialty crop farm and a successful processor that ferments specialty crops.</li> <li>• <b>Grow Your Online Presence, Fans &amp; Sales through E-Newsletters &amp; blogs:</b> Led by the marketing manager at Pike Place Market</li> <li>• <b>Engaging your Customers to Increase Sales and Build More Demand:</b> Led by a veteran marketing consultant and specialty crop farmer.</li> <li>• <b>Keeping Your Market Competitive in a Changing Marketplace*.</b> * Led by a panel of seasoned farmers, chefs, market managers.</li> </ul>
2017 Farmer Track	<ul style="list-style-type: none"> <li>• <b>Destination Agriculture: Bringing Shoppers onto the Farm.</b> Led by farmers who are successfully incorporating on-farm tourism as part of their revenue generating strategy, talked about how to invite the public onto the farm, how to use farmers markets to build relationships and increase sales and customer connection to the land itself.</li> </ul>

	<ul style="list-style-type: none"> <li>• <b>State of Tree Fruit in Washington:</b> Led by a representative from the WA Tree Fruit Association who gave an overview of the state tree fruit industry including industry trends that farmers can tap into to better promote tree fruit.</li> <li>• <b>Giving Chefs What They Want:</b>* Four chefs/restaurants talked about how farms can attract them to their booths at markets and to their farms and how to promote their produce.</li> <li>• <b>Come Early, Stay Late: Season Extension Strategies for Market Produce Growers.</b> Two successful specialty crop growers discussed how they use greenhouses and succession planting to maintain the best variety of produce for market year round.</li> <li>• <b>Simple and Effective Ways to use Social Media for Your Market or Farm.</b> New presenter (to farmers markets) from a local social media firm, presented a new way of incorporating social media into farm and market practices and offered a checklist of simple ways to implement social strategies.</li> <li>• <b>What's New in Produce Safety.</b> Presented by WSDA staff with current information about the new rules and how direct marketing specialty crop farmers are impacted</li> </ul>
	<p><i>*special workshops for marketing training for specialty crop farmers and market managers on how to facilitate farm sales to businesses that operate near the farmers' market neighborhood (e.g., chefs, restaurants, caterers, independent grocery stores, day care, food pantries, and dining</i></p>

**II. Provide Direct Specialty Crop Farmer Support Services.** Responded to 334 specialty crop farmers' and 1151 market managers' individual requests for information about how to access farmers markets in WA, FMNP, EBT, new technologies, and training opportunities specific farmers market needs and opportunities. Represented farmers markets and farmers in state and stakeholder meetings for SNAP EBT development and improving FMNP communications and reporting between the state and markets. Posted the most requested farmer support information and resources to the WSFMA website to facilitate distribution and access. Expanding low income access to markets and consumption of WA grown fruits and vegetables has been an increasing share of workload over the 3 years of the grant cycle. Beyond reducing hunger and improving nutrition, it is vital for the future of the specialty crop industry that WA fruits and vegetables are accessible to all WA residents regardless of income and are not marginalized as lifestyle choices or luxury purchases.

**III. Coordinate Statewide Specialty Crop Promotions at Farmers Markets.** In collaboration with farmers, market organizers and marketing specialists, WSFMA developed a promotional campaign for specialty crops that leverages promotions for the annual Farmers Market Week. Building on the 2015 success when WSFMA designed three recipe cards, a graphic designer and marketing consultant was hired to produce a set of 3 specialty crop recipe cards in 2016 for distribution during National Farmers Market Week. Over 25,000 postcards were distributed to 115 markets and more than 68 farms. Press releases were sent out statewide to promote markets and specialty crop consumption. WSFMA greatly increased its social media activities during this grant cycle with Facebook followers doubling from 1,500 to over 3,300 during the grant cycle. An Instagram account was created in 2016 and its following has grown rapidly. WSFMA staff visited over 100 markets across the state during the grant cycle and promoted each of the markets' specialty crop producers through its social media accounts. WSFMA also held trainings for board members on social media promotions for specialty crops at each of its three annual retreats. In 2017 WSFMA took a new tack in Specialty Crop promotions by bringing in a new designer to produce a series of four postcards that provided information on the purchase and use of lesser known early season spring vegetables. These info cards were well received and will be reprinted and distributed again in 2018. Educating shoppers about lesser known shoulder season specialty crops to promote year-round eating became a new focus for WSFMA as a result of the surveys during this project, and will take priority in future years over some of the Farmers Market Week activities, which have largely promoted crops consumers were already familiar with. WSFMA's new focus will be to help educate consumers on new eating opportunities that will lead to more sales for specialty crop farmers during time periods that growers have traditionally found challenging.

2017 postcards:

# HAKUREI

## TURNIPS

ARE DELICIOUS TO EAT

← FIND OUT HOW →

### SURPRISE AND INSPIRE WITH HAKUREI TURNIPS

Crunchy, sweet, creamy, and mild enough to be eaten raw, Hakurei Turnips are not your great grandparents' turnips. Unless your grandparents are Japanese, then yes, they are your great grandparents' turnips. But if you think a turnip is something big and ugly and hairy and best fed to a horse, they are not like that. Those turnips are harvested in the fall.

**DID YOU KNOW?** Hakureis (also known as Salad, or Tokyo Turnips) were developed in Japan by people who like to eat raw vegetables. They are best grown in cool weather, and can be found in Washington farmers markets in the spring and fall. Summer too, but not as commonly as they require a lot of water and aren't as sweet with heat.

**HOW TO EAT:** Like an apple! Pull the greens off and just eat the whole thing, whether it's baseball or egg-sized (the ideal range). Or slice the root and put it in a salad, chop it up and add it to a veggie plate or a stir-fry (just for the last minute or so) to get that all important crunch. Bake or roast them, even the greens are fantastic! Sauté them quick instead of spinach.

BROUGHT TO YOU BY YOUR FRIENDS AT THE WSDA Specialty Crop Block Grant Program

WSFMA WASHINGTON STATE FARMERS MARKET ASSOCIATION

# FOLLOW THE LEEKS

← FIND OUT HOW →

## LEEKES

EMBODY THE DELICATE SIDE OF THE ALLIUM TRIBE, ADDING MORE OF A WHISPER AND LESS OF A SHOUT. -Deborah Madison, *Vegetable Literacy*, 2013.

**HOW TO EAT:** Subtlety is the superpower and the Achilles' heel of the leek, a low key friend to cooks and gardeners. It's easy to grow and overwinters well, hence its prominence in spring farmers markets. Leek whites don't caramelize like an onion and their greens, though edible, aren't meant to be sliced raw like scallions. Leeks are an ideal aromatic, best in soups and braises. Or, for the extravagant, poached in oil. Another way to show them off is to trim the darkest green of the tops away so only the slender white and light green tubular section is left. Slice six of them lengthwise, toss in oil and salt and roast at 400°, covered at first and then uncovered to finish. Add some thyme sprigs towards the end to really bring out the flavor.

**DID YOU KNOW?** Though less common in modern cuisine, leeks are ancient and have a prominent place in a number of world histories. Ancient Egyptians favored them as did the infamous Emperor Nero of Rome. Welsh Soldiers once wore leeks on their helmets to distinguish themselves from the Saxons. Wild leeks, called ramps, were favorites of Eastern Native American tribes and early American pioneers.

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### TASTE SPRING AT YOUR LOCAL FARMERS MARKET

WAFARMERSMARKETS.ORG

## WHAT'S RAAB GOT TO DO WITH IT?

← FIND OUT NOW →

### SAY IT LIKE ROB OR BOB: RAAB

**YOU DON'T KNOW:** What raab is. It's okay, most people don't. And it's not one thing. There's broccoli raab, which is not the same as kale raab, which is almost the same as collard raab, or mustard raab, but not the same as mustard greens. Raab is the tender flowering top of a brassica (broccoli/cabbage). At the farmers market, raabs are the last harvestable crops of overwintered greens like kale and collards. Too strong tasting in the summer or fall, in wet cool spring raabs are tender and a perfect green for any sauté or stir fry.

**DID YOU KNOW?** Broccoli Raab is not a variant of broccoli but instead a form of turnip. Raab is a small town in Germany which may be where the term comes from. Raap is Dutch for turnip, Rapini is the Italian term for Broccoli Raab.

**YOU SHOULD KNOW:** A head of broccoli is composed of thousands of tiny tightly packed flower buds. Raabs feature larger looser softer buds, some of which have opened into little yellow flowers by the time they arrive at market, usually in the form of a handful of tops bundled together. Undo the twist tie, cut off the stem bottoms (if woody), and use as you would any kale. Chopped finely and quickly sautéed in olive oil with garlic and a little chili pepper is ideal.

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TASTE SPRING AT YOUR LOCAL FARMERS MARKET

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# EXPLORE *the* WIDE WORLD of RADISHES

← FIND OUT HOW →

**YOU DON'T KNOW RADISHES**

**NOT WHAT YOU THINK:** Spring radishes from the farmers market are nothing like supermarket veggie tray radishes. It's the summer temperatures and dry conditions that make radishes spicy, too long in storage makes them bitter and limp. Spring radishes are crisp and sweet with only a hint of heat.

**DID YOU KNOW?** Radishes are not all round. Nor red, nor pretty. They can be pale white and big as a man's arm (daikons) or wrinkly-skinned and not so different looking from a beet (black radishes). They can be leathery green on the outside and magically red pink underneath (watermelon radishes). They can even be two-toned, slender and finger-shaped (French breakfast). Or multicolored Easter egg radishes: vivid pink, red, purple and white. Also, every part of the radish is edible: the greens, the bulbs, the seeds!

**KNOW THIS:** Love Radishes? Pull the greens and brush or wash any residual dirt from the root and then pop them in your mouth, or onto a plate. A little leery? Slice thin (especially with a mandolin) and salt them. Feeling adventurous? Cut them in quarters and fry in clarified butter, garnished with fresh coarse ground pepper and salt. Feeling French? Eat them sliced on a baguette with fancy salted butter. Master Class? Quick pickle or ferment them.

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TASTE SPRING AT YOUR LOCAL FARMERS MARKET  
[WAFARMERSMARKETS.ORG](http://WAFARMERSMARKETS.ORG)

2016 Postcards (next page):

## BLUEBERRIES



These flavorful blue gems are a nutritional powerhouse. A good source of vitamin C and dietary fiber, the antioxidants in blueberries may also help protect against cancer, heart disease and other illnesses.

Blueberries can typically be found at the farmers market from June through September. Varieties range in size from a pencil eraser to larger than a quarter. While all types are delicious, some varieties excel at baking and others are ideal for freezing. Ask about the differences if more than one is available at your farmers market.

**CHOOSING:**  
 Choose blueberries that are plump with smooth skin and a silvery sheen. Discard any berries that are soft, or appear shriveled.

**STORING:**  
 Do not wash berries until you are ready to use. Store in the refrigerator for up to 5 days. To keep berries longer, place on a tray in a single layer and freeze. Transfer to a resealable freezer bag for storage.

WSDA Specialty Crop Block Grant Program

## BLUEBERRY CUCUMBER

Salad with Feta



- 2 cucumbers
- 2 cups (1 pint) fresh blueberries
- 2 tbsp olive oil
- 2 tbsp white wine vinegar (or white balsamic)
- 2 tbsp thinly sliced mint leaves
- 1/2 cup (2 ounces) crumbled feta cheese, optional

Peel the cucumbers, then slice them in half lengthwise. Scrape out the seeds with the tip of a spoon. Cut into thin slices.

Wash the blueberries and discard any stems, leaves, or shriveled berries.

Combine blueberries and cucumber in a large bowl.

In a small bowl, whisk the olive oil, vinegar, salt and pepper and mint.

Pour over the cucumber mixture and gently toss.

Sprinkle with feta cheese, if desired. Serve chilled.

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## CORN SOUP

Adapted from *Good and Cheap* by Leanne Brown



- 4 cups corn kernels (approx 4 ears)
- 1 tbsp butter
- 1 onion, finely chopped
- 2 sticks celery, finely chopped
- 1 green or red bell pepper, finely chopped
- 1 small potato, diced
- 4 cloves garlic, finely chopped
- 1 chili pepper, finely chopped (optional)
- 1 tbsp cornmeal or flour
- salt and pepper
- 4 cups vegetable broth or chicken stock

Melt the butter in a large pot or Dutch oven on medium heat. Add onion, celery, bell pepper, and potato, then stir. Cover the pot and let everything fry and steam for about 5 minutes.

Take the lid off the pot and add the garlic and chili pepper, if using. Stir the vegetables, using a splash of water or broth to free any that get stuck to the bottom of the pot.

Let the vegetables cook, stirring occasionally, for another 5 minutes. They should be lightly browned and soft, although the potatoes will not be fully cooked yet.

Add the corn and cornmeal or flour to the pot and stir. Cover with broth and bring to a boil, then turn the heat down to low and simmer for about 30 minutes. The broth will thicken and become opaque.

Add salt and pepper to taste.

Serve with a slice of garlic bread. Boost the protein by adding a hard-boiled egg, shredded roasted chicken or browned sausage.

For more delicious recipes from *Good and Cheap* visit [www.leannebrown.com](http://www.leannebrown.com)

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## CORN



Fresh is best when it comes to sweet corn. As soon as it is picked, corn's natural sugars begin gradually converting to starch, robbing it of flavor and tenderness.

Corn grown in Washington is typically at its peak from July through October. There are many varieties ranging in color from deep yellow to pearly white and even bi-color corn.

The farmers market is a great place to find the freshest corn. You can ask the farmer exactly when the corn was harvested and if there are differences in flavor between the varieties available.

**CHOOSING:**  
 Look for ears with bright green, tightly wrapped husks and golden brown silk. The kernels should be plump with tightly-spaced rows.

**STORING:**  
 Plan to use your corn the same day it is purchased, or store in the husk in the refrigerator for a day or two.

WSDA Specialty Crop Block Grant Program



# PEACHES

The hot summer days and cool nights typically found in Washington give our local peaches rich, deep, complex flavors.

Peaches begin appearing in farmers markets in June and different varieties can be found through September. Look for a wide range of sizes, shapes and colors in peaches as well as other favorite stone fruits including nectarines, plums, apricots and fun combinations like pluots and apriums.

**CHOOSING:**  
Look for peaches that are fragrant and free of obvious bruises. When ripe they should be firm with just a bit of give when squeezed.

**STORING:**  
Keep peaches at room temperature until they are fully ripe. To speed the process, store in a brown paper bag. Once ripe, refrigerate for 2 to 3 days.



# PEACH COFFEE CAKE

Adapted from *Good and Cheap* by Leanne Brown



6 peaches, cut into 8 slices each  
1 tsp cinnamon  
½ lemon, juiced  
2 cups all-purpose flour  
2 tsp baking powder  
½ lb unsalted butter  
1 ½ cups brown sugar  
¼ tsp salt  
2 large eggs  
1 tsp vanilla

Turn oven on to 350. Lightly butter an 8"x11" pan.  
In a large bowl, mix the peach slices, lemon juice and cinnamon, making sure the peaches are well coated in cinnamon.  
In a medium bowl, stir the flour with the baking powder, getting rid of lumps.  
In another large bowl, beat the butter, brown sugar, and salt with a mixer or wooden spoon until fluffy and lightened in color. Add the vanilla, then the eggs one at a time, mixing completely before adding the next.  
Gently incorporate the flour mixture into the butter mixture until it's smooth.  
Spread half the batter over the bottom of the pan. The batter will be quite thick, so use moistened fingertips to spread if necessary. Evenly distribute half the peach slices over the top. Spread the remaining batter over the peaches, then top with the rest of the slices. Sprinkle with a tablespoon of sugar.  
Bake for 1 hour or until a knife inserted into the center comes out clean.  
For more delicious recipes from *Good and Cheap* visit [www.leannebrown.com](http://www.leannebrown.com)



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**IV. Developed New Tools to Evaluate Project Performance.** Enhancing WSFMA’s capacity to evaluate and improve performance was a key part of this grant project. WSFMA began its approach to conference planning in 2014 by determining priority topics for trainings through a methodical system of: a) assessing feedback and expressed needs of specialty crop farmers who attended the 2014 (or previous year’s) WSFMA conferences; b) evaluating results of the WSU Farm Vendor Survey; and c) analyzing logs of information requests farmers have made to WSFMA staff. This system was adapted for subsequent years and worked very well, with the 2016 and 2017 conferences setting all time attendance records, and all conferences receiving very positive feedback. WSFMA, with assistance from WSU Small Farms Program staff also developed and implemented a comprehensive evaluation survey for farmers market managers to report on impacts of the WSFMA statewide print market directory, the new WSFMA rack card, and the Farmers Market Week recipe cards, toolkit and other resources. The online survey results were largely positive, but participation levels were low. Because of this WSFMA is working to develop a more “focus-group” oriented approach to assessing its promotional and organizational efforts in the future. Gathering information from participants through passive surveys has been more successful at conferences where audiences are focused on the conference and workshops, and can easily complete paper surveys.

Many organizations have contributed significantly to this work. Staff at Pike Place Market and WSU Small Farms Program helped Latino and Hmong specialty crop farmers attend the 2015-17 conferences and offered interpretation services at a number of workshops.

Staff from the State Department of Health have participated in statewide meetings to discuss the WIC and Senior Farmers Market Nutrition Program, and offered FMNP training for market managers and specialty crop farmers at each conference.

Colleen Donovan with the WSU Small Farms Program has been a key partner. Besides promoting the conference through the WSU networks, she led two very popular workshops for specialty crop farmers and market managers at each conference and helped plan others. She provided feedback about all materials that WSFMA created and conducted the follow up survey for promotional materials in 2016 and evaluated the results. Ms. Donovan also co-presented about using farmers markets to leverage increased sales for specialty crop and other farmers, at the Tilth Conference. WSU was essential in helping design the parameters for measuring the effectiveness of programs and projects, as well as designing conference surveys and workshop evaluation forms for WSFMA to analyze and report on. WSU also participated in the trade show each year.

Michele Catalano at Tilth Producers attended the 2016 WSFMA conference to make better connections with direct marketing farmers and state agencies that work with farmers markets and their vendors. As a result of the more formal partnership, Tilth now includes WSFMA print directories in all conference packets and promotes the WSFMA conference via their listserv.

As in previous years, Catholic Charities of Spokane through its “Food for All” program worked with all of the farmers markets in the Spokane area to promote WSFMA activities, distribute materials, and encourage specialty crop farmers to attend the conference. They also helped develop some of the workshops.

Staff at WSDA led workshops about the Food Safety Modernization Act each year and participated in the trade show. The WA Sustainable Food and Farming Network and Cascade Harvest Coalition extensively promoted the conference through their networks. In addition, the HumanLinks Foundation provided scholarship funds for specialty crop farmers to attend the conference.

All work spent on this grant, using grant funds is tracked on time sheets and documented in the bookkeeping system to ensure that all SCBG funds are spent on activities and expenses directly related to this grant. All volunteer time is considered a match for the grant to ensure that staff time paid by the grant is used to benefit specialty crop farmers. The grant proposal anticipated this situation and outlined that WSFMA would tailor its programming only to specialty crop farmers and processors and that registration would require farmers to identify their products and materials will be posted on the WSFMA website.

To ensure that WSFMA is only using grant funds to benefit specialty crop farmers, it prioritized their participation for the annual conference and focused the farmer workshop track on topics most relevant to specialty crop farmers. All specialty crop farmers wanting to participate in the conference receive free registration from a scholarship. All other farmers and market managers have to pay full registration or go through the scholarship application process.

**GOALS AND OUTCOMES ACHIEVED**

<b>Activity</b>	<b>Description</b>	<b>Results</b>	<b>Notes</b>
<b>Conference Workshops</b>	Research, develop, and implement training workshops on expanding markets and sales for specialty crop farmers.	17 Farmer track workshops at WSFMA conferences over 3 years trained 135 specialty crop farmers. Two workshops at 2015 and 2016 Tilth Conferences with at least 100 farmers.	Staff collected all evaluations completed at the end of each workshop.
<b>Direct Support to SC Farmers and Market Managers</b>	Respond to specialty crop farmers’ and market managers’ individual requests for information about how to access farmers markets in WA, FMNP, EBT, new technologies, and training opportunities.	Through 2016: 334 responses to farmer inquiries. 1,151 responses to manager questions. Data not tracked in 2017, but inquiry rates similar.	Staff facilitated a number of connections between specialty crop farmers and market managers looking for new farmers.

<b>EBT and FMNP Support</b>	Represent farmers and markets to State DOH and DSHS to improve opportunities with understanding of EBT and FMNP programs.	4 Farmers Market Access Partnership (FMAP) meetings held during grant cycle. 91 participants from state agencies, markets, non-profit partners.	Working with partners, the WIC Farmers Market program continued with the same level of funding, which generated over \$3.1 million in sales to 575 specialty crop farmers in Washington selling at 125 farmers markets in 2014-2016.
<b>Specialty Crop Promo Campaign</b>	Develop print, ads, web and social media materials to promote specialty crops in WA state.	Over 30,000 recipe cards printed for 10 different WA specialty crops distributed to over 115 markets and 68 farms in 3 years. Press releases sent out to statewide media.	Primary distribution was at the market info booth (100%), to vendors selling the featured products (59%) and posting on social media (31%) or in newsletter (24%). 86% of market managers want the WSFMA to continue to create printed recipe cards.
<b>Goal</b>	<b>Expected</b>	<b>Actual Accomplishment</b>	
<b>Direct marketing specialty crop farmers will increase their direct marketing skills and knowledge, enhancing their success and sales.</b>	150 total or 50 SC farmers per year	235 specialty crop farmers were trained and reported increasing their knowledge after the workshops.	

<b>Farmers markets will catalyze new sales opportunities by connecting their specialty crop farmers to new market channels in their community</b>	10 market managers and 10 SC Farmers	Over 40 managers and 20 specialty crop farmers participated in the three conference workshops designed to facilitate these connections.
<b>Farmers markets participate in the strategic, statewide promotions of specialty crops.</b>	50 participating markets	115 markets reported that they participated.
<b>FMNP authorized farmers will increase their sales at farmers markets 5% per year</b>	20% of farmers authorized by FMNP	WSFMA Farm Sales are up 12% since the beginning of this grant cycle. 75% of all farmers selling at WSFMA member markets are Specialty Crop producers.

One of the expectations was that the materials developed would help increase specialty crop sales at farmers markets and increase the visibility of farmers markets in the public’s eye. The two evaluations of the Farmers Market Week materials and support were the first that WSU has done for WSFMA. The surveys went out to 117 member markets. The results showed that markets used the recipe cards, the online “toolkit” and were very appreciative:

- 93% displayed/distributed recipe cards at the market info booth, 80% gave to vendors, 33% used the recipes in cooking demos/sampling at the market, 27% posted recipes on social media, 27% included recipes in the market newsletter.
- 79% said the Farmers Market Week online toolkit was useful.
- 93% said WSFMA should continue to create printed recipe cards for Farmers Market Week.
- Comments from survey participants: *“The recipe cards were well received and fun this season. Since this was the second year of the recipes, the farming vendors who received them in the market were ready and happy to promote them with their produce. At the info desk, they provided a fun way to engage the shoppers and offer additional suggestions to what they might want to try at the market that week, and in weeks to come we heard stories from shoppers who tried or adapted the recipes to their liking.”*

**This project had one Expected Measurable Outcome:**

Direct marketing specialty crop farmers will increase their direct marketing skills and knowledge, enhancing their success and sales.

**Target:** 25 farmers per year (75 total) report an increase in direct marketing skills and knowledge and sales of at least 5% each year, as a result of attending the WSFMA trainings, connections made at markets, and other marketing expertise shared by the WSFMA either in person or online. **Benchmark:** Individuals will self-assess their current level of direct marketing skills and knowledge. **Performance measure:** Farmers participating in trainings will be asked to complete an evaluation at the annual conference. WSFMA will conduct a follow up survey in the 4<sup>th</sup> quarter 2015 and 2016 to document sales increases.

WSFMA has tracked changes in sales for farmers attending the annual conference since 2011 by sending a follow up survey at the end of the market season. During the 2011-2013 market seasons, farmers reported sales increases of 12-15%. In 2014, 50% of the farmers reported sales increases and 50% reported sales decreases. The survey was not sent after the 2015 market season due to internal staffing changes.

In 2016, the survey was sent in late fall, to 48 farmers that participated in the 2016 conference. 92% of the respondents were specialty crop farmers. 44% reported that they applied ideas they learned from the conference although there was a high response rate (37.5%) of farmers who were not sure whether they applied any ideas. 44% of respondents indicated their sales increased (28% reported sales increased 10-20%, 14% reported sales increased 0-10%) and 43% indicated they “stayed about the same.” Comments from one farmer: *“I feel like so many things that happen at the*

*conference influence my success. Simply having the opportunity to talk with other farmers helps! Trading ideas and practices....”*

The surveys completed at the 2017 conference indicate strong farmer enthusiasm and sense they acquired useful knowledge and skills, and expanded their network of relationships to use during the upcoming market season. 95% of the farmers responded that they increased their direct marketing skills and would recommend this conference to other farmers. 75% of the respondents were specialty crop farmers. These results have been similar every year.

It is difficult to make a direct connection between farmer skills and knowledge acquired at the conference with impact on sales throughout the year. When asked what impacted sales increases or decreases during the market season, farmers pointed to such things as family tragedy, selling at more farmers markets, sending their sales person to the conference, weather, adding more value-added products, or change in market manager.

## **BENEFICIARIES**

This project targets producers who direct market one or more of over 60 different types of fruits, vegetables, cut flowers, herbs or honey through the Washington State farmers markets. Preliminary WSU research has documented the diversity of farmers market farmers including women farmers (51%), immigrant farmers (up to 15%), limited resource farmers (28%), and beginning farmers (47%). There are over 330 specialty crop farmers who sell at farmers markets throughout Washington State and benefited directly or indirectly, from this project. Over 125 farmers benefited from the specialty crop marketing training with follow up assistance, and at least 331 farmers benefited from direct assistance from the WSFMA throughout the year.

Specifically, this project directly benefited specialty crop farmers by:

- Increasing their marketing skills and confidence;
- Providing ongoing, in-market assistance and support;
- Giving them access to one-on-one consultations and support from the WSFMA;
- Learning about other training opportunities;
- Creating a direct means of being part of the WSFMA;
- Increased sales through individual marketing efforts, market-wide specialty crop promotions, and FMNP/EBT sales.

**Farmers Markets.** Over the course of the three years, this project benefited over 200 individual farmers market managers by increasing their skill level so they can more effectively advise specialty crop farmers about ways to improve their sales at farmers markets and create market-wide promotions. Managers who attend the annual WSFMA conference and participate in workshops specific to market leaders, learned basic shopper demographics and marketing psychology, vocabulary to discuss key concepts, booth design and layout. The managers learned communication skills to better support their vendors and respond to questions positively. Managers also learned ways to create seasonal special events around specialty crops that will generate increased sales for vendors and build stronger customer loyalty to the market.

**WSFMA.** WSFMA benefited from this project in many ways. The conference workshops better targeted the needs of specialty crop farmers and market managers who provide vital sales venues for those producers. Conference surveys and follow up surveys showed that farm sales improved, and both farmers and market managers had increased confidence in their marketing and outreach skills. The impact is that WSFMA is on stronger footing and farmers, managers, partners and stakeholders have a much better understanding of what WSFMA is and its role in Washington’s agriculture and food system. WSFMA benefited from the support of partner organizations that made it easier for specialty crop farmers to attend the conference and offer a number of the high quality workshops.

Although WSFMA is not able to track member market vendor specialty crop sales, overall member vendor farm sales grew by 6% from \$25.3M in 2013 (before the grant) to \$26.8M in 2016 (our last year available as 2017 data is not compiled until winter 2018) and specialty crop vendors make up 75.24% of all WSFMA member market farm vendors. While sales have grown by 6%, the number of reported specialty crop vendor booths at WSFMA member markets (which do get tracked) has remained relatively constant growing by less than 1%

from 1,557 booths in 2013 to 1,559 booths in 2016. The especially positive take away from this data is that while the number of participants has not increased, those who are participating are seeing their sales go up.

In the same time period, overall member market total sales grew 12% from \$41.8M in 2013 to \$47M in 2016.

**LESSONS LEARNED**

The effects of taking a more methodical approach to conference planning had many positive effects. The time spent reviewing previous conference surveys and partnering with WSU to create better evaluation systems led to better conferences with better attendance and more specialty crop farmers receiving marketing and sales support training.

While the survey systems worked well for informing the conference activities, getting markets and farmers to participate in the follow-up surveys for the promotional work proved more difficult. The feedback was gathered and helpful, but return rates were lower than hoped for, making the data less reliable. What was clear from the results was that markets and farms appreciate the extra consumer educational print materials for specialty crops more than the online materials. Another lesson was that market managers would prefer a promotional campaign at other times instead of early August, during Farmers Market Week, as August typically the highest sales month of the year for farmers markets, and it is hard to track if the promotion as designed help affected sales. A more controlled model would be needed in the future, likely during a different time of year.

During the course of this work, the WSFMA Board, with assistance from WSU, evaluated the conference format to determine whether it could continue to deliver high quality training and essential networking opportunities for farmers and markets in a more sustainable way. After a series of interviews, review of the conference evaluations and discussion with the contracted event planners, the board decided to try a new strategy in 2018 with alternating years of the large conference format and a smaller-shorter regional market “intensives” that would bring market organizers together for in-depth trainings to build operational skills. Farmers are interested in attending the WSFMA conference and most lack the funds to pay the registration fee without significant scholarship support, which takes significant organizations energy to do. The results are always very positive and the board recognized that it might be easier to reach more specialty crop farmers by offering workshops at conferences sponsored by partner organizations, such as Tilth Alliance. It is trying this at the 2017 conference.

Although the initial thought that tracking FMNP farmers as a defined group would make outreach and evaluation easier than in previous years, this did not turn out to be the case. Creating a subset of specialty crop farmers minimally increased the number of survey results returned by specialty crop farmers and saved no time or effort in direct outreach to request participation.

An interesting development in the facilitation between specialty crop farmers and DOH’s FMNP programs was the discovery that FMNP redemption at farmers markets surpassed EBT sales. Both EBT and FMNP connect low income shoppers with WA fruit and vegetable growers at WSFMA member markets. For many years much of the focus has been on assisting with EBT. The activities in this grant cycle helped to understand that while more EBT dollars are available for WA low income shoppers to spend, more FMNP vouchers (which can ONLY be used at farmers markets) are redeemed in the state. This has led to additional research, happening now, to understand the impact of food assistance usage on farm sales at farmers markets.

Goals were largely achieved.

**ADDITIONAL INFORMATION**

<b>Organization</b>	<b>Staff/Item</b>	<b>Product/Service</b>	<b>Quantity</b>	<b>\$ Value</b>
<b>WSFMA</b>	Mahala Greer, Vade Donaldson, Samantha Kielty, Jordan Lowe, Sophie Kauffman, Kate Delavan	Temp Conference Staffing	520 hrs. staffing conference over 3 years	\$13,000

<b>WSFMA</b>	Indirect Costs	Indirect Costs	\$10,182 in Year 1, \$10,100 in Year 2, \$4,265 in Year 3	\$24,547
<b>HumanLinks</b>		SC Farmer Scholarships	3 annual donations to cover farmer registration and lodging costs	\$30,000
<b>Catholic Charities of</b>	Brian Estes	conference organizing	200 hours over 3 years	\$10,000
<b>Salmon Creek Farmers Market</b>	Ann Foster	conference organizing	200 hours over 3 years	\$10,000
<b>Bellingham Farmers Market</b>	Caprice Teske	conference organizing	300 hours over 3 years plus use of facilities, equipment	\$18,750
<b>Bellingham Farmers Market</b>	Zach Zink	conference organizing	40 hours organizing 2017 farmer dinner	\$2,000
<b>Bellingham Farmers Market</b>	Mike Finger	Keynote Speaker Friday eve 2017	Cedarville Farm owner and one of the founders of the Bellingham Market	\$500
<b>Olympia Farmers Market</b>	Mary DiMatteo	Host city promotional campaign, organizing help in 2015 and 2016	50 hours organizing, plus shared promotions	\$4000
<b>Pike Place Market</b>	Zack Cook	conference organizing & promotional	200 hours over 2 years plus shared promotions and sponsorships	\$15,000
<b>Sedro Woolley Farmers Market</b>	Jeremy Kindlund	conference organizing	80 hours total between 2015 and 2016	\$4,000
<b>total</b>				<b>\$131,797</b>



Specialty crop growers at the market:

Above Left: Spring Vegetable Postcard used to promote and explain Hakurei Turnips from Kettle's Edge Farm at the Bayview Farmers Market.

Above Right: Full Tilth Farm proudly displays their WIC sign beside fresh berries at the Bainbridge Island Farmers Market.

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## **PROJECT #8**

**Project Title:** Value Added Processing Facility Feasibility Study

**Partner Organization:** CADC (Community Agriculture Development Center)

### **PROJECT SUMMARY**

Stevens County WA has a number of existing Specialty Crop farmers and growers, including garden produce farmers and orchard produce growers. Historically, prior to the current big-ag, big-shipping Specialty Crop delivery model, Stevens County was a major supplier of Specialty Crops regionally. However, most of the Specialty Crops produced currently in Stevens County are sold only direct to consumers fresh in season. With a relatively short growing season in Stevens County, farmers are limited to four or five months of the year when produce can be sold fresh in season. Produce sold direct by farmers is often low-margin when direct marketing time is included in farm costs (farmers markets, for example). In turn, local consumers would prefer access to locally grown produce year round. National trends are in the direction of consumer demand being high for processed food, making it economically possible for farmers and food entrepreneurs to create processed food that locally would benefit consumers, farmers and growers.

The purpose of the project was to perform a feasibility study to understand the specifics of a processing facility and how it would enable local Specialty Crop farmers and growers to extend the number of months of the year that they could sell farm and orchard products. The plan was to survey consumers of several sorts, local Specialty Crop producers, then design a facility to the two through locally produced value-added produce products. The “design” of the facility would include:

- Selection of the highest potential value Specialty Crop items grown in Stevens County
- Design of food processes necessary to process fresh produce into value-added products
- Enterprise business models to support production of value added products in the proposed facility
- A focus on food safety and compliance with food safety regulation

Local sourcing of Specialty Crops, including season extension, is currently a national trend, and Stevens County and the NE corner of Washington is no exception. In fact, simultaneous to this project, Stevens County has seen a Farm to Food Pantry program expand to become a Farm to Community program, including delivery to local schools and small rural grocery stores. Also through the term of this project, a farmer owned cooperative has developed in Spokane (LINC Foods). LINC has developed to become a large opportunity for distributing value added products to Spokane markets, particularly minimally processed fruit and vegetables for school systems. All of these produce outlets have the same need; season extension and more access to value-added produce products.

### **PROJECT APPROACH**

#### **a. Supply Analysis**

To understand which Specialty Crop items grown in Stevens County are good candidates for processing, CADC volunteers and partners conducted interviews with local farmers and growers. Some farmers were interviewed at their farms on a one-on-one basis. Some were also interviewed or surveyed at pre-existing local events and meetings. The goal of these interviews was to determine if there are particular fruit, berries, or vegetables that farmers felt were good candidates for a food processing facility.

Feedback from local growers and farmers showed that there is plenty of capacity to grow a broad range of fruits and vegetables in Stevens County, as long as there is a market to sell those Specialty Crop items, preferably at prices similar to those at farmers markets. This perspective of local farmers points to one of the key roadblocks to overcome before a processing facility could be successful, local farmers developing growing techniques to allow their own profitability at wholesale price points.

During Supply Analysis interviews, it became obvious that most farmers in Stevens County are not interested in processing their own Specialty Crops, so the focus of Supply Analysis was expanded to include prospective and existing food processing entrepreneurs. There were very few exceptions to this farmer perspective. As a result, the final facility design was scaled to accommodate food processing entrepreneurs who are building a dedicated processing business, rather than farmers trying to add an additional product line to sell at farmers markets.

Tree fruit growers reported that they currently have a large amount of seconds-quality fruit each year that they don't have a market for. Currently that fruit is just left to rot as there's no market for it. More than one tree fruit grower said they'd offer that fruit at zero cost if an entrepreneur could use it and had sufficient resources to harvest the fruit.

## **b. Demand Analysis**

To understand the local market demand for frozen or jarred Specialty Crops, a demand analysis was done. This analysis involved conducting meetings and onsite visits with schools, food banks, Spokane tribe groups, restaurants, grocery outlets, farmers markets, online markets, and farms doing direct sales. Results of this series of meetings and surveys showed that there are two distinct markets for the two processing technologies being evaluated in this project.

### 1) Canned (in jars) fruit and vegetable products.

At the scale and price point that a small processing facility might produce, these products have markets mainly as direct sales settings. Example direct sales venues are farmers markets, craft fairs, and local boutique stores. Analysis showed that an effective processed food incubator should accommodate two different production scales, one at a direct-marketing scale, and the second a mid-production scale where a direct marketing scale entrepreneur was ramping up to mid-scale and might be producing their product for boutique national chain (example; Williams & Sonoma) or a smaller local mainstream grocery store chain.

The Specialty Crops which are key ingredients in these types of jarred products fit into two categories.

-Jams, jellies, fruit butters and preserves - these products are made primarily of fruit and berries.

Of the fruit and berries that could be processed this way, apple butter rose to the top as a product that a facility should be designed to process. Apples grow well in Stevens County and apple butter is itself a very challenging product to make economically in a rented facility because it involves many hours of "cooking down" apples to become apple butter. The facility necessary to make apple butter would also accommodate almost any other type of jam, jelly or preserve using the same equipment. The "butter" process is the more limiting of all other fruit or jam type products.

-Pickles - these products are primarily made of vegetables.

Of the vegetables often processed into pickles, garlic rose to the top as a crop around which a prospective processing facility should be designed. This was in part because garlic is very well suited to the growing conditions in Stevens County and is also a high-value boutique item. As with apple butter, garlic is particularly problematic to process as a pickle because of safe processing methods, if not done very carefully have a tendency to make for a low-quality product. This problem has to do with the fact that garlic can easily become mushy if it's cooked at too high a temperature or for too long. Garlic was chosen as the limiting Specialty Crop item for pickled processing because most other pickled products are easier to process but can be processed on the same processing line where garlic is processed. Additionally, smaller sized garlic, is a low-value byproduct of growing large sized garlic sold into the seed industry. High quality seed garlic can sell at a wholesale value of upwards of \$20 per pound while smaller garlic has a value of only \$2 or \$3 per pound. It's this smaller garlic that's ideal for processing into pickles because it's smaller size makes for less processing time and a higher quality pickled product.

### 2) Frozen (in bags) fruit and vegetable products.

The market for frozen local produce is primarily the institutional market. While there might be a small demand for frozen berries for consumers shopping at local grocery stores, the largest demand for minimally processed local produce is in school districts and the local emergency food supply system (food pantries). In other regions outside of Stevens County, there's a strong demand for frozen local produce from healthcare institutions. There's every reason to believe that it would be possible to build this demand for frozen local produce in the healthcare industry in Stevens County if sufficient supply were available. That demand just doesn't exist currently.

The produce items in demand by school districts were found to be consistent with a state wide study prepared by the WSDA Regional Markets team. The three Specialty Crops that came to the top of demand list for Stevens County schools were frozen broccoli florets, frozen cauliflower florets, and frozen corn on the cob. This later item is considered as more of a luxury item in school lunches than the first two items and could support a higher price point.

## **c. Visit Existing Processing Facilities for Evaluation and Analysis**

One of the project action items was to lead two group tours of food processing facilities that might work for Stevens County. To select these two facilities for the group tour, CADC volunteers visited a total of five food processing facilities. Of these five facilities evaluated, group tours were conducted at only two of them. Details related to each site visit are given below.

**1. Facility: 21 Acres, Woodinville WA**

This facility was visited June 10<sup>th</sup>, 2015. Based on the feedback from that report, the CADC decided that this site would not be one of the facilities for a group tour. The reason for the choice was that while a very impressive facility, especially from an environmental angle, 21 Acres is effective mainly as a teaching kitchen and somewhat effective as a commissary kitchen. Both of these two kitchen usages require a large population nearby, which is not a characteristic of Stevens County.

Some of the key limitations found at 21 Acres did inform final processing facility design as follows.

- Dry, chilled, and frozen storage  
Each client who might use a processing facility will need secure space for one of these types of storage.
- Office and Meeting Space  
Inexpensive office space close to a processing floor would be valuable for most food processing operations. Shared meeting and business facilities typically provided by business incubators would be valuable.
- Versatile and Configurable Space  
21 Acres found most effective use of their kitchen spaces when they used portable equipment that could then be stored away and kitchen spaces reconfigured quickly when needed by different processing operations.

**2. Facility: The Mid-Columbia Market at the Hub, Pasco WA**

This facility was visited in May of 2015. Based on the feedback from that report, the CADC decided that this site would not be one of the facilities for a group tour. This facility was mainly effective as a shared vendor kitchen for processed food vendors who sell their wares at the attached local food market. Much like the 21 Acres facility this facility lacked the storage and office space needed that the food processing entrepreneurs would require.

**3. Facility: Mission Mountain Food Enterprises Center (MMFEC), Ronan MT**

The MMFEC is really a mid-scale food processing factory and doesn't even have a retail space. This facility has been around for more than two decades and has pretty much invented itself from scratch. This facility was visited three times during the project starting with an evaluation visit on May 27<sup>th</sup> 2015 for evaluation purposes and then twice more with two group tours sponsored by the CADC. The first tour in November 28<sup>th</sup>, 2016 took eleven volunteers on the tour. A second CADC sponsored tour on May 3<sup>rd</sup>, 2017 took eight volunteers through MMFEC. Volunteers on these tours include community organizers, food entrepreneurs both, experienced and just starting out, as well as staff and officials from local institutions including the director of WSU Stevens County Extension and one of the three Stevens County Commissioners.

The Mission Mountain Food Enterprises Center in Ronan MT was chosen by this feasibility study as the most likely food processing facility model to be successful in Stevens County. Some of the key attributes of MMFEC are discussed below

- Dry, chilled, and frozen storage  
As with other food processing facilities visited, MMFEC showed the need for as much storage space as possible. In fact frozen storage space at MMFEC is a net revenue generator, even for clients who are not food entrepreneurs. This fact indicates that especially chilled and frozen storage space is very important for a facility's viability.
- Office and Meeting Space  
As with other food processing facilities, MMFEC found there to be market for small entrepreneur scale office rental space. Some office rental clients at MMFEC are not food systems businesses, so in this way MMFEC acts as a generic business incubator as well a starting scale food processor and a small full production processing facility.

- **Options for Client Scalability**  
MMFEC has several different processing spaces which can be configured and used independently. Not only does this fact allow multiple clients to use the facility at the same time but it allows a single client starting at an entrepreneur scale to scale up to mid-level production inside the same facility.
- **Food Safety Methodologies that Minimize Safety Risk and Optimize Efficiency**  
The staff at MMFEC over the years have perfected a methodology and facility layout that allows delivery and storage of food product ingredients such that they can be accessed from un-sanitized delivery and storage areas into sanitized production areas with a minimum of food safety risk in the most efficient way. This layout had a strong influence on the final facility designed in the study.
- **Food Safety and Marketing Staff are Critical**  
The MMFEC in conjunction with the Lake County DC provide food processing incubator help to clients through their own skilled staff. Access to this sort of help from food processing entrepreneurs is critical to decrease barriers to entry. The two key staff positions that stood out as critical are the Food Safety person and the Food Systems Marketing person. Experience at MMFEC shows that any food business incubator must provide its clients these two areas of support if it is to be successful. This is an important detail because finding funding for these critical staff positions in fees that can be charged for entrepreneur scale processing is a difficult task. MMFEC pays for its production staff with client fees but has to find outside funding for entrepreneur support staff.
- **Processing Facility Layout**  
The MMFEC was developed in an existing building, a fact which has affected the nature of its growth. Over the years it has built and rebuilt a number of spaces in its facility. Based on interviews with multiple MMFEC staff, the final facility design output by this study is based on a combination of the existing MMFEC facility and what it might be if it were purpose built today. MMFEC staff contributed heavily to both the facility and the chosen processes in this project.

#### **4. Facility: Blue Mountain Station, Dayton WA**

Blue Mountain Station is a facility operated by the Port of Columbia in Dayton WA. It was purpose built to become a food tourism destination. This facility was visited three times by CADC volunteers as part of this project. Two trips were evaluation visits and a third trip on November 28<sup>th</sup> 2016 was a group tour with eleven Stevens County volunteers. This group tour was part of the same tour that visited the Mission Mountain Food Enterprises Center (MMFEC) the previous day. While much different from MMFEC, Blue Mountain Station has a number of characteristics that might make it a good model for some areas in Stevens County. These characteristics are:

- **Demonstrated Success**  
The most notable characteristic of Blue Mountain Station is that it appears to be very successful. Even in the time of this project, Blue Mountain Station has gone from a freshly built facility with only a handful of tenants, to a full facility which has already spun off multiple businesses into other buildings in town and is in the process of designing an additional facility on site. Considering almost all the other facilities evaluated in this project consistently struggle for clients, Blue Mountain Station stands out among all the rest because of its heavy use by clients.
- **Food and Ag Tourism**  
Blue Mountain Station draws a food-agriculture tourist crowd from nearby Walla Walla WA. Some areas of Stevens County are well suited for this type of facility, particularly sites near the south of the County within a reasonable driving time from Spokane. The Deer Park/Clayton area and the town of Chewelah for example are within a similar driving time from Spokane as is Dayton from Walla Walla.
- **Production Spaces designed with Retail Space**  
Blue Mountain Station has individual rental spaces in different sizes but each one is designed to allow retail from that space. The combination of retail and production in the same space is key for food and agricultural tourism.

#### **5. Facility: Livingston Food Resources Center (LFRC), Livingston MT**

This facility is an excellent example of cooperation between for-profit and non-profit sectors. Located in a purpose-built building which houses the Livingston Food Bank, this facility was recommended for evaluation by the staff

of MMFEC and was toured in July of 2017. As a result, this facility informed the later parts of the study, namely choice of particular pieces of processing equipment as described below. The LFRC was evaluated only by an individual CADC volunteer, not a group tour so far.

- **Scale of Processing Equipment**  
Processing equipment and its layout in the processing space at the LFRC matches the processing scale that this feasibility study found was needed by entrepreneurs in Stevens County. Processing lines had already been designed by the time of visiting the LFRC, but having this second “sanity check” of scale for the project facility design was invaluable.
- **For-Profit-Nonprofit Partnership**  
A number of the partners in this project are interested in the for-profit-nonprofit partnerships pioneered at the LFRC. There’s strong interest among this group of partners for a group trip to the facility, albeit outside the timeframe of the project.

**d. Develop business plan supporting supply match with demand**

This portion of the project turned out to be the most challenging part of the whole project, in part because the small-scale food processing industry is a very economically challenging industry. Even the Mission Mountain Food Enterprises Center continues to struggle supporting itself with revenue from its own clients. A literature review found very few examples of existing business plans for small facilities. In part due to the experiences of the CADC with previous small-scale processing projects, an agriculture-style enterprise budget format was chosen for business modeling, with an 8-year ramp-up scale. This project produced two separate enterprise budgets, each with its own version of facility design (see section 4.e below).

Both business models were developed as spreadsheets so they’d be useful for predictive modeling for any future food processing facility plans. They both show that even after they reach full production, neither business model shows profitability without outside funding sources.

The two enterprise budgets developed are described below.

**1) Startup Scale Only**

This business model focuses on small processors who sell food products made from Specialty Crops at Farmers Markets, Craft Fairs, and other direct marketing venues.

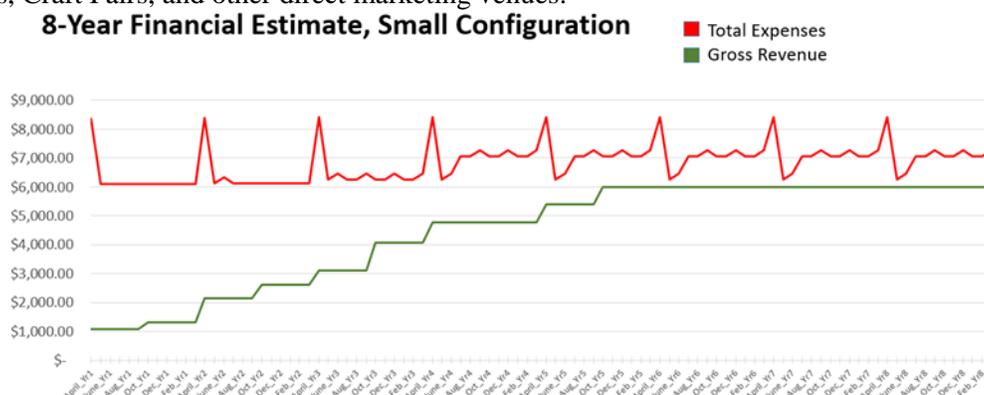


Figure 1 - Financial business model predictions for startup scale only facility.

Figure 1 (above) shows that when the Startup Scale Only facility reaches full capacity after 5 years of production, it will still require \$6000 per year of funding to stay open.

**2) Startup Scale and Mid-Scale**

This business model includes the Startup Scale business but also includes facilities for mid-level production, sufficient for a business to move from a direct-marketing scale to a boutique wholesale scale.

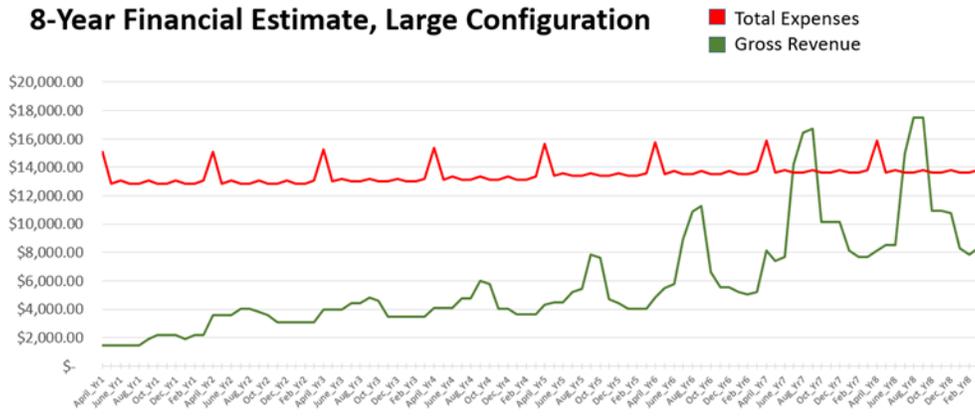


Figure 2 - Financial predictions for startup scale and mid-scale facility.

### 8-Year Profit/Loss Estimate, Large Configuration



Figure 3 - Profit/Loss prediction for startup and mid-scale facility.

Figure 3 above shows that the larger facility configuration which includes startup scale and mid-scale processing operations still must raise significant outside funding to remain viable, a figure of \$30k per year in year 8 alone.

Both business models are available on the WSU Stevens County Extension website at: <http://extension.wsu.edu/stevens/event/value-added-processing-feasibility-study-results/>

#### e. Analyze equipment and facility options

##### Processing Lines

Based on site visits to other processing facilities, interviews with prospective processors, information from contractors, WSU Extension, and WSDA, three main processing lines were developed. These three processing lines are described below. Figure 4 (below) is a graphical representation of all three processing lines.

##### 1) Wash-Blanch-Freeze Line

This processing line is the simplest of all three lines. It includes equipment sufficient to “minimally process” Specialty Crops so they can be quick-frozen in bags. An example of a product from this sort of process is frozen broccoli florets.

##### 2) Hot-Fill-Invert Line

This processing line includes the Wash and Blanch equipment described in the Freeze line above. It includes equipment necessary to can specialty crop products in jars which are compatible with a Fill-Invert process. Fruit and vegetable products which are hi-acid and relatively homogenous (such as sauces) are compatible with this sort of process. Apple butter is an example of a product which works well with this sort of process.

##### 3) Water Bath Processing Line

This processing line shares some elements with the Hot-Fill-Invert line described above, but it also includes equipment necessary to process less homogenous Specialty Crop products such as those containing solid pieces or chunks. Pickled Garlic is an example of a product compatible with this processing line.

Figure 4 below shows each of these processing lines.

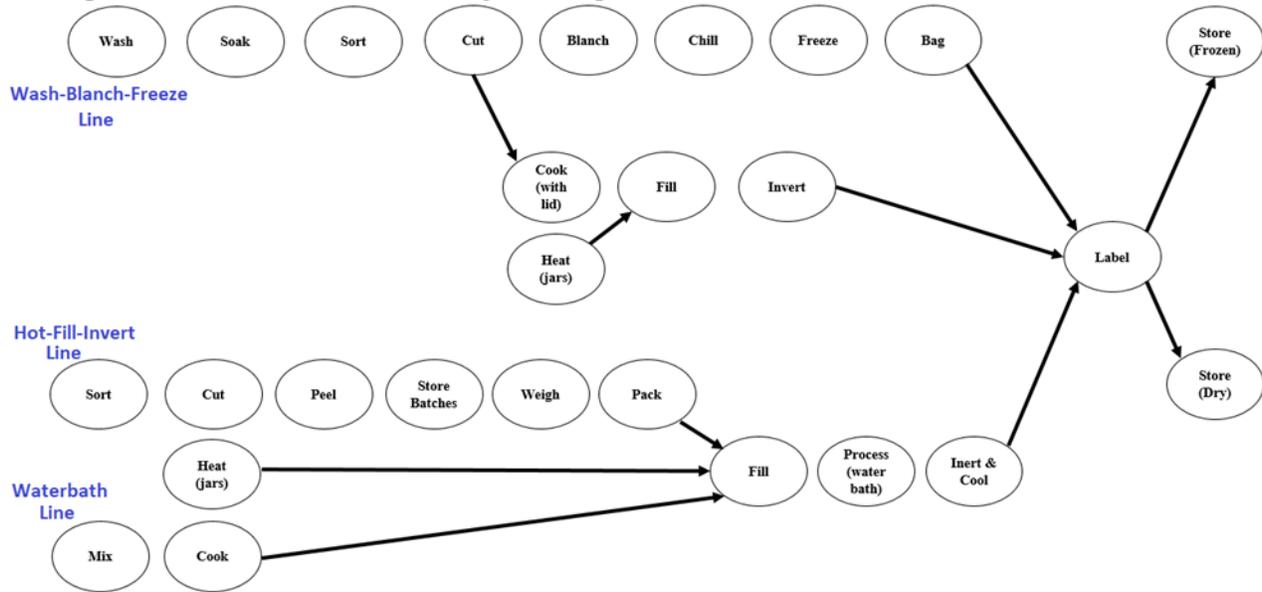


Figure 4 - Three fruit and vegetable processing lines selected by this study.

### Processing Equipment

Design of the three processing lines described above include choosing individual pieces of equipment that would be used in each of the steps in the processing lines described above. A complete list of these pieces of equipment is included in the two business model spreadsheets, posted at:

<http://extension.wsu.edu/stevens/event/value-added-processing-feasibility-study-results/>

### Facility Design

The CADC chose to advance two separate facility designs. One design is a small standalone facility designed to support startup-scale fruit and vegetable product production only. The second facility design includes the startup-scale facility but is designed to accommodate mid-scale production as prospective entrepreneurs scale up. The Startup-scale facility is designed so it could be built as a first stage in a larger project that eventually would include the mid-scale facility.

#### 1) Startup Scale Only

A plan view sketch of this facility is shown in figure 5, below.

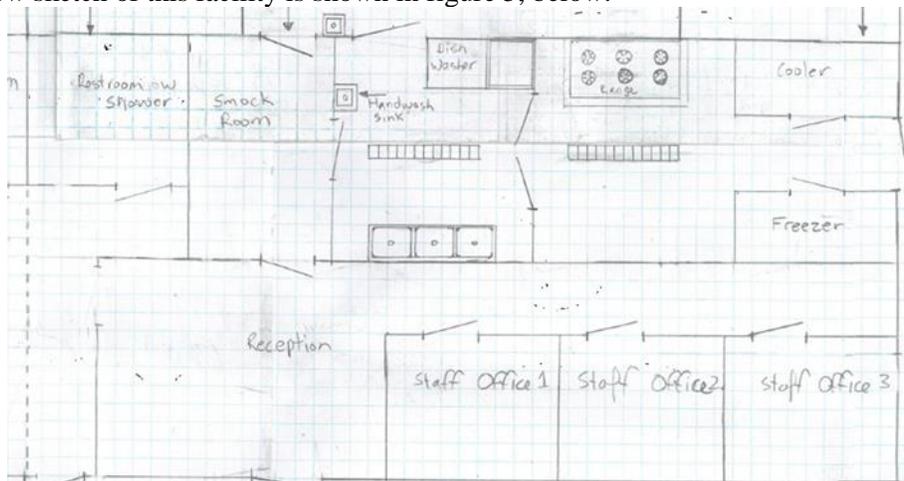


Figure 5 - Startup Scale Only Facility Design

Construction cost for the facility shown in Figure 5 is estimated at \$335,000 including building, building site, and food processing equipment required.

#### 2) Startup Scale and Mid-Scale

A plan view sketch of this combined facility is shown in Figure 6, below.

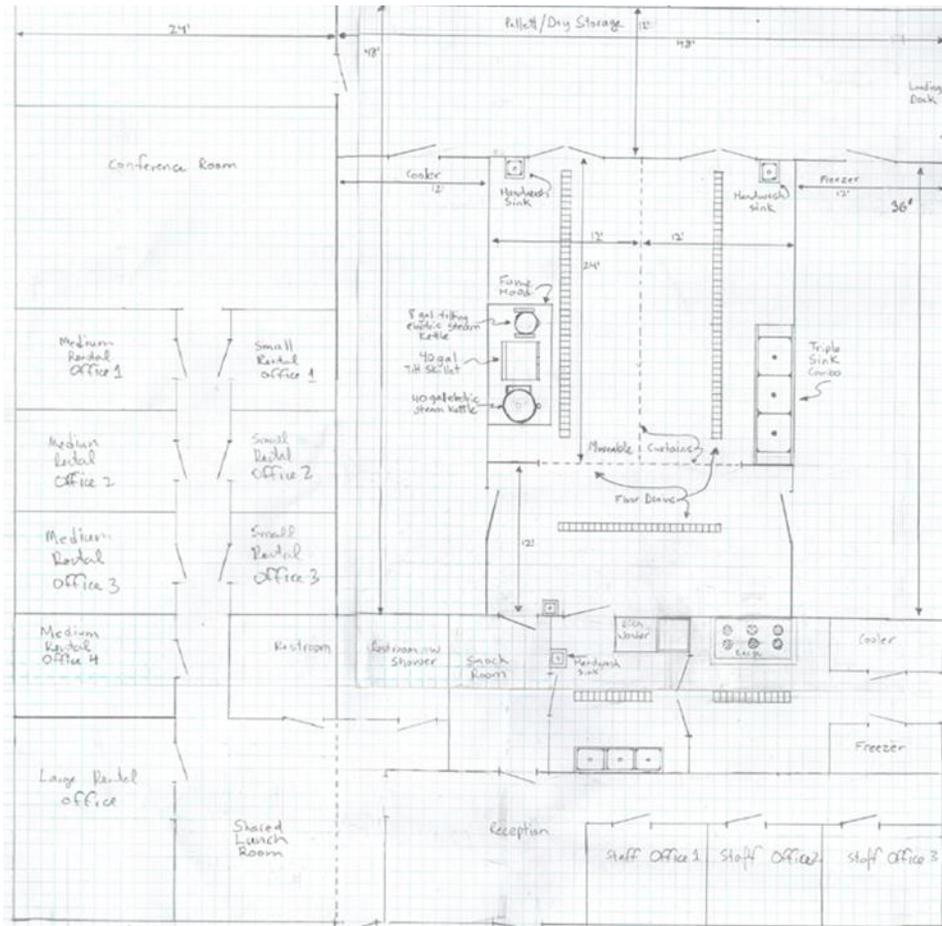


Figure 6 - Startup Scale and Mid-Scale Facility Design

Construction cost for the facility shown in Figure 6 is estimated at \$1,405,000 including building, site, and food processing equipment. This construction cost figure includes the startup scale facility construction if completed as a single project.

**f. Project Representatives to Attend Better Process Control School**

At the time this project was designed, the best food processing safety training course available was called Better Process Control School. This course is a nationally approved program offered by various agencies around the country, and is offered by WSU in Washington State usually once per year. Completing this course is a requirement for anyone operating a cannery, but it covers food safety in processing and packaging for many other food products. When this course was offered by WSU in February 7<sup>th</sup> 2017, two CADC volunteers successfully completed the course.

After the project started, a new food safety directive came out, commonly referred to as the Food Safety Modernization Act or FSMA. As part of the rollout of the FSMA, a new food processing safety course was developed called Preventative Controls for Human Food, a course developed by the Food Safety Preventative Controls Alliance (FSPCA). When the course was offered on May 24<sup>th</sup> 2016 in Prosser WA, taught by WSU and WSDA staff. One CADC volunteer completed this training and became a Preventative Controls Qualified Individual (QCPI).

**g. Coordinate with WSDA Food Safety Program on process/equipment**

Throughout this project, CADC representatives and project partners have been in contact with food processing safety experts from the WSDA, and WSU. Relationships with staff from these organizations were developed through contacts made through execution of this project. During the project, information and advice was provided by WSDA through their Food Safety Outreach coordinator, as well as the Food Safety Modernization Act specialist in the WSDA Regional Markets group. Information about processes associated with Food Safety Modernization Act compliance was provided by the WSDA Food Safety regulation officer for the Northeast Washington region.

Food safety itself and compliance with current and new food safety regulation was a very important aspect of this project in developing the final food safety facility design and the processing lines as well as planning. Including a dedicated food safety staff person in the business models produced by this project was important. The need for this food safety position was one of the key takeaways gained from visits to Mission Mountain Food Enterprises Center in Ronan MT. Understanding food safety issues and processes is one of the major roadblocks that every food processing entrepreneur will see, so having a staff person available to advise entrepreneurs is critical. This staff position is important because the cost of paying this person is what tips the scales in the business model from running in the black to running in the red.

**h. Release study results, business plan, and facility/process plan to partners and study participants, Chambers of Commerce, city governments and through local media outlets.**

When the project stages were complete, the CADC partnered with WSU Extension to hold two public events at the Extension office where results were presented.

The first of these events was a half-day seminar designed for food processing entrepreneurs. More information about this seminar is provided in item section 4.i below. This seminar was well attended with a total of forty one attendees in person and an additional eleven sites attending remotely through an online web meeting tool. During this seminar, processing lines and facility design were introduced.

The second event was a one-evening seminar focused on rolling out results of the entire Feasibility Study. This seminar had seven attendees in person, which is typical attendance for evening events held in Stevens County. During this seminar, processing lines and facility design were introduced along with the two enterprise budgets (see section 4.d above). More information about this event, including presentation materials is available online at:

<http://extension.wsu.edu/stevens/event/value-added-processing-feasibility-study-results/>

Both events were promoted with help from the WSU Stevens County Extension office through local print media, email lists, and through the CADC Facebook site. Press releases were published in multiple local papers, which led to articles in three local papers about the project as well as radio interviews on the Colville AM radio station and on the Spokane Public Radio.

**i. Training Class on Developing Value-Added Products**

WSU Stevens County Extension developed and hosted this training class. Content was modeled after a similar course offered by the Northwest Ag Business Center (NABC) in the western part of Washington. The class included instructors and material from the WSDA, WSU Extension, and the Tri-County Health District. A course outline and materials for this event is posted online at:

<http://extension.wsu.edu/stevens/agriculture/seminar-value-added-processing-for-entrepreneurs/>

Chewelah Farmers Market: Made their space available for the CADC to conduct consumer surveys with farmer market shoppers.

Chewelah Chamber of Commerce: Twice invited the CADC representatives as guest presenters to share current status of this feasibility study.

City of Chewelah: Provided time in the agenda of a Chewelah City Council meeting for the CADC to present results of this Feasibility study.

Northeast Washington Hunger Coalition: Helped WSU Staff and CADC volunteers connect with food pantries in Stevens County for conducting food pantry client Specialty Crop preference surveys.

Tribe Groups: The Chewelah Casino (Spokane Tribe) hosted a meeting with their food service staff in order to provide data for produce demand analysis conducted by CADC contractors.

Tri-County Economic Development District (TEDD): Provided technical assistance creating and deploying Specialty Crop preference surveys for the general public. TEDD provided business model technical assistance as well as example business models as part of this project. TEDD invited the CADC to present feasibility study results to the TEDD Board.

Unfortunately, TEDD had emergency items come up so the CADC presentation had to be postponed until past the end date of the project.

Wizbang Research: Was the main contractor hired by the CADC for the technical work of this project. Wizbang research contributed many hours of un-paid time working on Supply Analysis, Demand Analysis, and the design of the food processing lines and facilities proposed in this project.

WSU Stevens County Extension: Organized and hosted a half-day seminar for entrepreneurs considering Specialty Crop value-added processing. The Extension office in Colville made one of their summer interns available for conducting a produce preference survey to food pantry clients. WSU Extension assisted by promoting CADC events and programs through its electronic and print media sources. WSU Extension staff from the Colville office and from Pullman provided many hours of in-kind work throughout this project. WSU Stevens County Extension accommodated CADC volunteers at their Specialty Crop farmer events so that they could conduct surveys and interviews with those farmers and provide printing and poster laminating services at a discounted rate.

The WSDA provided technical assistance on food safety processes through this project. They provided an instructor on an in-kind basis for the value added processing seminar described in section (4.i) above.

This project did not benefit any commodities other than Specialty Crops. Some of the existing facilities that were reviewed as part of this project processed non-Specialty Crops, but the only processes considered during evaluation of those facilities were ones focused on Specialty Crops. From a food safety perspective, the processing lines developed in this project are not compatible with any food product other than fruits and vegetables.

## **GOALS AND OUTCOMES ACHIEVED**

### **Activities Completed:**

1. Supply Analysis was completed. This analysis was done to understand which Specialty Crop items could be produced at competitive process and high volumes in Stevens County.
  - Outcomes
    - Farmers can grow lots of different Specialty Crops, if there's a market for them.
    - Garlic is well suited for growing in Stevens County and is a good choice for processing.
    - There's good availability of good quality seconds of tree fruit in Stevens County.
2. Demand Analysis was completed. This analysis was done to understand which Specialty Crops that could be supplied in Stevens County were in demand by the various markets in the area, including individuals, institutions and other markets. This analysis was designed to inform choices of particular processing line equipment specific to individual Specialty Crop produce items.
3. Outcomes
  - Two distinct markets for processed Specialty Crops
    1. Canned in jars – high-end boutique markets
    2. Frozen in bags – institutional markets such as schools and food pantries
  - 1. Outcomes

Based on Supply analysis, Demand analysis, and evaluation of existing food processing facilities a facility and three processing lines were designed.

    - Processing Facilities Designed
      1. Startup Scale Only facility – Estimated total cost: \$335,000
      2. Startup and Mid-Scale facility – Estimated total cost of both facilities together: \$1,405,000
    - Processing Lines Designed
      1. Frozen line designed to process broccoli florets and corn on the cob into bags.
      2. Hot-Fill-Invert line designed to accommodate apple butter and other fruit and berry jams and preserves in jars.
      3. Water Bath Canning line was designed to accommodate picked garlic and other types of vegetable and fruit pickles.
4. Community members were introduced to existing facilities that do Specialty Crop value added processing.
  - Outcomes

Project sponsored group tours, took a total of 16 community organizers, food processing entrepreneurs, and prospective food processing entrepreneurs to tour the Mission Mountain Food Enterprises Center in Ronan MT and Blue Mountain Station in Dayton WA on two separate trips.

5. Community representatives received food safety training necessary to assist development of value added Specialty Crop products once a prospective facility is constructed.

Outcomes

Two individuals were trained, both of them completing Better Process Control School and one completing Preventative Controls for Human Food training.

6. A half-day seminar focused on decreasing barriers to entry for food processing entrepreneurs was given.

Outcomes

At least 53 individuals were trained on starting a food processing business and introduced to the process. 42 students attended in person and 11 attended through a remote site/webinar service. Some of the remote sites had multiple people at them.

7. Two business models were created, one to match each of the two facility design scales.

Outcomes

Both business models show that their respective production levels will likely not produce enough revenue to cover entrepreneur staff salaries without additional revenue sources. This is a very important outcome because it puts both scales of prospective facility into the arena of business incubator, where indirect economic development benefit of the facility through clients is where value lies, not as an economic development source directly. Business incubators often require outside funding to be viable.

8. Study results were released through local media, during workshops, and through presentations to local government officials and business leaders.

Outcomes

- At least two local papers printed press releases associated with this project.
- Three local papers printed news articles discussing the project and its results.
- One local radio station ran an interview discussing the project.
- The PBS station in Spokane ran an interview discussing results of the project.
- Members of the Chewelah Chamber of Commerce are now discussing a tour of their own to evaluate Blue Mountain Station as a model for a facility in the Chewelah area.
- The director of the Tri-County Development District is considering a trip of his own to the Mission Mountain Food Enterprises Center in Ronan MT to evaluate the facility as a prospective model for an incubator facility in Colville WA.
- The Northeast Washington Hunger Coalition board members, including staff of Rural Resources Community Action is considering a trip to the Livingston Food Resources Center in Livingston MT as a prospective model for a food-access focused processing facility.

The one Long Term measurable outcome planned as part of this project was to keep a record of any increase in Specialty Crop production or sales in Stevens County that might be attributed to this project. The achievements towards this remain to be seen.

All the major goals of this project were met. The primary goal was to end this project with sufficient information to then seek funding to build a facility, which the CADDC now has in hand and it has been shared with the public. Since this project was a feasibility study, there wasn't any baseline data for comparison. However, the two business models generated from this project will now serve as something like baseline data for evaluating new prospective projects.

## **BENEFICIARIES**

Beneficiaries of this project include anyone considering a business processing Specialty Crops for sale, including those who might want to use processes such as pressure canning or dehydrating, which were not part of this project. Stevens County has almost a dozen citizens who've toured existing processing facilities who can act as advisors for new entrepreneurs considering food processing. Likewise, the two volunteers who received food safety training as part of this project are now available to serve as advisors for entrepreneurs. Farmers who produce Specialty Crops would be beneficiaries if one of the proposed facilities were built, as would consumers wishing to consume products produced in the facility. Of these consumers, regional school systems would be beneficiaries.

This feasibility study shows that if the larger-configuration food processing facility were built and operated according to plan, it would generate three new processing jobs, two new salaried jobs in the facility itself. It would require the equivalent of three new farming operations to supply the necessary Specialty Crop items for processing. It would create the equivalent of at least two new full time jobs through the entrepreneurs using the facility. These are all conservative estimates totaling 10 new jobs.

In addition to the jobs created, this facility would enable the food access movement in Stevens County to develop a program to manufacture pre-packaged senior meals locally using local produce. The revenue from this prospective operation is already included in the job estimates above, but the social value of this operation has intrinsic value for the growing number of seniors in Stevens County who need specialized diets to accommodate their health conditions, mainly diabetes and hypertension.

### **LESSONS LEARNED**

One of the biggest surprises that came as the result of this project was local opposition to the idea of building a Specialty Crop processing facility from one of the local farmers markets and from a property rights group. Both of these two entities felt that somehow a processing facility would threaten their own plans and activities. The farmers market group assumed that a processing facility would house a retail store, which they thought would compete with their open air downtown farmers market. The property rights group, while small was vocal about their conspiracy theory style concern that a processing facility was part of a government plot to “put in a food hub” who’s purpose was to control access to existing food supplies for local citizens. The farmers market group did decline to allow surveying shoppers at their market, and the combination of concerns from both groups led to a language change in all materials associated with the project in that the term “food processing facility” was used and the term “food hub” was not used.

One key insight from this project was that it took much more time to execute the tasks of the project than expected. Because most stakeholders in this project are either associated directly with farming or with the school system, both of which are seasonal. The only time of the year that was convenient for these stakeholders to participate in surveys and meetings was January, February and half of March. Because of this seasonal nature of stakeholder availability, both Demand Analysis and Supply Analysis of the project was delayed.

On the positive side, evaluation of Mission Mountain Food Enterprises Center in Ronan MT led to a general feeling among stakeholders in this project that building a processing facility is very much doable. Ronan MT is very similar in many ways to Colville. Economics are similar in Ronan and the Lake County economics are similar to Stevens County. Even growing season is similar in Lake County, as is transportation access to the closest city (Missoula) compared to the city of Spokane to Colville. Establishing MMFEC as a model project for any of local business leaders, elected officials, and entrepreneurs to visit and evaluate for themselves was very important for this project.

Though not included in the two technology types officially considered in this project, interviews with K-12 school kitchen directors showed that there is significant demand for minimally processed fresh produce. Two produce items that are a good fit for Stevens County farmers to produce for schools are carrots and snow peas. Carrots store well and could be minimally processed (washed, cut, packaged) in either one of the two proposed processing facilities, providing a local fresh Specialty Crop item throughout the school year. Snow Peas could be grown year round in Stevens County using common season extension techniques. They too could be minimally processed for schools in either of the proposed facilities. These two produce items represent an additional Specialty Crop production and consumption opportunity not accounted for in the job creation figures discussed earlier in this report.

All activities, goals and Expected Measurable Outcomes of this project were met.

### **ADDITIONAL INFORMATION**

The CADC contributed \$4000 in cash to this project. This funding was used to cover travel expenses for group trips and individuals visiting existing food processing facilities. CADC volunteers contributed an equivalent of \$14,516 in volunteer time. This includes the time of volunteers who toured and evaluated existing processing facilities as well as volunteer time to administer this project.

WSU Extension contributed an equivalent of \$3701 of in-kind donation time. This time was used in executing the two group tours and in planning and executing the Value Added Processing seminar. This in-kind time figure includes contributions by WSU Stevens County Extension and WSU Extension from Pullman WA.

Wizbang Research contributed the equivalent of \$9892 of in-kind time donation. This time was used in Supply Analysis, Demand Analysis and in the process of facility design.

The Tri Count Economic Development District (TEDD) provided an equivalent of \$694 in in-kind time. This time was spent providing assistance for the business modeling portion of this project.

Total contributions:

Cash (CADC): \$4000

In-Kind: \$28,803

Combined total: \$32,803

Spokane Public Radio aired an interview with Nils Johnson, WSU Stevens County Extension Farm and Food Systems Coordinator about this project. Also included in the interview was Dan Wallace, a garlic farmer in Stevens County. This interview is available through the following link:

<http://spokanepublicradio.org/post/stevens-county-works-develop-value-added-food-industry>

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## **PROJECT #9**

**Project Title:** Preserving and Increasing Access to Irrigation Water in the Snoqualmie Valley

**Partner Organization:** Snoqualmie Valley Preservation Alliance

### **PROJECT SUMMARY**

The purpose of this project was to increase specialty crop production and increase competitiveness of specialty crops by removing a key barrier to cultivation of specialty crops in the lower Snoqualmie Valley: access to irrigation water. Prior to this initiative, there was no efficient mechanism for making water rights available to individual farmers who need them. There was great need to address irrigation on a system-wide basis on behalf of specialty crop growers, and to identify water supply alternatives such as water right transfers, permitting, mitigation, and water banking.

As unused water rights are subject to relinquishment, there is an urgent need for legitimate means to efficiently move water rights to where they can be exercised, and an economic incentive to move use of water rights from lower value uses like animal feedstock to higher value specialty crop irrigation. Loss of existing water rights in this Valley would be devastating to the long-term competitiveness of local specialty crop growers. The Snoqualmie Valley Preservation Alliance (SVPA) was encouraged by farmers, community members and county officials to undertake the responsibility of developing an irrigation water strategy and to identify reliable mechanisms to move irrigation water to where it can be used.

This project did not build on a previously funded SCBGP project.

### **PROJECT APPROACH**

At project's start, a working group was established, including a diverse group of specialty crop growers, SVPA staff, and Washington water law expert, Attorney Bill Clarke. Through this work, it became clear that water rights available for transfer would be opportunistic and nearly impossible to predict when an operator will be making a change and therefore have water available. Two such opportunities arose, and pilot water transfer program was pursued right away. This changed the original work plan from a theoretical exercise to a test-and-learn exercise. It was fortuitous because the pilot plan emerged just as the 2015 drought was declared, and immediate short-term demand was met by transferring water to ten specialty crop farmers in desperate need of water. More than half of those small farms were new incubation farm businesses, and had water not been made available, the drought might very well have wiped them out and discouraged these new farmers from continuing to farm. Most of these new farm businesses still exist today, and several have bought their own land and established new farm sites.

In addition to the pilot transfers, other water supply strategies were pursued. A major project activity was to investigate the possibility of leasing water from Seattle Public Utilities, from the Tolt Reservoir. This was a long-standing concept proposed by the Dept of Ecology, and the agriculture community. With the grant funding, it was possible to conduct legal and hydrology feasibility analyses once and for all. Unfortunately, while it is legally feasible, it was not feasible from a hydrologic perspective.

Another project activity was to investigate establishing a long-term water bank to facilitate ongoing transfers between buyers and sellers. This also included feasibility analysis for acquiring an existing water right that was known to be on the market (Weyerhaeuser/Tokul Creek) for permanent sale. The research included a funding proposal for acquiring the water right and using it to seed a water bank. The funding proposal was approved by the Department of Ecology, and the Weyerhaeuser water right was purchased for use by specialty crop farmers in the Snoqualmie Valley. This is a major step, and will ensure that the strategy development work of this project will be sustained indefinitely.

King County DNRP's ag team helped facilitate meetings and connections between watershed partners and the Department of Ecology to identify potential solutions, and to vet proposed strategies. Snoqualmie Valley Tilth and Snoqualmie Valley Farmers Coop helped with specialty crop grower outreach, and served on the working group.

Only specialty crop growers benefited from this program. Every farm participating in this project grows and irrigates specialty crops exclusively. Commodity crop growers in Snoqualmie Valley generally do not irrigate, and none expressed interest in participating in the program.

## **GOALS AND OUTCOMES ACHIEVED**

The amended EMO for this project is the number of farms and acreage participating in the pilot water transfer program. With the grant funding, staff and water law expert Bill Clarke were able to complete water transfers to ten farms during the 2015 drought.

The amended EMO for this project was short term, and is described above.

This project evolved into a test-and-learn exercise, rather than a broad theoretical exercise. Therefore, many of the activities were more action-oriented than originally planned. At the outset, goals of the project were conservative because it had not been done before, and project proponents were hesitant to over-promise. Several key strategies emerged, and these SCBGP funds enabled the opportunity to develop and test several components that resulted in irrigation water being made available in the very first year of the grant program, and it has grown each year since.

No water right transfers like this had ever been implemented in the Snoqualmie Valley; these were the first. No new irrigation water rights had been issued since the late 1970s, so the baseline for delivering new water supply is zero. The actual increase in production as a result of this project can be estimated by examining the increase in irrigated acreage. In 2015, with the drought, the approximately 40 acres of land that was irrigated with the pilot transfer program can attribute most all of its production to new access to irrigation as a result of this program. In 2016, the number of irrigated acres rose to approximately 50 acres, but due to the 2016 high water table, without irrigation made available through this program, some production would have been possible, but only at a level of an estimated 50%. In 2017, the irrigated acreage through ongoing implementation of this program was expanded to 70 acres. Because 2017 rainfall has been way below average (95% below normal for July and Aug), like in 2015, most all of the production in the 70 acres can be attributed to new access to irrigation.

## **BENEFICIARIES**

This project directly served ten specialty crop farmers; the water bank program that this project enabled added five more farmers by the 2017 season. Existing and new specialty crop growers have benefitted from this program. Some were established growers with severely inadequate water rights, and they were able to increase production dramatically with availability of new water rights. Others were new and/or tenant farmers who might have not continued farming during the statewide 2015 drought or the very dry 2017 season.

Fifteen farmers have gained new access to irrigation water rights since the start of this program. This represents an estimate of over 70 acres of intensely cultivated specialty crops which have already benefitted from the program. A planning figure of \$25,000 per acre is widely accepted, based on generalized reports on Snoqualmie Valley market crops, which are most typically sold direct, for example to restaurants, farmers markets and farm subscriptions (e.g. CSA farms). This project contributed to an estimated \$1,750,000 in specialty crop business by year three. The long-term value of the project, which is difficult to predict because of the number of variables, is no doubt much, much larger. Larger scale growers have shown interest in establishing beans, berries and herbs now that water is available.

## **LESSONS LEARNED**

When this project began, it wasn't clear exactly what water supply strategies would emerge, nor how difficult implementation would be. There were two notable keys to success. First, because water is managed by the state, it turned out to be critical to engage the services of an expert in Washington water law, and one with experience in irrigation water rights. Legal expert, Bill Clarke, served the community well, and has set the Snoqualmie Valley on a course for long term success as it relates to access to irrigation. Second, because water rights are so sensitive, with much fear, mistrust, and confusion among the landowners, a grass roots group with direct accountability to the ag community is critical. An outside group would have been very unlikely to earn the trust of the individual water right seekers and existing water right holders. Grass roots organizations such as the Snoqualmie Valley Preservation Alliance, armed with the help of professionals (made possible by this grant program), are well-suited to taking up the charge of solving water supply problems at a community scale.

It was not expected that water supply would be delivered directly to specialty crop farmers in the very first season; that was an unexpected boon, and created support and confidence in the overall project. That early success helped secure the water bank funding from the Department of Ecology.

As discussed, EMOs were amended, and these amended EMOs were achieved.

**ADDITIONAL INFORMATION**

In-kind hours were proposed at 500 hours of volunteer committee time, @ \$25/hour for a total of \$12,500. Nearly 100 hours of volunteer time occurred in the first six months, with an estimated 8 volunteers, 2 hours each for 6 meetings. An additional estimated 50 hours was contributed in subsequent meetings by volunteers. Once the pilot projects were underway, it became clear that implementation of them required staff and water law expertise, so the regular meetings did not continue.

These funds were heavily leveraged, however, in that the water bank funding investigation yielded a grant of \$578,000 from the Department of Ecology to purchase the Weyerhaeuser Tokul Creek water right and to start the water bank.

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## **PROJECT #10**

**Project Title:** Enhanced Irrigation Management of Sweet Cherries

**Partner Organization:** Eltopia Communications

### **PROJECT SUMMARY**

The project will demonstrate the effectiveness of an irrigation decision-management tool using remote Bistatic Ground Penetrating Radar (BGPR) on cherry farms. Cherries are sensitive to moisture. Despite this, few orchard managers use precision soil moisture measurement practices to make irrigation management decisions. This project will test a simpler, cost effective and accurate irrigation decision-making tool that has the potential to reduce disease and improve Washington's cherry crop by up to 5-percent. It has three main objectives:

1. Evaluate the effectiveness of BGPR to provide an accurate 3-D shallow hydrology model in cherry orchards.
2. Investigate the influence of the Decision Making Tool using BGPR on management decisions and subsequent impacts on optimal soil moisture levels, water usage, yield, quality, and levels of mildew.
3. Raise awareness of BGPR as a new, practical tool to optimize irrigation for cherry production.

This project will benefit all producers of sweet cherries in Washington and other irrigated production areas. This project aims to support industry growth by helping growers improve irrigation management of cherries to enhance the industry's competitiveness in both domestic and global markets. Efficient and effective irrigation water management of cherry and other specialty crop growers can only improve the profitability of agricultural producers, making it is critical for this issue to be addressed.

This project was not built on a previous Specialty Crop Block Grant.

### **PROJECT APPROACH**

Eltopia Communications developed ten field ready soil moisture sensor prototypes that take measurements of the level of moisture in the ground at five different depths at and below the root zone of cherry trees. These prototypes remotely transmitted data through the cellular network to a time series database designed for sensor data. As the project progressed, Eltopia redesigned the soil moisture probes with the goal of increasing its durability and created two different variations for testing. Eltopia also travelled to Tulare, CA for the World Ag Expo in February 2016, and gave a presentation about the soil moisture project through the WSDA's Specialty Crop Block grant program to an audience of approximately 50 people. Eltopia installed probes at Jackass Mountain Ranch at the end of April 2016. On a weekly basis, thereafter, sensor data was compiled and was stored on a SQL server database at Eltopia's office location in Seattle. Algorithms were tuned to correlate sensor data with water content. Yield metrics of harvested fruit in June were added to sensor data for interpolation in the yield map.

The probes had initially transmitted accurate data for VWC (volumetric water content), however, as time progressed, the probes in the field deteriorated due to oxidization, and the subsequent data being transmitted was inaccurate beyond the scope of filtering. At times, there were gaps in the data, sometimes days long indicating that the stations were not transmitting. The source of this problem was discovered to be inadequate power supplies.

Further research could have been completed with more robust and resilient materials, along with additional personnel resources.

Remington Furman has a Computer Engineering degree from the University of Washington and a background in developing embedded systems software as well as some RF electronics and small-scale organic farming experience. He has been responsible for the research and development of the soil moisture sensor prototypes, data processing, storage, and visualization. Remington ended his employment with Eltopia at the end of Dec 2015, and handed off his research and findings to Richard de Leon.

Richard de Leon has a strong background in mechanical, electronics, and robotics prototyping. He has helped with portions of the prototype construction, fabrication of probes, and solar panel power system. Richard took over as the project lead when Remington Furman ended his employment with Eltopia, and determined that the probes were failing and compromised.

Glenn Borland is an RF engineering contractor with experience in ground penetrating radio. Eltopia hired him to develop the RF components of the custom soil sensor hardware. Eltopia determined that the components that Glenn had designed were not compatible with the goals Eltopia was set to achieve. Mainly, Glenn's components were not easily reproducible, they were unreliable in terms of consistency of gathering data, and the expense of his production was greater than originally budgeted for.

Will MacHugh is founder and president of Eltopia Communications. He is responsible for the project, and supervision of his employees and contracted personnel.

Troy Peters is an Extension Irrigation Specialist and Associate Professor at Washington State University. He has provided advice on experiment design and information on existing soil sensors.

Duncan Smith has a background in software and GIS systems and a degree in Geography from the University of Washington. His responsibilities included the mapping portions of the project, as well as writing a software system to transfer sensor data to a database via text messages. He constructed a 3D map of the test site from aerial imagery captured during a drone flight.

Tom Moxon is an electrical engineer who was slated to help with the electrical engineering portions of the project. He left Eltopia prior to the start of the grant period.

Jackass Mountain Ranch, located north of Pasco, WA, is a partner for the field installation of sensors and measuring the progress on Expected Measureable Outcomes of the project.

Accurate soil moisture sensors have the potential to benefit many areas of agriculture as well as civil and environmental engineering, however, the current field tests and resources are restricted to the cherry orchards Eltopia was working with.

### **GOALS AND OUTCOMES ACHIEVED**

Activities Completed:

1. Develop prototypes of probes to test for VWC in soil
2. Install probes into pre-determined locations in Jackass Mountain Ranch
3. Develop software and algorithms to correlate readings from probes to actual water content
4. Test longevity of said probes

Due to the failure of the probes long term progress will not be made.

Eltopia's goals for the project included:

1. Increased quality and yield of specialty crops by >5% by altering irrigation practices on a micro-climate level over 2 years.
2. Reduce mildew outbreaks through the identification of over-saturated soils by 50%.
3. Improve the quality of data available to cherry farm managers.
4. Increase the number of acres under precision irrigation management.

Eltopia planned to achieve these goals by accomplishing the following:

Install Soil Moisture probes at Jackass Mountain Ranch, Franklin County

In April of 2016, Eltopia installed 10 Soil Moisture Probes at Jackass Mountain Ranch, Franklin County at the locations that were determined to be most productive in yielding moisture data

Conduct weekly collections of TDR, Neutron, ET, and available plant water

Eltopia was unable to collect weekly collections of the TDR, Neutron, ET, and available plant water data to compare the probe readings. This was due to the lack of resources to travel from Seattle to Jackass Mountain Ranch on a weekly basis. Remington Furman had ended his employment with Eltopia during this time and Richard de Leon was still familiarizing himself with the technical details of the project.

Conduct monthly surveys of mildew outbreaks

Eltopia was unable to collect monthly surveys of mildew outbreak data due to the lack of resources to travel from Seattle to Jackass Mountain Ranch on an ongoing basis. Remington Furman had ended his employment with Eltopia during this time and Richard de Leon was still familiarizing himself with the technical details of the project. There were also clear issues with the probes' ability to withstand the elements in the field.

Collect harvest yield and grade metrics

Eltopia did not collect harvest yield and grade metrics, again due to lack of resources, as well as significant issues with the soil moisture probe materials.

Present research and finding (oral and booth) at Washington Horticulture Meeting in Yakima

Due to the technical delays and change in responsible party from Remington to Richard, Eltopia decided to forgo presenting at the WA Horticulture Meeting. However, Will MacHugh did speak at the World Ag Expo in Tulare, CA in February 2016.

As part of the work plan schedule, Eltopia needed to have sensor prototypes ready to install during the cherry growing season in order to determine effectiveness of sensors. Unfortunately, Eltopia was unable to finish the sensor prototypes before the end of the growing season, and as such Eltopia was unable to perform the necessary tests and data collection for the 1<sup>st</sup> year. However, Eltopia was able to install the prototypes in April 2016. The sensors were created and they self-calibrated regardless of soil salinity and conductivity which provides farmers and managers with more accurate measurements compared to current sensors.

The original targets and any necessary adjustments follow.

1. Increase quality and yield of specialty crops by >5%.  
Due to having unreliable data from the current model of probes, Eltopia cannot provide an estimate of the increase of quality and yield. A revised model would need to be created and tested in the field.
2. Reduce mildew outbreaks through the identification of over-saturated soils by 50%.  
Due to having unreliable data from the current model of probes, Eltopia cannot provide an estimate of the reduction in mildew outbreaks.
3. Provide real-time, user-friendly data to farm managers on smart phone, tablet or computers.  
The foundation for the database structure is set-up and in place, however without reliable and consistent data from probes, efforts were discontinued in porting the data to various mobile devices.
4. By disseminating the successes Eltopia hopes to increase from 3,000 to 12,000 acres into the precision irrigation concept the next year. Eltopia hopes to continue to increase acreage incrementally each year thereafter.  
Eltopia had planned to disseminate the results, but due to the delays encountered, priorities shifted to product development and making the sensors more robust. Due to personnel changes and other resource shortages, this task was not completed.

The project was not completed as originally planned due to a number of unexpected issues, therefore, expected measurable outcomes were also not collected.

Eltopia was unable to collect weekly collections of the TDR, Neutron, ET, and available plant water data to compare our probe readings. The 10 probes were initially installed at Jackass Mountain Ranch, Franklin County. This inability to collect data was due to the lack of resources to travel from Seattle to Jackass Mountain Ranch on a weekly basis. Remington Furman had ended his employment with Eltopia during this time and Richard de Leon was still familiarizing himself with the technical details of the project.

Furthermore, Eltopia was unable to collect monthly surveys of mildew outbreak data due to the lack of resources to travel from Seattle to Jackass Mountain Ranch on an ongoing basis. Remington Furman had ended his employment with Eltopia

during this time and Richard de Leon was still familiarizing himself with the technical details of the project. There were also clear issues with the probes' ability to withstand the elements in the field.

Lastly, Eltopia did not collect harvest yield and grade metrics, again due to lack of resources, as well as significant issues with the soil moisture probe materials.

As part of our work plan schedule, Eltopia needed to have sensor prototypes ready to install during the cherry growing season in order to determine effectiveness of sensors. Unfortunately, Eltopia was unable to finish the sensor prototypes before the end of the growing season, and as such Eltopia was unable to perform the necessary tests and data collection for the 1st year. The sensors were created and they self-calibrated regardless of soil salinity and conductivity which provides farmers and managers with more accurate measurements compared to current sensors.

Eltopia Communications has learned that the probes created needed to be vastly more robust, to withstand elements beyond what was tested in a controlled laboratory. Data collection was initially successful, and if Eltopia Communications was able to employ additional dedicated personnel to this project, further testing could have been completed. Also, customized hardware is not recommended due to lack of testing, therefore, using off-the-shelf, pre-vetted components could potentially save time and funding when developing prototypes.

Eltopia Communications has learned that the probes created needed to be vastly more robust, to withstand elements beyond what was tested in a controlled laboratory. Different materials could be used to prevent premature deterioration and oxidization. Data collection was initially successful, and if Eltopia Communications was able to employ additional dedicated personnel to this project, further testing could have been completed to address failures in the data collection (i.e. power shortages, etc.). Also, customized hardware is not recommended due to lack of testing, therefore, using off-the-shelf, pre-vetted components could potentially save time and funding when developing prototypes.

In conclusion, cherry producers in Washington State could benefit from Eltopia's failed project by developing more robust probes, created with off-the-shelf components; and assigning a dedicated, reliable, and proximity-based team to troubleshoot probes as the probes withstand outdoor elements, and analyze the probe readings.

### **BENEFICIARIES**

Any organization that is researching this type of monitoring system for agriculture could benefit from the data and trials and errors that Eltopia has encountered and unveiled.

Because the project by Eltopia Communications was not successful, the quantitative data is limited.

### **LESSONS LEARNED**

Eltopia Communications has learned that the probes created needed to be vastly more robust to withstand elements beyond what was tested in a controlled laboratory. Data collection was initially successful, and if Eltopia Communications was able to employ additional dedicated personnel to this project, further testing could have been completed. Also, customized hardware is not recommended due to lack of testing, therefore, using off-the-shelf, pre-vetted components could potentially save time and funding when developing prototypes.

Staff issues and sensor durability affected the implementation and progress of the project.

Eltopia Communications has learned that the probes created needed to be vastly more robust to withstand elements beyond what was tested in a controlled laboratory. Different materials could be used to prevent premature deterioration and oxidization. Data collection was initially successful, and if Eltopia Communications was able to employ additional dedicated personnel to this project, further testing could have been completed to address failures in the data collection (i.e. power shortages, etc.). Also, customized hardware is not recommended due to lack of testing, therefore, using off-the-shelf, pre-vetted components could potentially save time and funding when developing prototypes.

### **ADDITIONAL INFORMATION**

Cash and In-kind Match Donations

Tom Moxon	Engineering consultant	\$103,960
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Matt Weaver	Engineering employee	\$10,385
Will MacHugh	Project director	\$80,000
Remington Furman	Benefits for engineering employee	\$6,976
Duncan Smith	Benefits for engineering employee	\$5,232
Richard de Leon	Benefits for engineering employee	\$6,114
Glenn Borland	Engineering consultant	\$9,633
Ken Clark	Grant consultant and analysis	\$4,929
Travel		\$5,495
	Probe Supplies (12 probes): VNAs Solar Panels Batteries RF Switch Hardware (wood, stakes, fasteners) Cables Connectors Stainless Steel Materials	
Supplies		\$19,000
TOTAL		\$251,724

**CONTACT INFORMATION**

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## **PROJECT #11**

**Project Title:** Local Buying Missions: Expanding Markets for Small-Scale Growers and Processors

**Partner Organization:** WA State Department of Agriculture

### **PROJECT SUMMARY**

The Local Buying Mission project's purpose was to increase market opportunities for small-scale and direct marketing farmers and processors by eliminating the mystique of local, direct buying. Small-scale specialty crop farmers and on-farm food processors can fail without knowledge about how to get the farmer's products into the marketplace, diversify and choose the most viable markets for their products. If a specialty crop producer/processor does not know how to approach a grocery store or farmers market manager, or does not even know about specific market options, they will have difficulty accessing the markets that are right for the volume and price points that are a fit for their production. Similarly, if a buyer does not know how to work directly with growers or food processors, the relationship is more likely to fail. Businesses need education and information on market matches for the product and scale of production, access to buyers, markets, and distributors, as well as technical assistance.

This project connected buyers with specialty crop growers and food businesses in interactive, travelling workshops and networking events. "Mobile Workshop" tours brought buyers onto farms and into value added food processing operations and brought growers behind the scenes of retail grocery, restaurant, farm stands, farmer "food hubs" and other local market options. Buyers and growers engaged in peer to peer learning and better understand the challenges and successes of working together to increase the competitiveness of Washington grown specialty crops and food products.

This project was needed because according to the 2012 census, 35,000 of the state's 37,000 farms were small businesses (USDA NASS) and finding markets and gaining market access is the number one request small farm ag professionals receive from farmers, food businesses and buyers. Washington State University research shows that Washington farmers selling at farmers markets, when given 11 options, ranked these 3 markets as the ones in which the farmers most want to increase sales: 1) direct markets such as roadside stands and farm stores, 2) restaurants, and 3) grocery stores.

At the time of the project start date, no state funds were allocated for local and regional events focused on assisting farmers and food processors to connect with buyers in their local regions. Specialty Crop Block Grant funding made this needed project possible. This project was directly aimed at enhancing local and regional markets by getting more small-scale specialty crops into profitable and strategic direct markets.

This project directly impacted the State's small-scale specialty crop producers and on-farm processors who currently sell or are seeking to diversify by direct marketing. While WSDA knows 1,400 unique Washington farmers sell at farmers markets with reported sales of \$47 million (many farmers markets do not report sales and so total sales are estimated closer to \$50 million), data for direct to restaurant, grocery, CSA, farms stands as well as other direct markets did not exist. Since the release of NASS data on direct marketing farms in 2016 it was found that 4,273 Washington farms sell direct to consumer through farmers markets, CSAs, online marketplaces, and farm stands totaling over \$71 million.

This was a new project designed solely for the needs of small-scale specialty crop producers and processors selling in direct markets and is being submitted only for specialty crop block grant funding. No projects like this were known in Washington State or nationally.

### **PROJECT APPROACH**

#### **Activities Performed:**

#### **Hosted six (6) Local Buying Mission:**

Project staff approached each of the six local buying missions with significant outreach and project planning to assess the specific needs and opportunities of each unique region where a mission was held. The local buying mission model and WSDA's approach was intended to allow for flexibility in scheduling the missions in specific regions in order to be more responsive to the distinct needs of producers in different regions of the state. This approach allowed WSDA to leverage opportunities for collaboration with partners in each region as they emerged. The realities of small and direct marketing

farms can vary so much from region to region across very diverse production regions and markets in different regions of Washington State. Designing successful local buying mission activities required a responsiveness to those differences in the design and implementation of each specific event as well as related technical assistance.

### **Education and Outreach:**

WSDA attended and offered technical assistance resources at events focused on specialty crop producers, processors and buyers. WSDA also met with stakeholders knowledgeable about grower needs, buyer interest, and market challenges/opportunities in different regions of the state. This allowed WSDA to offer information and resources while also learning to inform event planning, participant outreach, and technical assistance content and delivery format. The information and connections generated through outreach and stakeholder input allowed project staff to tailor the focus (content, format, regional draw, etc.) of the various local buying missions and related technical assistance to be more responsive to the realities of the different agricultural regions of the state. In total, WSDA provided outreach and direct marketing resources at events to over 1,360 individuals.

### **Technical Assistance:**

Throughout the grant reporting period, WSDA offered technical assistance to over 500 producers by presenting and providing resources at workshops, grower meetings, and conferences as well as via phone and email. With knowledge gained from initial stakeholder and partner interactions, WSDA developed an approach to technical assistance that included ongoing availability for one-on-one technical assistance and presentations to farmers when requested, as well as a strategy focused on pre-local buying mission outreach and education to farmers, distributors, and processors to build knowledge of buyer and farmer needs and prepare participants in advance to confidently engage with and learn from each other during the local buying missions.

Partners were extremely valuable for the success of this project. Local partners contributed input and insight which shaped the design and focus of the missions themselves to best serve the local producers in the three separate regions. Partners also provided significant in-kind contributions including Local Buying Mission event venues, refreshments, staff time, outreach and promotion.

Individual farmers and processors such as Blue Heron Farm, Rama Farm, and Seattle Wholesale Growers Market Cooperative provided initial support and request of this work and participated in local buying missions or provided guidance in their design. 24 farms and business participated as speakers and tour locations. Trade groups, local food and agriculture organizations, other WSDA programs, and WSU Extension were also important project partners.

A representative sample of partners and their contributions includes:

- LINC Foods, a specialty crop producer-owned cooperative food hub, did extensive outreach and promotion to their members and other specialty crop growers in the Spokane and Stevens County and broader “Inland Northwest” region.
- WSU Extension in Clark, Stevens, Spokane, Jefferson, Clallam, Kitsap, and Yakima Counties all contributed input to the design of events, outreach and promotion and supplied materials and meeting space for events.
- Gonzaga University and “Zag Dining” Sodexo food service at Gonzaga University promoted the event to food service buyers, volunteered to be a stop on the local buying mission tour, donated use of their meeting facilities for the tradeshow, and hosted a catered reception featuring local specialty crops during the trade meeting, all at their in-kind expense for the Spokane Local Buying Mission.
- 21 Acres, a non-profit organization contributed the venue for the King County Local Buying Mission’s Farmer Chef Meet and Greet, provided a professional photographer to document the event for later promotion of local producers, contributed a venue and catering for the networking event which highlighted local specialty crops, coordinated chef tours, and helped with promotion and outreach of the King County Local Buying Mission.
- Northwest Agricultural Business Center, a non-profit supporter of the Puget Sound Food Hub, a cooperative food hub serving restaurants and other customers, contributed in kind staff time for outreach to producers and other event costs at the King County Local Buying Mission
- FamilyFarmed.org through its partnership with WSDA was able to bring their “Wholesale Success” training to 3 regions as part of the “Market Access” Workshop Series thanks to a USDA RMA education cooperative agreement. WSDA incorporated the trainings into the technical assistance for farms in advance of the local buying missions in Spokane, Yakima, and Olympic & Kitsap Peninsulas to help farms understand marketing for local grocery and food service, post harvest handling for quality and food safety, and business planning

Participants were required to identify if they produce, purchase, or work with specialty crops on the registration form for each related event. Many of the small farms are diversified and some may produce non-specialty crop products in addition to their specialty crops, but the clear emphasis, technical assistance, and marketing information provided was all specifically targeted at the specialty crop elements of their operations. The registration process was designed to identify and restrict any exclusively non-specialty crop applicants through the information required from participants to register.

### **GOALS AND OUTCOMES ACHIEVED**

The following activities were completed in order to achieve the performance goals and Expected Measurable Outcomes with the goal of increasing access to direct markets for small-scale specialty crop growers and on-farm processors:

1. Hosted six regional local buying missions totaling 255 participants and conducted baseline day-of event surveys and follow up surveys conducted 6 months to 1 year after the events.
2. Providing Outreach and Education at local events, conferences and classes to over 1,360 attendees impacting participants with new market knowledge, estimating at least half the participants were producers
3. Providing Technical Assistance to approximately 500 producers, food businesses and buyers totaling with 130 individuals receiving direct one on one assistance.

### **Local Buying Missions:**

#### **Local Buying Mission #1: Spokane Area Workshop Series – September & October 2015**

The Spokane area Local Buying Mission was structured as part of a “Market Access” series of workshops, presenting all the events under the umbrella of the local buying mission to help producers understand the manner in which all the topics were geared towards increasing their own market-readiness and access to their desired markets. The preceding events included a workshop on Good Agricultural Practices (funded through another SCBG project) and one on Wholesale Success. The local buying mission event consisted of a morning tour to two farms, a food hub facility and food bank, and Gonzaga University’s Sodexo food service. The afternoon trade meeting opened with a panel discussion on “Top Tips for Successful Local Sourcing” and was followed by scheduled one-on-one speed meetings. A closing reception hosted by Gonzaga’s food service allowed for informal networking and consultations with resource providers who offered resources specifically geared towards specialty crop producers and buyers. The event was successful with the tour filled to capacity and a total of over 40 producers and buyers attending some portion of the day. There was a sufficient mix of producers and buyers to schedule each attendee with 3 to 4 one-on-one meetings.

#### **Local Buying Mission #2: Olympic and Kitsap Peninsulas - April 2016**

Approximately 41 participants attended the Kitsap/Olympic Peninsula Local Buying Mission, with many small farms operated by new farmers who were still identifying the market channels that work best for them. Participants at the event expressed interest in on-farm stands, small CSA’s, smaller farmers markets, and small batch production of value added products tended not to be as familiar with selling directly to restaurants or local retailers. With specific regional needs in mind, this unique event focused on bringing farmers and buyers together for robust discussions on the bus about direct marketing strategies while traveling between stops. Tour locations were selected to give farms exposure and connections to buyers at different market channels that they can use into the future as they plan for business development. The mobile workshop tour included a regional grocery chain, an on-farm stand, two very different restaurants, an on-farm commissary kitchen, and event venue where farms learned about opportunities for producing their own value added products. A panel discussion during the trade networking session presented direct marketing perspectives from farms and produce buyers, including the potential for growth and access to new markets, especially restaurants, via a new food hub in the region.

#### **Local Buying Mission #3: Snoqualmie and Snohomish Valleys (King County) - September 2016**

This Local Buying Mission was designed specifically to build connections between direct marketing farms and culinary businesses in the city. Snoqualmie and Snohomish Valleys are rich agricultural areas surrounding the largest metropolitan area of Seattle and the largest market in the state for local specialty crop products. Instead of farmer workshops, the emphasis was strongly on opportunities for chefs and culinary buyers to visit farms, connect with farmers, and learn about available farm products. The event emphasized the role a strong cooperative food hub is playing in facilitating the logistics of those sales relationships with restaurants. The primary event was a “Preserving the Harvest Farmer-Chef Meet and Greet” trade networking evening where farmers presented their products. Prior to the networking event, chefs and farmers were invited to an afternoon workshop in an on-site commercial kitchen to learn about using preservation as a strategy for incorporating local specialty crop ingredients into menus year round. Chefs, farmers, and other culinary tastemakers spent the day canning

and learning about food processing regulations while building relationships. Over 50 people participated in events of the day. The “Meet and Greet” trade networking event was bolstered by two prior tours for chefs and culinary professionals to 6 farms in the region. Approximately 30 culinary professionals participated in the tours which were organized in partnership with a local food systems non-profit.

#### Local Buying Mission #4: Yakima Valley - April 2017

The Yakima Valley Local Buying Mission Tour & Business Networking Social gathered 46 participants ranging from small to mid-sized diversified Specialty Crop farmers and buyers from restaurants, schools, retailers, and farmer’s markets. The Yakima Valley region presented the unique opportunity to strengthen direct market relationships for diversified small farms, mid-scale orchards and value-added producers. The event was built around the theme of pride in the agricultural heritage and industry of the valley to create local demand for local, source-identified specialty crop products. This event included three farm stops where farmers learned from their peers and buyers discovered the local and direct marketing farms in the region that produce a diversity of crops and value added products for local consumers but are overshadowed by the predominant tree fruit and other globally-oriented production that characterizes the region. WSDA took participants to Sunnyslope Ranch – a direct marketing organic soft stone fruit orchard where participants toured the orchard, scale-appropriate packing line, and dry and cold storage, heard the farmers describe their current and prospective market avenues, including for seconds, and value added products. Participants then toured two farm stands that retail products for a collection of seven different farms as well as local and regional value-added products, offers use of a cider press, and is the base for produce distribution via re-purposed insulated milk trucks throughout the valley. The final stop was a family farm that grows tree fruit and hosts short but intense u-pick season and extensive mail-order business that operates from their farm store. Bale Breaker Brewing Company, a local brewery that sources its hops from surrounding family farms, was the host site for the afternoon trade session which included a locally sourced lunch and presentation by the marketing team at Rooted Yakima Valley. Rooted promotes consumer-producers connections through media story-telling. The event concluded with speed networking and one-on-one technical assistance from WSDA’s Farm-to-School staff and project partners.

#### Local Buying Mission #5: Methow Valley - May 2017

The Methow Valley Farm-to-Chef & Shelf Farm Tour and Networking Event was held in Twisp. The Methow Valley is a distinct micro-region but the event drew participants from four surrounding counties and new connections were formed between farms across regions. The unique opportunity presented in this region of North Central Washington was to highlight the diversity of products farms offer and get local commitment from buyers to source from the region, reducing the miles traveled by producers to reach markets on the West side of the mountains. There were 30 participants ranging from small to mid-sized diversified farmers and buyers from restaurants, schools, resorts and retailers. The day’s events included an afternoon tour of two farms to learn about their unique marketing outlets both within the Methow region and Seattle area markets. Participants visited a small orchard that produces over 55 varieties of organic tree ripened pears and apples that they sell directly to consumers at Seattle area farmers markets and process into specialty products. Also on the tour was a diversified row crop operation that specializes in serving the Methow Valley with its produce ranging from micro-greens, root crops, and value-added sauerkraut varieties, made in an on-farm licensed processing facility. The afternoon continued with a group discussion on opportunities and challenges in sourcing and selling in the Methow Valley. Attendees discussed reasons why farmers in the Methow choose to sell outside of the region citing price and volume, and distance as considerations when weighing the long distances required for relatively small volume sales within the region compared to higher prices and sales volumes at more distant urban markets. However, the commitment to sourcing from Methow producers was apparent from all of the buyers present and the session resulted in a shared commitment experimenting with collaborative storage, aggregations, ordering, and delivery possibilities to make local sourcing work. A local agricultural organization will lend support for further development of the ideas surfaced. It was an encouraging takeaway for producers that attended the event.

#### Local Buying Mission #5: Clark County & SW Washington - September 2017

The Clark County & SW Washington Farmer-Buyer Mobile Workshop & Business Networking Event gathered 48 participants ranging from small to mid-sized diversified Specialty Crop farmers and buyers from restaurants, school districts, wholesalers, food hubs, CSAs, and farmer’s markets. Producers expressed the desire to work together to enter new markets through collaboration and possibly exploring starting a food hub for the region. Defining a brand identity of the region was also an ongoing conversation at this event. Key partners for the event included SlowFood SW WA and WSU Clark Co Extension. The day included a mobile workshop with three locations visiting a variety of farm operations ranging from a small diversified farm that markets its produce direct to restaurants and retailers, a small food processor that makes value added dried herb products with a WSDA processing license and on-farm facility, and a final stop at a future food aggregation

site, commercial kitchen center, and food business park that hopes to spark additional local food enterprises. A local Vancouver restaurant committed to local sourcing, a panel discussion on direct marketing opportunities featuring chefs, producers, and a distributor. Afternoon networking was focused around making one-on-one connections and also included a mini-session on selling to schools from WSDA's Farm-to-School staff.

### **Outreach & Education:**

WSDA Small Farm Direct Marketing staff was available to farmers and food businesses across the state for education and technical assistance via phone, email, publication and update of WSDA fact sheets for direct marketing producers, and through presentations at conferences and classes. Project staff responded to 93 direct requests for information and guidance from direct marketing specialty crop producers and food businesses. Project staff presented on specialty crop direct marketing topics at 18 classes and workshops for small farms hosted by other agricultural resource providers such as a Cultivating Success course at WSU Extension. WSDA also conducted outreach and education at 15 regional conferences, staffing resource tables and presenting.

For example, WSDA presented at the statewide Tilth Conference for small farms with a workshop titled "Exploring Direct Marketing Strategies in a Changing Marketplace". The workshop was designed to be participatory and interactive. Farmers were encouraged to think about their marketing strategies in the context of rapid market change where shoppers have more options than ever for buying "local" food with grab-n-go grocery, restaurants, meal preparation services, online ordering, customization, and home delivery. The workshop helped farmers explore how they can differentiate themselves and hone their direct marketing strategies by understanding and meeting the customers needs. In addition, the project staff presenter provided follow up 1:1 technical assistance and information to farms about direct marketing strategies and requirements via phone and email after the event.

An example of some of the outreach and presentations conducted include:

- Washington State Farmers Market Association Conference
- Focus on Farming Conference
- Tilth Producers Conference
- Women in Ag Conference
- Center for Latino Farmers Conference
- Bellingham Farm to Table Trade Meeting
- San Juan Agricultural Summit
- WSU Cultivating Success Classes

WSDA's goal for this project was to "Increase access to direct markets (retail grocery, restaurant, farmers market, CSA) for small-scale specialty crop growers/processors." That overarching goal is an on-going, long term objective. However, the specific Expected Measurable Outcomes for this project were defined by targets to be achieved within the period of the funded project.

The goal of this project was to foster new relationships between Specialty Crop Producers and Buyers that would lead to new sales relationships. The activities included technical assistance through conferences, presentations, and helping farmers and buyers develop direct marketing strategies as well as hosting six regional Local Buying Missions. Through project activities of TA, Outreach, and LBMs, WSDA achieved all goals and targets established through the project and serve farmers and buyers with new direct market knowledge to build successful sales relationships.

The first local buying mission workshop piloted a approach of a "Market Readiness" workshop series culminating in a local buying mission event. Based on success with this approach, the Yakima event took a similar approach. The approach was possible through a partnership between WSDA and the organization FamilyFarmed.org which worked with WSDA to bring their "Wholesale Success" to three regions in Washington, supported by a USDA RMA education grant. In further collaboration, WSDA staff hosted a Good Agricultural Practices workshop as a part of each series (funded by the Bridging the GAPs Specialty Crop Block Grant project).

Offering all three events under the umbrella of a "Market Readiness" series allowed WSDA to integrate technical assistance expertise from each of the projects. Combining the workshops offered a comprehensive set of resources and technical assistance to farms that highlighted how topics of post-harvest handling for quality, marketing, business management, and on-farm food safety practices all contribute to their success in accessing the direct markets they choose. Each workshop

served as an opportunity to connect directly with specialty crop producers a resource table, publications and in-person questions and guidance on market access topics.

By collaborating with local partners, each local buying mission was promoted with technical assistance offerings to support the event's "mobile workshop" tour and trade show. Through this model, the local buying missions were an opportunity to directly apply the lessons and information learned in some preceding workshops or technical assistance sessions. Following each event, WSDA continued to be available for follow-up one-on-one technical assistance to help growers build on sales relationships or new questions about market opportunities that they encountered during the local buying mission events.

Each local buying mission provided an opportunity to create a baseline measure of participant's interests and readiness to enter into new markets and make new sales. WSDA followed up these surveys one year to six months after each event to measure success towards the goals established for the project and was a successful approach in exceeding project targets and achieving success with this project.

The goal of this project was to "Increase access to direct markets (retail grocery, restaurant, farmers market, CSA) for small-scale specialty crop growers/processors."

The specific targets by which to accomplish this goal were as follows:

- 1) Producers:
  - a. 50 specialty crop producers/on-farm processors will enter new local markets.
  - b. 400 producers/on-farm processors will be impacted with new market knowledge.
- 2) Buyers:
  - a. 20 buyers will have new knowledge on buying raw and processed specialty crops directly from farmers and processors.
  - b. 15 buyers will purchase directly from new suppliers for raw and processed specialty crops.

Progress towards the objectives of impacting producer and buyer market knowledge and fostering new sales relationships was tracked through numbers of conference presentations, outreach events, 1:1 technical assistance delivered, and surveys of farmer and buyer participants in local buying mission events .

**The overall targets achieved are summarized as:**

- 1) **Producers:**
  - a. **53 specialty crop producers/on-farm processors reported entering new direct markets .**
  - b. **631 producers/on-farm processors will be impacted with new market knowledge.**
- 2) **Buyers:**
  - a. **43 buyers reported having new knowledge on buying raw and processed specialty crops directly from farmers and processors.**
  - b. **22 buyers reported making new direct purchases from specialty crop producers.**

Baseline surveys were obtained for each event through online registration which asked attendees to identify as producer or buyer and provide basic farm business information. At the event, evaluation surveys asked participants to report on sales connections made and new knowledge gained. Approximately 6 months to one year after each local buying mission, WSDA sent a follow-up survey to participants to obtain up to date information on sales relationships, entry into new markets, and knowledge gained from the event.

In total, 255 participants attended six regional local buying missions over the grant period. Of the 255 participants, 167 attendees completed initial baseline surveys at the event, and 50 participants completed follow up event surveys. Of those surveyed, 53 producers reported entry into new direct markets and 22 buyers reported making new direct purchases from Specialty Crop farmers they met at the event. In addition, 117 producers reported being impacted with new market knowledge thanks to participation in the local buying missions. Farmers reported gaining new knowledge on topics including on-farm stands, selling to chefs and restaurants, on farm food processing, making value added products, and selling to grocers. Over 50 buyers reported gaining new direct market knowledge on buying directly from Specialty Crop products from farmers due to their participation in a local buying mission.

In addition to data collected at local buying mission events, WSDA engaged over 1,500 individual producers, food businesses, and buyers through outreach events, conferences, and classes (approximately 600 in year one and 800 in year two). In addition, project staff recorded 98 1:1 technical assistance calls and emails made throughout the grant period; 37

of those calls where from buyers – increasing their knowledge on buying raw and processed specialty crops directly from farms, successfully completing target 2b by a healthy margin. WSDA conservatively estimates through conference and event sign-in sheets, materials given out, conversations documented through email and phone logs that over 500 producers were impacted with new market knowledge, successfully completing target 1b.

#### Local Buying Mission #1: Spokane Area Workshop Series – September & October 2015

WSDA gathered baseline data from participants to be compared to data gathered during subsequent annual surveys to all participants through evaluations at the workshops. The number of participants surveyed was approximately 30 individuals. Farmer participants reported on average 3 new sales relationships and buyers reported 2 new relationships. Responses for the follow-up survey were postponed due to staffing changes which made it a challenge to get responses from participants due to the extended amount of time between the event and follow up. Many producers and buyers acknowledged that the event had been helpful in making connections but only a few participants were able to quantify the impact of the event on their business. The response rate was about 21% with all growers reporting entry into new markets, and a few buyers making direct purchases from the event.

#### Local Buying Mission #2: Olympic and Kitsap Peninsulas - April 2016

41 people attended the mobile workshop and networking trade session. Base line data from initial survey of about 22 participants indicated that 60% of participants gained new market knowledge where 80% of participants were able to establish new market connections that may lead to sales, and 33% of participants made new sales connections at the event. Again, the follow-up survey for this event was postponed due to staffing changes, which made it a challenge to get responses from participants due to the extended amount of time between the event and follow up. The response rate was about 15% of those attending and 27% of those initially surveyed. Producers reported 90% entry into new markets, and 80% of buyers reported making direct purchases connections from the event.

#### Local Buying Mission #3: Snoqualmie and Snohomish Valleys - September 2016

Base line data from initial survey of about 30 of the 50 attending participants indicated that 65% of participants gained new market knowledge where 75% of participants were able to establish new market connections that may lead to sales, and 30% of participants made new sales connections at the event. The follow-up survey for this event was postponed due to staffing changes, which made it a challenge to get responses from participants due to the extended amount of time between the event and follow up. The response rate was about 18% of those attending and 30% of those initially surveyed. Producers reported 70% entry into new markets, and 60% of buyers reported making direct purchases connections from the event.

#### Local Buying Mission #4: Yakima Valley - April 2017

The follow-up survey for this event was conducted about 6 months after the event due to a condensed timeline resulting from staffing changes. This was a benefit in that more participants were able to recall the event and the impact, but not long enough to truly measure impact. All producers and buyers acknowledged that the event had been a meaningful experience leading to new relationships, increased knowledge and sales. The response rate was about 36% of those attending and 50% of those initially surveyed. Producers reported 80% entry into new markets, both buyers and producers reported an increase in market knowledge, and 50% of buyers reported making direct purchase connections from the event.

#### Local Buying Mission #5: Methow Valley - May 2017

Baseline survey (22 of 30 participants) at the event reported an average of six new connections at the event and two-three new sales relationships. The follow-up survey for this event was conducted about 6 months after the event due to a condensed timeline resulting in staffing changes. This was a benefit in that more participants were able to recall the event and the impact, but not long enough to truly measure impact. The response rate was about 38% of those attending and 47% of those initially surveyed. Producers reported 40% entry into new markets, both buyers and producers reported an increase in market knowledge, and 35% of buyers reported making direct purchase connections from the event.

#### Local Buying Mission #5: Clark County & SW Washington - September 2017

Baseline data from the day-of event survey was completed by about 35 participants indicating that 95% of participants gained new market knowledge where 70% of participants were able to establish new market connections that may lead to sales, and 40% of participants made 2-3 new sales connections at the event. Due to the timing of this final local buying mission being near to the project end date, the event survey is the only metric data for the event, though WSDA and partners anticipate an increase in new market entry and sales from producers due to conversations and connections made at the event.

## **BENEFICIARIES**

Farmers, buyers, local agricultural marketing organizations, and agricultural resource providers all benefited directly from attendance at local buying mission events. In addition farmers and buyers benefitted with technical assistance from WSDA staff related to new market entry, development of fresh sheets and suggestions on marketing and promotional materials, as well as information on market entry requirements and licensing. Peer-to-peer learning during the mobile tours and panels supported specialty crop producers and buyers with helpful information on communication and relationship building between farmers and buyers. Producers in particular benefited from this project's peer-to-peer learning and on-farm workshops showcasing how other producers both diversify their offerings as well as their direct market channels. Producers reported an increased knowledge of various direct market channels, diversified product offerings, value-added products, and exposure to new buyers. Buyers benefited from this project with peer-to-peer learning from other buyers on how they source locally from producers, building successful relationships with farms, and adjusting their purchasing models to work with local producers. In addition, this project benefited emerging and new farmers with access to resources and markets, plus peer mentorships from other farms, as well as Latino farms by providing translated and interpreted materials and outreach specific to the Latino population.

The Local Buying Mission project directly impacted over 255 Specialty Crop farmers and food businesses and indirectly impacted over 1,500 individuals in the food system across the state through outreach, education, and technical assistance. Collection of quantitative data demonstrating the outcomes of this project over time was limited due to the challenges of staff changes that resulted in a lag in follow-up surveys to participants. Improvements from the baseline reporting data, directly tracking sales that result months or years after initial contacts are made at a local buying event can be hard to track in the best of circumstances. Unfortunately, the effectiveness of follow up surveys intended to measure longer term sales outcomes from the local buying missions was reduced due to delayed administration of the survey and farms being unfamiliar with new project staff. To mitigate these impacts, WSDA made efforts to contact each participant of the local buying missions multiple times, through an online survey, personal emails, and phone calls. For those participants who did respond, resulting sales were likely underreported due to a few factors 1) the lag in reporting time – participants couldn't accurately remember whether sales increases were directly attributed to the project and 2) a hesitancy to respond on actually dollar amounts, be it increases or decreases, to their business bottom line.

There is also an inherent challenge of linking future sales that might have developed since Local Buying Missions due to the fact that it often takes a few instances of connection before a producer and buyer enter into a relationship that leads to new sales. WSDA has a thorough understanding of this challenge and sought to get qualitative data about relationships that would highlight some of the outcomes of the project. WSDA staff fostered relationships between producers and buyers through events, outreach, and technical assistance, however, reporting on the successful outcomes was up to whether the producer or buyer wanted to share data or tell their story. There will be ongoing sales developments long after the conclusion of this project that will be not captured by data measurements.

Qualitative responses gleaned through in-person follow up technical assistance and surveys indicate that the buying missions had their intended impacts. For example, in the Yakima region, McIlrath Family Farms was able to establish wholesale and new buyer connections leading to an increase in sales. Guerra's Gourmet Peppers was able to establish a new selling relationship to a local grocer for their value added products. J&M Mushrooms secured three new buyers at the event including one wholesaler for their gourmet mushrooms. In addition, a sense of regional pride was fostered around the vast variety of agricultural products in the region from apples to berries and mixed vegetables. Two farms opened up new farm stands the following growing season and were able to increase their sales through these new channels. Pasco Farmers Market was also able to recruit new farmers to sell at their market and diversify market offerings.

In Clark County and SW Washington, a unique connection was made between farmer George Brereton's apple orchard and the La Center School District. Because of the local buying mission event, La Center culinary staff were able to meet with Brereton and invite him to participate in the school district's first Harvest of the Month event with great success. La Center purchased apples from Brereton and he was invited to come to visit a school and present his apples during a Meet the Farmer event at La Center Elementary. The event was a hit with students and a great beginning to a lasting relationship between a producer and buyers.

## **LESSONS LEARNED**

This project promoted the importance of working regionally to support direct marketing farms and buyers, as each region is unique in its challenges and opportunities. WSDA staff found strong interest and desire for workshops that provided peer-to-peer learning, opportunities to meet with other producers and farmers of similar scales as well as learn from businesses

that have expanded their customer base or product offerings. The project resulted in enhanced collaboration between regional producers and buyers as well as service providers, often building a region's local branding efforts or latent pride in local agricultural offerings. For example, Yakima is often seen as a large production agriculture region but now has a burgeoning small scale agricultural scene that caters direct to consumers and retailers. The project successfully provided value in making direct connections that will lead to sales for producers and buyers.

The local buying mission model and WSDA's approach was intended to allow for flexibility in scheduling the missions in specific regions in order to be more responsive to the needs of regional partners and to leverage opportunities for collaboration as they emerge. For example, the Olympic/Kitsap Peninsulas and Yakima Valley missions were initially slotted to occur in fall of 2016. They were shifted to spring 2016 to when partnership opportunities arose that will allow the impact of the technical assistance model to increase by linking the buying missions with partner activities. The greatest lesson learned in this project is to collaborate whenever possible and find alignment with project partners. The first three local buying mission events were built on a series of direct marketing workshops while the last three were built on established regional relationships.

Key issues to take into consideration, which can vary greatly between regions, include the typical size and scale of specialty crop producers, the type and diversity of crops on a single farm, accessibility to markets of interest including geographic distance and the existence of distribution systems that are viable for small or direct marketing growers, possible mismatches in production volume and buyers' standard purchasing volumes, barriers and opportunities such as market-required food safety certifications, etc. For example, in the NE region where the first local buying mission was planned for October 5, 2015, most specialty crop producers grow mixed vegetables on very small acreage. In another region, this might lead to a strong interest in restaurant or farm stands as markets of interest but in Spokane, the recent formation of a cooperative "food hub" offered growers the ability to aggregate and distribute product together to schools and institutions. Their technical assistance requests were about food safety certifications and post-harvest packing and handling standards required by their markets of interest. Working closely with partners in the area and learning about the very particular needs of growers in that region allowed the design of the Spokane area local buying mission to highlight those markets of interest.

In addition, it is best to do follow up surveys with careful timing, not in a growing season, not too soon after, but not too long after, either. Due to staff turnover, WSDA experienced a lower response rate on follow up surveys than desired, despite calls and multiple emails. As explained in the section above, there were struggles in obtaining specific sales data, which resulted in developing additional follow up data collection approaches such as phone calls and customized surveys to participants which required an adjustment of the measurable targets from the original proposal.

Due to many local buying mission events reaching capacity and being shared through media and networking channels, there was a request for more workshops, a strong signal of interest in the regional food system and building stronger local economies.

Though goals and outcomes for this project were achieved, in order to expedite problem-solving, WSDA would encourage others considering a similar project to remain flexible and adjust when necessary. Due to staff turnover, targets were adjusted and timelines were altered. The result was a manageable project with attainable outcomes.

### **ADDITIONAL INFORMATION**

Total in kind match contributions to this project are estimated at \$42,584.

WSDA match contribution included the costs of indirect administrative support services for project staff, calculated at WSDA's federally negotiated indirect rate of 17.7% of salaries and benefits equal to \$34,086. WSDA also provided in-kind match in the form of the Project Director time dedicated to program financial and management oversight (\$530 for approximately 3hrs and 45 minutes per year including salaries, benefits, and indirect). Administrative Assistant time also contributed to the project (\$706 for approximately 15 hrs per year including salaries, benefits, and indirect).

Project partners also contributed in kind match in the form of event venues and catering including:

- Gonzaga University event space and Sodexo catering estimated at \$3,000
- 21 Acres Center for Sustainable Agriculture Education event space, catering, and a chef-demo in a licensed food preservation estimated at \$2,000.

- WSU Extension staff in Stevens, Spokane, Kitsap, Clallam, Jefferson, Clark, and Yakima counties all contributed staff time for outreach and promotion, estimated at \$1,500 (based on 8 hours per county at a generalized rate of \$27 per hour)
- WSU Clark County contributed the demonstration lunch featuring usage of ingredients from local farms prepared by a restaurant that sources directly from farms, valued at \$750

**Following Page: Photographs from Washington State Local Buying Missions Photographs**



A new farmer-buyer connection. Farm-direct local apple sales to the LaCenter School District are a result of the Clark Co. and SW Washington Local Buying Mission.



Farmers and chefs talk local ingredients and direct sourcing relationships at the King County local buying mission Farmer-Chef Meet and Greet.



Images from the Methow Valley local buying tour and networking meeting in N. Central Washington.



Farmers tour a university dining service to learn about direct marketing opportunities. Buyers hear from a produce grower and farmers and buyers talk in 1:1 sales meetings at the Spokane/Stevens local buying mission.



WSDA project coordinator introduces a panel of specialty crop producers and buyers who share their successes and challenges with direct farmer-buyer sales at the Yakima Valley local buying mission.

**CONTACT INFORMATION**

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**See Attachment C- 2014 SCBGP-FB**

## **PROJECT #12**

**Project Title:** Improvement of Honey Bees for Pollination: Evaluation of Genetic Differences

**Partner Organization:** Washington State University – Walter Shepard

### **PROJECT SUMMARY**

Managed honey bees are the primary pollinators of WA specialty crops, yet the honey bees currently used for pollination in Washington are derived from a subspecies that originated from and is adapted to a Mediterranean climate. While well-suited for warm regions of the US, these bees are less suited for pollination during periods of inclement weather (cold, wet) that often accompanies the bloom periods of tree fruit, small fruit and other specialty crops in Washington. Many specialty crops bloom during the early part of the growing season (cherries, apples, almonds, other tree fruits) or can be affected by rainy weather that reduces pollinating flight (cranberries and others). The impact of frost events in some PNW cherry growing districts has been estimated to result in a yield reduction of up to 40% due to lack of adequate bee pollination.

Honey bees and commercial pollinating operations in the US faced significant challenges in recent years due to a number of intersecting factors, including honey bee parasitic mites, new pathogens, and reduction of quality forage, pesticide stress and increasingly intensive agricultural monocultures, among others. Collectively, these have been attributed to be potential causes of Colony Collapse Disorder (CCD). Due to import restrictions in place since 1922, current honey bee stocks in the US contain only a subset of the genetic diversity of the original Old World populations from which all US populations are descended. Access to additional genetic diversity through germplasm importations provides a foundation for improvements in pest and pathogen resistance through bee breeding.

The team recently introduced germplasm of additional honey bee subspecies, including two that are endemic to cool climate geographical regions of Europe. The importation of honey bee subspecies from cold climates (Caucasus Mountains, Alps Mountains) makes it possible to select for improved foraging characteristics for WA specialty crop pollination in commercial honey bee stocks.

This project did not build on a previously funded SCBGP project.

### **PROJECT APPROACH**

Over the course of the project, queens from four different honey bee subspecies/strains and tested colonies headed by queens of each group were used for foraging behavioral differences in almonds (California), cherries, and apples (Washington) in 2016 and 2017. In addition to measuring foraging activity as a function of temperature variation and diurnal differences, data on rainfall, hygienic behavior, and wind and crop status were taken. Significant differences in hygienic behavior were found among the strains. Foraging activity was shown to be dependent on temperature, rainfall, and wind and colony strength. Comparison of the effects of low temperature on foraging propensity related to specific strains was inconclusive. Selection for hygienic behavior as practiced by commercial queen producers and in the WSU breeding program had a measureable effect to increase expression of this trait was concluded. Such selective breeding represents an important stock improvement tool, related to disease resistance. An unusual development during the Almond bloom in California in 2016, was the theft of frames from a portion of the experimental colonies (approximately 25% of the frames from 20 affected colonies were taken). Field trials in Washington were continued using the unaffected colonies and colonies needed for 2017 were replaced.

Contributions of project partners include:

- Dr. Brandon Hopkins – provided research oversight, bee breeding and field assistance.
- Sue Cobey – provided bee breeding assistance and insemination service.
- Megan Asche – graduate student assigned to this project conducted research in the field in 2016 and 2017.

The current study involved only evaluation and comparison of honey bee strains on specialty crops as originally directed.

## **GOALS AND OUTCOMES ACHIEVED**

Goal 1- Determine comparative subspecies performance... The team produced the majority of queens needed to head colonies used for this project using instrumental insemination (Caucasian, Carniolan) or natural mating in an isolated station (WSU Program). Commercial Italian queens were obtained through the collaborator Mr. Eric Olson and derived from commercial sources in California. Colonies were placed in commercial orchards in California and Washington State and data were collected on foraging activity, colony strength and abiotic factors, such as temperature, rainfall, wind, and solar radiation.

Goal 2- Evaluate honey bee subspecies/breeding strains for comparative resistance to pests and pathogens...The team measured all colonies for Varroa mite levels and hygienic behavior over the two field seasons of the project. Assessments were also made on a continual basis for diseases, including chalkbrood and American foulbrood.

Goal 3- Conduct a large-scale field comparative experiment in a commercial pollinating operation...in both field seasons of the project, experimental colonies were maintained within commercial pollinating operations during the pollinating season.

While the expected measureable outcomes were not technically long term, honey bee breeding and stock improvement is an ongoing process. The team recently demonstrated that a significant increase in genetic variability occurred in commercial honey bee populations that received germplasm from the WSU importation and distribution program. This effort will continue on behalf of honey bee stock improvement for US beekeepers.

GOAL 1: Proposed to compare subspecies performance in tree fruit orchards, cranberry bogs and small fruit plantings in Washington during wet and/or cool weather pollinating conditions. Pure breeding strains of three honey bee subspecies (*A. m. carnica*, *A. m. caucasica* and *A. m. ligustica*) were to be evaluated under variable early spring pollinating conditions in these crops in Washington. The team proposed to measure pollinating propensity, temperature parameters of foraging, colony growth rates, foraging behavior under inclement weather conditions (precipitation) and foraging range. Actual accomplishment: The team evaluated 4 genetic strains (instead of three), and included evaluation of early season performance in almonds in California. This is relevant because almost all commercial bees are moved to California for Almond pollination before being moved back to Washington for specialty crop pollination. The team concentrated on apples and cherries in Washington, as these are the early season crops that sometimes bloom during inclement weather. The team was unable to include cranberries due to logistical and transportation issues.

GOAL 2: Evaluate honey bee subspecies breeding strains for comparative resistance/tolerance to pests and pathogens. The team will screen experimental colonies for the presence and infection rate of parasitic mites (Varroa and tracheal), internal pathogens (Nosema) and brood diseases (American foulbrood and Chalkbrood). Actual accomplishment: This goal was fully accomplished as proposed.

GOAL 3: Conduct a large-scale field comparative experiment with multiple honey bee subspecies in a commercial pollinating operation. The team will compare the use of these three subspecies in a large commercial operation involved in active tree fruit, cranberry and blueberry pollination. Traits of apiculture importance (pollinating propensity, temperature parameters of foraging, colony growth rates, and foraging behavior) will be compared. Actual accomplishment: The team chose to include almonds as the earliest season crop for foraging behavior study. The bees were transported by semi-truck as part of a large commercial pollinating operation and placed in almonds in California. They were then moved back to Washington within the same operation for tree fruit pollination of cherries and apples. The team used both WSU and collaborator colonies as proposed.

EMO and GOAL 1: Proposed to compare subspecies performance ...Over 1900 individual foraging behavior measurements were made during the course of the project in orchards during wet and/or cool weather pollinating conditions. Under the time period and weather conditions of the study, no significant differences in foraging propensity at colder temperatures was apparent, although difference in hygienic behavior (an indicator of disease resistance) was noted. The recommendation to beekeepers would be that genetic improvement due to selective breeding is an important component to help assure pollination services using honey bees.

EMO and GOAL 2: Evaluate honey bee subspecies breeding strains for comparative resistance/tolerance to pests and pathogens... The team assessed the removal of freeze-killed brood to assess hygienic behavior - a trait known to be linked to disease resistance in honey bees. The finding of significant differences among strains indicates that beekeepers can enhance the overall colony health of their bees and reduce the need for antibiotic treatments by using stock that is selectively bred to exhibit this trait.

EMO and GOAL 3: Conduct a large-scale field comparative experiment with multiple honey bee subspecies in a commercial pollinating operation... This project represents one of the largest field studies undertaken to compare genetic strains of honey bees and provides a path to conduct future work in this area. In 2017, coincident with the current project, the effects of antiviral fungal extracts on 530 commercial colonies belonging to 4 collaborating beekeepers were evaluated. The use of commercial beekeeping operations to conduct research under “real-world” conditions provides both a large test bed for data gathering and an immediate connection to the key players within the pollinating industry. The latter serves to assist greatly in outreach and distribution of findings to beekeepers.

The following data findings, conclusions, and recommendations were made to beekeepers, growers and researchers at a series of meeting in 2017.

- 1) Significant differences in the expression of the selectable trait “hygienic behavior”, was found among the subspecies tested. Hygienic behavior (assessed by rate of diseased brood removal) at high levels allows honey bee colonies to effectively recover from infective, highly contagious diseases...including American Foulbrood.
- 2) Foraging behavior was more affected by temperature, rainfall, colony strength and wind than the genetic background of the foragers. Evaluation of local strains of honey bees is a viable approach to acquire regionally-adapted populations.
- 3) Genetic improvement by selective breeding is the most stable and sustainable long-term means to improve honey bee resistance to pests and diseases. Beekeepers can have a major impact on expression of this trait and once established, can reduce or eliminate the need to place anti-biotics inside the beehive.

2017 Venues where growers and beekeepers were addressed and received content described above:

Nov 30, 2017 Association of Applied IPM Ecologists - Visalia, CA  
Oct 13, 2017 North Dakota Beekeepers Assoc. – Jamestown, ND  
Sept. 30, 2017 Apimondia (World Beekeeping Congress) – Istanbul Turkey  
Aug 9, 2017 Queen rearing and instrumental insemination course - Algeria  
May 6, 2017 UC Davis Bee Symposium - Davis, CA  
April 27, 2017 European honey bee genetic meeting – Berlin, Germany  
January 14, 2017 American Beekeeping Federation – Galveston, TX

## **BENEFICIARIES**

The primary direct beneficiaries of this project are growers of WA specialty crops that require insect pollination. The project has provided beekeepers with useful information on strains of honey bee pollinators for WA specialty crops. New honey bee strains are available as a result of germplasm collection and release by WSU and propagation by commercial queen producers and this project helped define the potential advantages for both growers and beekeepers. While genetic differences in foraging propensity were not observed, differences were observed in hygienic behavior, a trait directly related to pest and pathogen resistance. This information can reduce in-hive antibiotic use and help maintain colony health for managed honey bee pollinator populations.

The quantitative data include measures of flight behavior (number of foragers/unit time), genetic strain, solar radiation, temperature, wind speed, rainfall, crop, time, hygienic behavior (freeze-killed brood removal), colony strength (frames of bees and brood) and presence absence of diseases (American foulbrood, chalkbrood), Nosema and tracheal mite prevalence and Varroa mite infestation rate.

The top forty WA agricultural commodities includes apples, cherries, pears, raspberries, strawberries, apricots and peaches with a total value of production of over \$3.1 billion dollars. Considering only the top specialty crop

(apples), there are over 1,700 Washington growers on about 150,000 acres. Estimates of pollination requirements in tree fruits alone in WA are 250,000 pollination “sets” (a “set” is one hive on one crop pollination cycle) and the value to beekeepers for tree fruit pollination alone (@\$60 per set) is \$15 million.

### **LESSONS LEARNED**

Primarily, aside from the scale of distances involved in conducting the study across geographic space, one of the main challenges involved the logistics of integrating a research project within a larger commercial pollinating operation. These included timing of the research efforts with movement and placement of colonies by the commercial operator within orchards. These were largely unavoidable, as the weather greatly affected the timing of bloom and grower’s need for spray windows and bee placement. Early spring weather also caused some inaccessibility due to mud in orchards and in some cases equipment had to be hand carried into the orchards with vehicles being left on the perimeter. On the positive side, the interest and support of growers and beekeeper collaborators was inspiring and gratifying. Students and staff working on the project felt they were involved in research that could have an impact on Washington agriculture in a meaningful way. The conclusions of the study point the way for future research that explores genetic variability within the honey bee. The finding of measureable differences in hygienic behavior among strains and the recent demonstration that genetic variability in commercial populations can be increased through germplasm distribution both suggest that genetic improvement of honey bees for agricultural needs is a sustainable and worthwhile approach.

No unexpected outcomes occurred during this project, other than the unexpected theft of a portion of the research bees during placement in almonds in 2016. Apparently, as pollination fees have increased, so has bee “rustling”.

The main lesson faced when actually conducting the field work, was the realization that similarities of bloom periods and geographical distances of growing regions made it a bit optimistic to think that simultaneous field studies could be conducted in the initial diversity of crops proposed, such as cranberries, small fruits, apples and cherries in a single year.

### **ADDITIONAL INFORMATION**

Olson’s Honey provided the use of 500 honey bee colonies for use in this research. At \$300 per hive, the value of the in-kind donations was \$150,000. Additional service, such as assistance with hive placement in the orchards, assistance with pulling out stuck bee trucks from the mud, etc. were not quantified but appreciated.

Currently two publications are in preparation related to this research and are expected to be submitted in spring of 2018

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## **PROJECT #13**

**Project Title:** Developing Innovative Practices to Enhance Low-input, Stress-tolerant Potatoes

**Partner Organization:** Washington State University, N.R. Knowles & M.J. Pavek

### **PROJECT SUMMARY**

The Pacific Northwest Variety Development Program (NWVDP) is a highly collaborative multi-state (WA, ID, OR) and multi-institutional effort focused on breeding new potato varieties. Selections from the program are evaluated using agronomic management tailored to the standard, input-intensive cultivar, Russet Burbank (RB). While this approach has served well in selecting and developing new varieties to replace RB (NASS, 2013), it falls short of identifying germplasm that is truly more efficient and stress tolerant. These attributes are only revealed by comparing the performance of clones grown under low input (e.g., N, P, water) and agronomically limiting conditions, and in response to controlled levels of stress (e.g., water, heat, inter-plant competition), where superior performance can be easily resolved. Stress not only impacts yield, quality and economic returns at harvest, but also attenuates retention of postharvest quality, resulting in increased storage losses (Zommick et al., 2013; 2014). This project identified genotypes that are truly more efficient in their use of agronomic inputs and tolerance of various stresses. Agronomic performance was evaluated under low-input production conditions with innovative planting designs to optimize interplant competition and maximize land use efficiency. Genotypes that were tolerant of heat, water and nutrient stress were selected for further work to develop best management practices, with a view to increasing resource utilization efficiency, maximizing economic return, and lessening environmental impact in the highly productive Columbia Basin.

Objectives of the research included: (1) assessing the tolerance of advanced clones and cultivars from the NWVDP to nutrient, water and heat stress; (2) optimizing plant population, interplant competition, and land use efficiency for selected traditional and newly developed cultivars; and (3) identifying potential techniques that can effectively increase the yield of raw product for processing.

Developing low-input cultivars with increased tolerance to heat and water stress will enhance the global competitiveness of the industry and contribute to the sustainability of production systems and to food security. Accordingly, a main goal of this project was to quantify the tolerance of advanced clones and cultivars from the NWVDP to nutrient, water, heat, and plant population stress. Results from the project are informing the development of best management practices that conserve resources (water, land, nutrients) and optimize yield, quality, and profitability for Washington potato growers. This project did not build on a previously funded SCBGP project.

### **PROJECT APPROACH**

Twenty-five in-field advanced agronomic trials to evaluate the efficiency of utilization of agronomic inputs (e.g., nitrogen, water, phosphorus) and stress tolerance of new clones and cultivars from the NWVDP, along with fourteen postharvest studies to assess subsequent effects on storability and retention of process quality, were completed from October 1, 2014 to April 30, 2017. Activities performed over the 2.5-yr study period were accomplished as described in the seasonal work plan table presented in the original proposal. These activities involved establishing and maintaining the field trials listed below, including application of water, fertility and heat stress treatments, processing tuber samples from in-season harvests, analysis of soil and petioles, application of plant growth regulators for tuber size distribution and shape studies, harvesting, sorting and grading of all trials (harvested in September/October each year), setting up storage studies with tuber samples from selected in-field trials, and data analyses.

Major goals of the research were to quantify the tolerance of selected advanced clones and cultivars from the NWVDP to nutrient, water, heat and plant population stress; evaluate planting designs to optimize plant population, inter-plant competition and land use efficiency for selected traditional and newly developed cultivars; and develop techniques for altering tuber length to width (L/W) ratios (tuber shape) of round but otherwise superior russet selections from the NWVDP. Five graduate students (3 PhD, 2 MS) were involved directly or indirectly in these trials as part of their degree requirements. The trials listed below were completed during the 2015 and 2016 growing seasons at the Othello Research Unit. All trials were showcased annually in June at the Othello Potato Field Day and results from selected studies were conveyed to stakeholders at the WA/OR annual Potato Conferences in Kennewick in January. Summaries of the significant results from each trial are provided below.

**Late Regional conventional (16 clones in 2015 & 19 clones in 2016) and low agronomic input evaluation screening trials (12 clones including Russet Burbank and Ranger Russet standard varieties)**

The objective of this trial was to identify advanced clones from the breeding program that have the potential to be produced more efficiently and sustainably than standard varieties. The clones were grown under conventional and low input fertility regimes (~50% of normal N and greatly reduced P and K). The results and recommendations are shown below:

- (1) Only 16% of the clones in the low input trial produced yields and economic return similar to the standard variety Russet Burbank when averaged across years. This included total yield, U.S. No. 1 yield, and pack out (carton yield).
- (2) Sixty-six percent of clones in the low input trial produced similar or higher yields and economic returns to the processing standard variety, Ranger Russet.
- (3) No clones were more efficient at producing yield when grown with the same agronomic inputs as the Russet Burbank control.
- (4) Clones in the low input trial only yielded 58% on average of what the clones in the conventional trial did.
- (5) Clones in the low input trial produced only half of the economic value of those in the conventional trial.
- (6) Relative to the industry standard (Russet Burbank), the newer clones were not more efficient under low input production. However, A03141-6 and Mountain Gem Russet produced similar results under low input conditions as Russet Burbank.
- (7) Compared to Ranger Russet, A03921-2, A03141-6, A06021-1T, Payette Russet, Mountain Gem Russet, Targhee Russet, AOR06070-KF, and Castle Russet produced similar or higher yield and economic return and could be used in low-input situations.
- (8) If possible, growers should follow university recommendations when producing any variety of potato. Reducing the inputs by 50% can lead to a 50% decrease in economic return.
- (9)

**Land use efficiency plant population trials – row width, in-row spacing, seed age x in-row spacing and directional planting trials (Clearwater Russet, Ranger Russet, Russet Burbank, and Umatilla Russet)**

Literature that explains why C. Basin growers plant potatoes into 34 inch rows is elusive if not nonexistent. Row width research was conducted between 2014-16 to identify the row width that maximizes grower revenue by optimizing land use efficiency, yield, and tuber size profile for certain varieties. Alturas, Chieftain, Ranger Russet, Russet Burbank, Russet Norkotah and Umatilla Russet were all planted into 28-, 30-, 32-, and 34-inch rows in 2014-16. Varieties were allowed to grow full season and harvested after 150 DAP. Results and recommendations are summarized below.

- (1) Research conducted on the WSU Othello Research Farm indicates that growers in the Columbia Basin of Washington and Oregon growing potatoes within the standard row width of 34-inches, may be planting too wide. Columbia Basin growers will most likely see an increase in economic return if they reduce their row width by two inches to 32-inches.
- (2) Averaged across years and seven varieties, total yield peaked somewhere between row widths of 30- and 32-inches, while the seed-cost-adjusted gross return peaked when rows were spaced 32-inches apart (Fig. 1). Planting potatoes into the current standard row width of 34-inches in the Columbia Basin appears to be an inefficient use of land and production inputs (irrigation, fertilizer, crop protectants, etc.).
- (3) The data indicate Columbia Basin growers should be planting into 32-inch rows. Tractor tires may have to be narrowed and equipment adjusted or eventually replaced. The average gain in yield across years and varieties was approximately 5% while the gain in economic return was around 4% (Fig. 1).
- (4) Other than a slight increase in irrigation quantity, seed, and extra rows to plant and maintain, growers should not need to increase their production inputs (fertilizer, protectants) significantly. All row widths included in the research trials were grown under 34-inch row management and in row spacing was fixed at 10 inches.

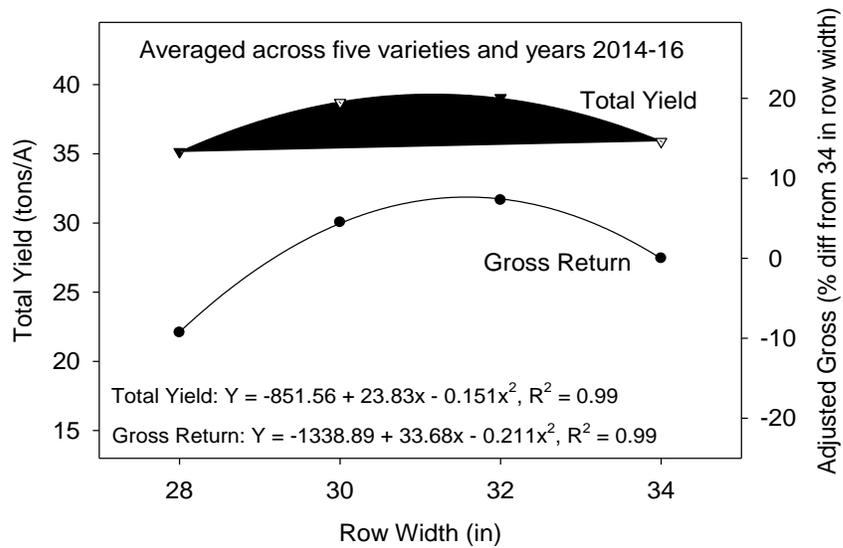


Fig.1. Effects of row width on total yield and gross return averaged across 2014-16 and five varieties: Alturas, Ranger Russet, Russet Burbank, Russet Norkotah, and Umatilla Russet. In-row spacing was 10 inches.

Acreage of Clearwater Russet is increasing rapidly as processors experience demand for the French fries produced from Clearwater Russet tubers. Small average tuber size has been an issue with this variety. The purpose of this trial was to identify the most economically feasible in-row spacing for Clearwater Russet in the Columbia Basin. During 2015-16, Clearwater Russet was planted at 8-, 10-, 12-, 14-, and 16-inches in-row at the WSU Othello Research Farm. Treatments were replicated 4 times. The trial was grown full season under standard Columbia Basin cultural management. Results and recommendations are shown below.

- (1) Yield decreased as plants were spaced farther apart; however, economic value tended to increase until it exceeded 12 inches in-row.
- (2) The adjusted gross value reached a maximum when Clearwater seed was planted between 11-12 inches in-row (Fig. 2).
- (3) From previous research, 11-12 inch in-row spacing was the economic optimum for Russet Burbank when grown near Othello, WA. Therefore, growers should plant Clearwater Russet, similar to what they use for Russet Burbank or 11-12 inches in-row in the upper Columbia Basin and 10-11 inches in-row in the lower Columbia Basin.

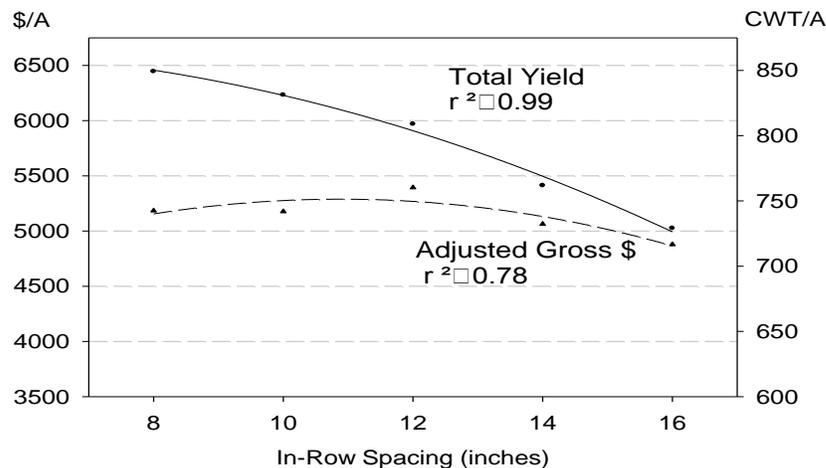


Fig. 2. Seed-cost-adjusted gross return (\$/A) and total yield for Clearwater Russet in 2015-16 across 5 in-row spacing treatments, 8-, 10-, 12-, 14-, and 16-inches. The trial was grown at the WSU Othello Research Farm.

Seed age x in-row spacing studies were completed for Umatilla and Ranger Russet. Seed aging decreased apical dominance, increased tuber set and shifted tuber size distribution toward smaller tubers without affecting yield. However, physiologically older seed planted at wider than conventional in-row spacing shifted tuber size distribution toward larger tubers, partly ameliorating the effect of age on reduced tuber size. Planting older seed at wider spacing may be economically advantageous because of the reduced seed expense on a per acre basis.

### **Nitrogen use efficiency studies - Clearwater Russet and Dakota Russet (harvest index, physiological maturity modeling, and effects on postharvest quality)**

Dakota Russet and Clearwater Russet (NWVDP) were grown under four levels of in-season N to model N use efficiency, define N requirements, and determine the effects of N on tuber physiological maturity and postharvest retention of process quality. Multiple harvests began ~56 days after planting and continued at approximately 12-day intervals through 186 days during the 2014, 2015, and 2016 growing seasons. Foliar and tuber growth were modeled as affected by N rate. The results for Clearwater Russet are particularly significant and timely as the industry begins to ramp up production in response to McDonalds recent (2016) acceptance of this cultivar for its signature French fries. A summary of growth and storage characteristics, along with key findings and recommendations for these cultivars is presented below.

- (1) Foliar biomass of Clearwater increased 31% (14.0 to 18.3 T/A) as N increased from 150 to 450 T/A. Total yield increased (11%, 3.9 T/A) as N rate increased from 150 to 350 lb/A, then fell by 1.4 T/A at the highest N rate (450 lb/A). A similar trend was characterized for the average yield responses of eight cultivars/clones over these N rates (2-3 seasons each, depending on cultivar). These cultivars/clones included Mtn Gem Russet, POR06V12-3, Targhee, A03921-2, A06084-1TE, A02424-83LB, GemStar, and Payette Russet. Maximum yield of these cultivars/clones was achieved at ~350 lb/A N and the increase in yield from 150 to 350 lb/A N averaged 2.8 T/A (8.2%). The economic implications of these yield increases in relation to N fertility recommendations are discussed below.
- (2) The ratio of tuber yield to whole plant (tuber + foliar) yield constitutes harvest index (HI) and is a measure of plant source/sink relationships at any point in time. N stimulated early foliar development and shifted the timing of 50% HI (where foliar and tuber growth curves intersect and yields are equal) from 83 to 90 DAP.
- (3) Averaged over the N rates, maximum foliar growth was achieved at 100 DAP. Moreover, HI at maximum foliar growth favored tuber growth over foliar growth at all N rates. When grown with 150 lb/A N, tubers accounted for 62% of total plant (tubers + foliage) fresh weight. This percentage decreased to 55% as N fertility increased to 350 lb/A (optimum rate), then increased slightly to 57% at 450 lb/A N. The 350 lb/A N rate resulted in ~3.1 T/A more foliar growth, which was maintained longer into late bulking than with 150 lb/A N. **The optimum source to sink ratio (55% HI at 100 DAP) for achieving maximum tuber yield of Clearwater was thus achieved with 350 lb/A N. Lower or higher N rates resulted in too much sink (tubers) for the available source (foliage) at ~100 DAP, thus contributing to lower yields.**
- (4) Yield increases with increasing N (150-450 lb/A) during 2014 and 2015 were modest, averaging 2.5 T/A (7.9%) for Clearwater and 3.8 T/A (12.1%) for Dakota Russet. Similar trials with Alpine and Sage Russet (2011-13) showed more substantial increases in yield (15 to 18%) with these N rates. The modest yield responses of Clearwater and Dakota to N in 2014 and 2015 may have been due to the excessively high heat during those seasons. N rate affected soil and petiole nitrate levels, foliar growth, selected indices of foliar and tuber growth (see above), and tuber total N content during these years, but this did not translate to large increases in yield. By contrast, record yields were achieved in 2016 for Clearwater on the Othello station. Yields in 2016 increased from 41.9 to 51.2 T/A (22%) as N increased from 150 to 350 lb/A then decreased to 48.7 T/A at 450 lb/A N. Past studies have shown that in 'cooler' years, tuber yield often correlates directly with N-induced increases in foliar growth. In hot years, this correlation may fall apart - foliar growth increases with N but tuber growth does not benefit as much, especially at higher levels of N. **From a practical standpoint, it should be possible to significantly decrease N rate during excessively warm growing seasons with minimal impact on yield, which may boost economic returns.**
- (5) Average tuber fresh weight of Clearwater increased 11% (6.6 to 7.4 oz/tuber) as N increased from 150 to 350 lb/A. No additional increase was observed at 450 lb/A N.
- (6) Tuber sucrose levels fell rapidly from 60 to 100 DAP and then remained at relatively low levels during late bulking and maturation. The attainment of maximum specific gravity was delayed with increasing N rate. Tubers grown with 150 and 350 lb/A N had final gravities averaging 1.095 and 1.088, respectively, over the 3-yr study period.

- (7) Similar to sucrose, reducing sugar (RS) concentrations were highest at 60 DAP when tubers were less than 1 oz in weight. Tuber RS concentrations at 60 DAP decreased with increasing N rate, a consequence of the more advanced early tuber development at the higher N regimes. Tuber RS concentrations fell from 60 to 100 DAP, remained low and constant through 130 DAP, then increased in the stem end of tubers through 186 DAP. The end-of-season increase in stem end reducing sugars was substantially greater for Clearwater than Dakota tubers, which correlated with darker stem end fry color for Clearwater tubers early in the storage season.
- (8) Tuber physiological maturity (PM) was calculated by averaging DAP to maximum yield, maximum gravity, minimum sucrose, and minimum RS in the stem ends of tubers. PM was delayed by 12 days (from 133 DAP to 145 DAP) with increasing N rate. Most importantly, the end-of-season post-PM increase in stem-end RS was attenuated at 450 lb/A N, resulting in lower RS in tubers 9 days after harvest, and 14% (2014) to 23% (2015) lighter fry color compared with tubers grown with 150 lb/A N by 229 days after harvest.
- (9) Tuber RS concentrations in 2014 and 2015 remained low and relatively constant over 7.5 months of storage at 48°F and were not affected by N rate. At 44°F, RS concentrations increased during the first month of storage and then remained constant or decreased over the 7.5-month storage period depending on N rate. By 229 days of storage, tuber RS concentrations in tubers grown with 350 and 450 lb/A N were 23 and 52% lower, respectively, than the average of tubers grown with 150 and 250 lb/A N and this resulted in lighter process color as described above.
- (10) Similar to other cultivars (e.g., Alpine and Sage), N fertility affected the timing of attainment of tuber PM for Clearwater and Dakota Russet, which in turn influenced buildup in reducing sugars and process quality at harvest and during storage. Clearwater and Dakota, however, are inherently resistant to low temperature sweetening (LTS) and this trait confers increased tolerance of delayed harvest beyond PM for maintaining low sugars and retention of process quality during storage compared with LTS-susceptible cultivars. **Nonetheless, this research demonstrates that tubers should be harvested as close to PM as possible (e.g., within 10 days of PM) for maximum retention of process quality during long-term storage. Therefore, planting dates, vine kill dates, and harvest dates should be coordinated to limit over-maturation of tubers under dead vines at season end. Tubers should be harvested within a week to ten days of achieving PM, which normally occurs approximately 140 to 150 DAP (approximately 2800-3200 cumulative degree days (45°F base) from planting in the central Columbia Basin). PM can be gauged by days after planting, cumulative degree days, and the degree of vine senescence.**

**Cultivar yield responses to N rate screening studies (4 N rates x 6 cultivars – Mountain Gem Russet, Targhee Russet, POR06V12-3, GemStar Russet, A03921-2 and Payette Russet)**

The responses of six cultivars to four levels of in-season N were evaluated to identify low N use varieties, determine optimum N rates, maximize grower income, and minimize potential N leaching. Petiole and soil samples were collected every two weeks for analysis of N and quantification of in-season N use efficiency. Results and recommendations are summarized below.

- (1) Nitrogen use efficiency (yield/unit N) decreased for all cultivars with increasing N rate.
- (2) Total and marketable yields increased an average of 12% (~5 T/A) across cultivars as N increased from 150 to 450 lb/A.
- (3) Tuber specific gravity fell modestly with increasing N rate.
- (4) Retention of process quality as affected by differences in seasonal N rate is currently being evaluated for tuber samples of all cultivars over full season storage.
- (5) Petiole and soil data demonstrated treatment differences throughout the year.
- (6) Yield and economic values varied across varieties, all appeared to be slightly unique.
- (7) Based on the data, Columbia Basin growers should use 300-325 lbs./A of N per year for Mountain Gem Russet, A03921-2, and A06084-1TE
- (8) Clearwater R., POR06V12-3, and Targhee R. should be grown with 350-375 lbs./A of N
- (9) GemStar R., and Payette R. should be grown with 375-400 lbs./A of N.
- (10) The petiole and soil values associated with the most economically feasible nitrogen rate will be charted and available to growers as a production guide.

**Additives to enhance Phosphorus use efficiency trial**

This research was conducted from 2014-16 to determine if products like AVAIL, Accomplish, or MESZ allow growers to use lower rates of P fertilizer or enable recommended rates of P fertilizer to be available to the plant longer throughout the

year. Umatilla Russet, a standard processing variety was chosen for testing. P Fertilizer was applied during planting in the form of 10-34-0 (50-, 100-, and 200-lbs/A P<sub>2</sub>O<sub>5</sub>), MESZ (50- and 100-lbs/A P<sub>2</sub>O<sub>5</sub>), Accomplish (50- and 100-lbs/A P<sub>2</sub>O<sub>5</sub>), and AVAIL (50- and 100-lbs/A P<sub>2</sub>O<sub>5</sub>) and applied to P deficient soils (< 14 ppm P) with a high pH (>7.0). Results and recommendations are below.

- (1) As with previous years, none of the treatments produced significantly higher gross returns than the non-treated control.
- (2) These products produced similar yields to the industry standard 10-34-0, but failed to pay for themselves when economic return was assessed.
- (3) The data also demonstrated that a rate of 227 lbs./A of P provided the greatest return versus the 113- or 454-lb/A rates. This would imply that applying rates greater than 227 lbs. P/A, which many growers do, may result in a loss of return to the grower and an over application of phosphorus from a sustainability standpoint.
- (4) Applying standard fertilizer (10-34-0 or 11-52-0) worked as well or better than any of the P supplements in this trial.
- (5) Growers are cautioned that using high quantities of P (454 lbs. or greater) may result in a loss of yield and economic value.

### **Water stress and use efficiency trial – (2-3 evapotranspiration (ET) levels x 9 cultivars – Bondi, Alturas, Targhee, Classic, Clearwater, Payette, Ranger, Russet Burbank, Umatilla Russet.)**

Nine cultivars (Alpine, Umatilla, Clearwater, Alturas, Ranger, Payette, RB, Targhee and Classic) were grown full season under three water regimes in 2016 (45, 65 and 100% ET, evapotranspiration) and two water regimes (65 and 100% ET) in 2014 and 2015. The 2016 water stress trial was affected by early die syndrome, which greatly reduced yields of most cultivars and confounded the study. This report therefore focuses on water use efficiencies (WUE) and the effects of water on storability of tubers from the 2014 and 2015 trials only (7 cultivars). Evapotranspiration was estimated by a modified Penman method and calculated using AgWeatherNet data (<http://weather.wsu.edu/awn.php?page=wateruse>) collected at WSU Othello, WA from June 3 to September 17, 2014 and May 15 to September 9, 2015. Planting date was April 15 in both years, vines were mowed September 15, 2014 and September 9, 2015, and tubers were harvested Oct. 1, 2014 and Sept. 18, 2015. Results and recommendations are summarized below.

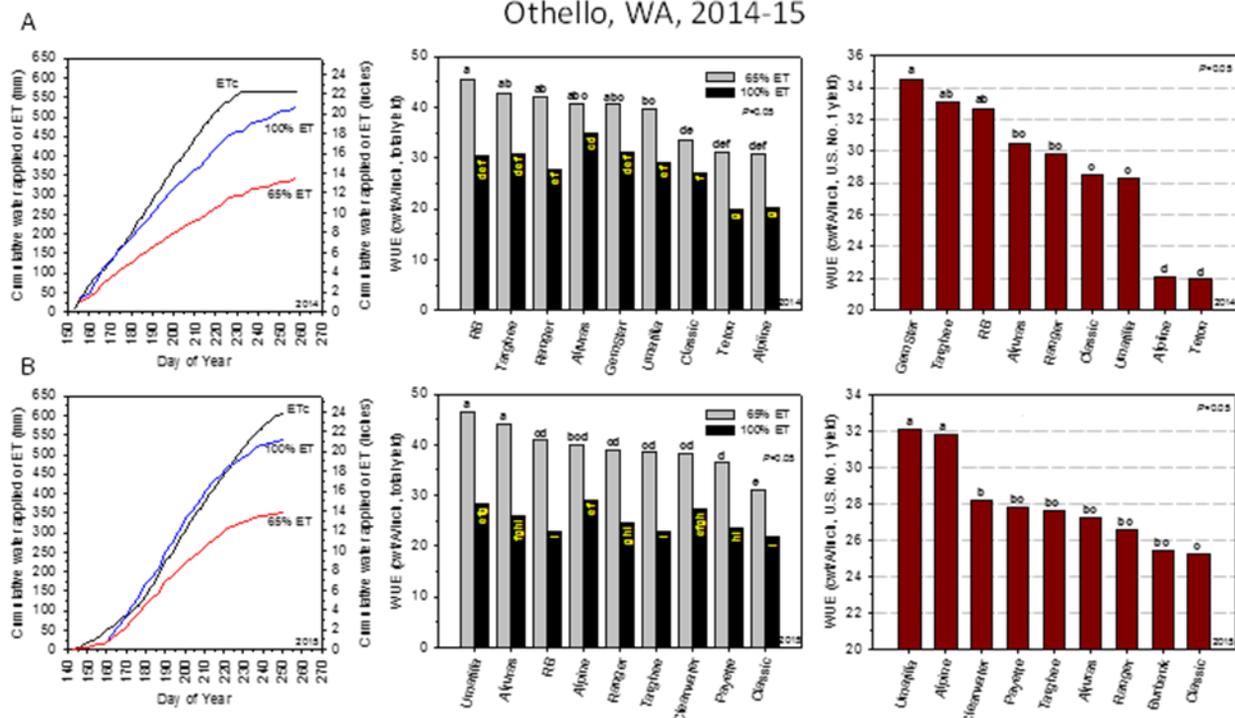
- (1) Cumulative water application amounts (irrigation + rainfall) were quantified with rain gauges located in the center and periphery of each mainplot. Plots were irrigated by central pivot with VRI technology. The design was a split plot with irrigation level as mainplot and cultivar as subplots (4 replications, 16.7-ft plots, 10-inch in-row spacing) in both years.
- (2) Fig. 3 shows the amount of water received by the plots (irrigation + precipitation) relative to the ET needs of potato in 2014 (A) and 2015 (B). Estimated seasonal ET was 564 mm (22.2 in) in 2014, which was 6.4 to 9.9% higher (7.8% avg) than during the previous 4 years (2010-2013). Including water applied prior to emergence, plots received 14.9 and 22.3 inches (378 and 566 mm) total over the 2014 season. Estimated seasonal ET was 640 mm (25.2 in) in 2015, which was 14% higher than 2014 and 23% higher than the previous 4-yr average (2010-2013), reflecting the warmer growing season. Including water applied prior to emergence, plots received ~16.6 and 25.2 inches (422 and 640 mm) total over the season. Water application totals were close to the target amounts of 65 and 100% ET in both seasons (Fig. 3 A and B).
- (3) For the 2014 trial, the ANOVAs for total and U.S. #1 yield showed significant main effects of water and cultivar. There was also a significant interaction of water x cultivar to affect U.S. #1 yields. On average, total and U.S. #1 yields were 7.7 and 6.7% lower, respectively, when the cultivars were grown at 65% ET compared with 100% ET. Marketable yield (U.S. #1 + <4 oz tubers) was 8.8% lower under the low water regime. Averaged over the cultivars, water stress specifically decreased the number of tubers per plant and per acre, and the yields of <4 oz, 12-14 oz, and >14 oz tubers.
- (4) The three cultivars most impacted by water stress in 2014 were Alturas, Classic and GemStar Russet. Decreases in marketable yields were 22.2% (Alturas), 16.8% (Classic) and 13.5% (GemStar). Water stress shifted the tuber size distribution profiles toward greater percentage of smaller tubers for all three cultivars. Collectively, these effects reduced overall crop values by \$1,752/A, \$876/A, and \$771/A for Alturas, Classic and GemStar, respectively. Interestingly, the remaining six cultivars (Alpine, Targhee, Teton, Ranger, RB and Umatilla) were mostly insensitive to reduced water for effects on marketable yield and tuber size distribution.
- (5) Water use efficiencies (WUE) for total, U.S. #1 (Fig. 3 A) and marketable yields (data not shown) in the 2014 trial were affected by water level and cultivar with no interaction. WUE ranged from 20 to 46 cwt/A/inch, depending on cultivar and water level. Averaged over cultivars, WUEs were 38% (total yield) and 40% (U.S. #1 yield) greater

at 65% ET than at 100% ET. GemStar, Targhee, Burbank and Alturas were the most efficient at producing yield per unit water, averaging 37 and 33 cwt/A/inch of water for total and U.S. #1 yields, respectively (Fig. 3A). In contrast, Alpine and Teton Russet were least efficient, averaging 26 cwt/A/inch for total yield and 22 cwt/A/inch for U.S. #1 yield.

- (6) For the 2015 trial, average (over cultivars) total and U.S. #1 yields were not affected by deficit irrigation. As indicated above, the water-induced reductions in total and U.S. #1 yields in 2014 were marginal (-1.8 to -2.4 T/A). **The data collectively suggest that the 100% ET irrigation model for potatoes in the central Columbia Basin could be revised significantly downward to conserve water with little effect on productivity. Clearly, 65% of recommended ET had minimal to no effect on yields of a diverse range of late season russet cultivars over the 2-yr study period.** However, tuber size distributions for some cultivars were affected by the reduced water.
- (7) Averaged over the cultivars in 2015, 65% ET increased the number of tubers per plant and per acre and decreased average tuber weight. Yields of 4-6 and 6-10 oz tubers increased and yield of >14 oz tubers decreased, characterizing a shift in tuber size distribution induced by the reduced water regime. In contrast to 2014, water rate had no effect on the marketable yields (U.S. #1 + <4-oz) of any of the cultivars in 2015. However, tuber size distributions of Alturas, Targhee, Clearwater, Payette and RB were significantly affected by water. The remaining four cultivars (Alpine, Classic, Ranger and Umatilla) were mostly insensitive to reduced water for effects on tuber size distribution. A similar shift toward higher yields of smaller tubers with reduced water was apparent for selected cultivars in 2014.
- (8) The effects of water level on WUE for total yield (cwt/A/inch) in 2015 depended on cultivar (Fig. 3B; water x cultivar,  $P < 0.05$ ). At 100% ET, Alpine, Umatilla, Clearwater and Alturas had the highest WUE's. At 65% ET, Umatilla and Alturas had the highest WUE's (Fig. 3B). Averaged over water levels, Umatilla, Alpine, Alturas and Clearwater had the highest WUE's for total yields. Significant main effects of water and cultivar were characterized for U.S. #1 yield (Fig. 3B). On average, the 9 cultivars produced 34 cwt U.S. #1 yield/A/inch of water when grown at 65% ET compared with 22 cwt/A/inch when grown at 100% ET (a 55% difference in WUE). Umatilla and Alpine had the highest WUE's for U.S. #1 yields (Fig. 3B).
- (9) Tuber samples from the 2014 and 2015 trials were stored at 44 and 48°F for 237 days to assess the effects of deficit irrigation on retention of fry process quality (stem end fry color). The extent of darkening of fry color (decrease in photovolt reflectance) over this 8-month storage period was expressed as a percentage of zero-time fry color and compared for tubers grown with 65 and 100% recommended ET and stored at both temperatures. Regardless of water regime and storage temperature, tubers of all cultivars retained acceptable process quality (USDA 0-2 stem end fry color) over the 8-month storage period. As expected, tubers stored at 48°F produced lighter fries than tubers stored at 44°F (data not shown).
- (10) Regardless of water regime and storage temperature, tubers of all cultivars retained acceptable process quality (USDA 0-2 stem end fry color) over the 8-month storage period. As expected, tubers stored at 48°F produced lighter fries than tubers stored at 44°F (data not shown).
- (11) When stored at 48°F, ET regime affected the retention of process quality of Alpine, Alturas, Targhee, Classic, and Russet Burbank tubers ( $P < 0.08-0.0001$ , depending on cultivar). Relative to fry color at harvest (zero-time), Alturas, Targhee, Classic, and RB tubers grown at 65% ET produced darker fries after 8 months storage (48°F) than tubers grown at 100% ET (data not shown). The opposite trend was apparent for Alpine tubers.
- (12) When stored at 44°F, ET regime affected the retention of process quality of Alpine, Alturas, and RB tubers ( $P < 0.08-0.001$ ). The loss of process quality for Alturas and RB tubers grown at 65% ET was greater than for tubers grown at 100% ET from 0-237 days of storage. The opposite trend was again apparent for Alpine tubers; tubers grown at 65% ET retained better process quality over the 8-month storage period at 44°F than tubers grown at 100% ET (data not shown).

# Water Use Efficiencies of Late-season Russet Cultivars

Othello, WA, 2014-15



**Fig. 3.** Cumulative water applied (irrigation + precipitation) to achieve target regimes of 65 and 100% evapotranspiration (ET) for potatoes in 2014 (A, top row) and 2015 (B, bottom row). ET was estimated from AgWeatherNet data at WSU Othello, WA. Planting dates were April 15 (both years), vines were mowed Sept. 15, 2014 and Sept. 9, 2015, and tubers were harvested Oct. 1, 2014 and Sept. 18, 2015. In 2014, estimated seasonal ET was 564 mm (22.2 in), which was 6.4 to 9.9% higher (7.8% avg) than during the previous 4 years (2010-2013). Including water applied prior to emergence, plots received 14.9 and 22.3 inches (378 and 566 mm) total over the season. In 2015, estimated seasonal ET was 640 mm (25.2 in), which was 14% higher than 2014 and 23% higher than the previous 4-yr average (2010-2013). Including water applied prior to emergence, plots received ~16.6 and 25.2 inches (422 and 640 mm) total over the season. Water use efficiencies (WUE) for total yield (middle) at 65 and 100% ET and U.S. #1 yields (right, averaged over 65 and 100% ET) are shown for the nine cultivars grown in each season. Letters indicate mean separation via LSD ( $P < 0.05$ ).

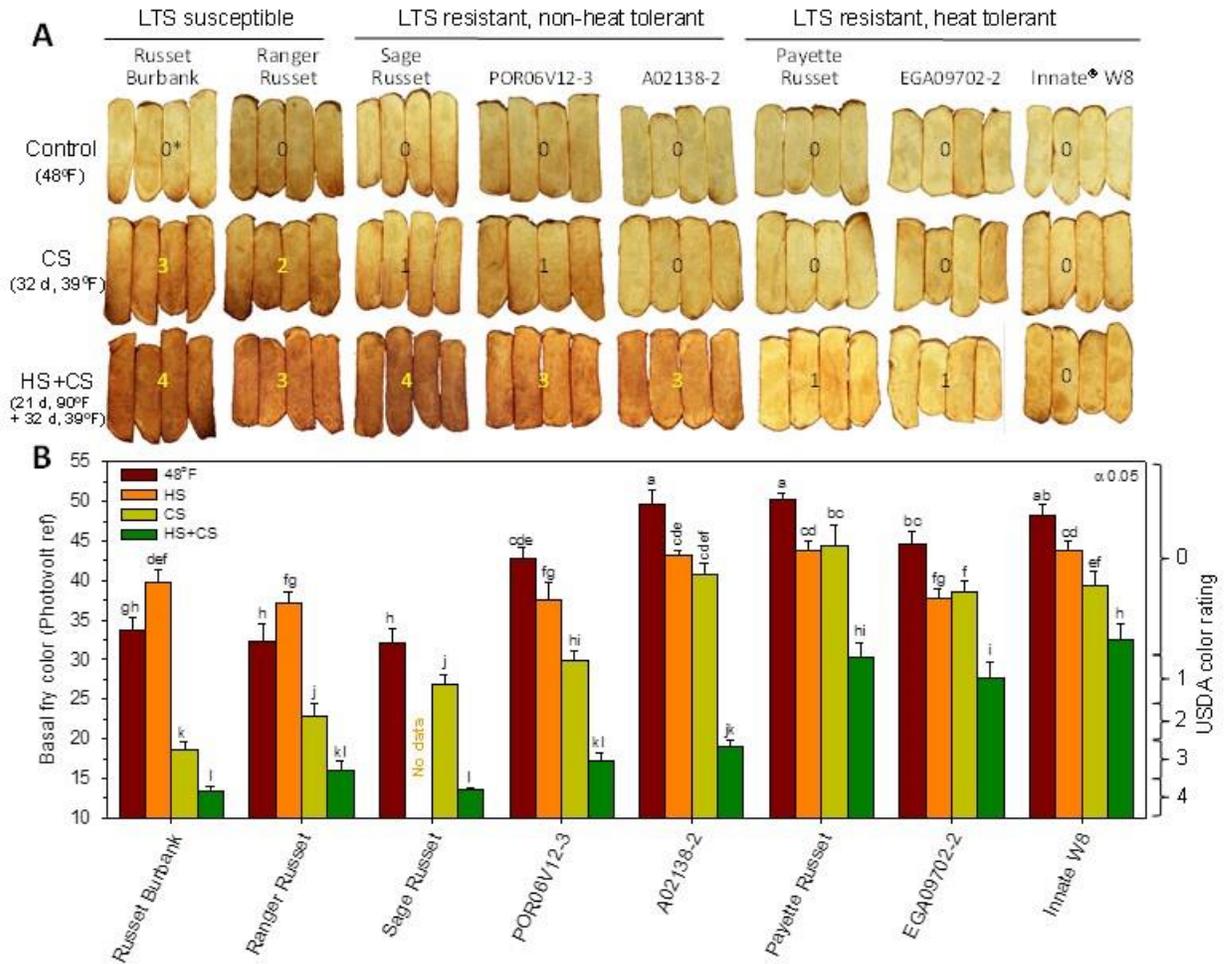
## Heat stress trials - screening for tolerance to high temperature (Russet Burbank, Ranger Russet, Clearwater, A03141-6, A03921-2, A03141-6, POR06V12-3, A02138-2, Payette Russet).

The heat cable plots were used to screen advanced clones for heat tolerance for retention of process quality and low temperature sweetening (LTS) resistance. Russet Burbank, A03141-6, A03921-2, and Clearwater were screened in 2016; Ranger, Clearwater, Payette, and A03141-6 were screened in 2015; and Ranger, A02138-2, POR06V12-3, and Payette Russet were screened in 2014. Replicated plots of each cultivar/clone were exposed to +14°F soil temperatures for 20 and 40 days starting ~80 (early bulking) or 120 days after planting (late bulking/maturation). All clones except Ranger and Russet Burbank were bred to have a high degree of resistance to low temperature sweetening (LTS) during storage.

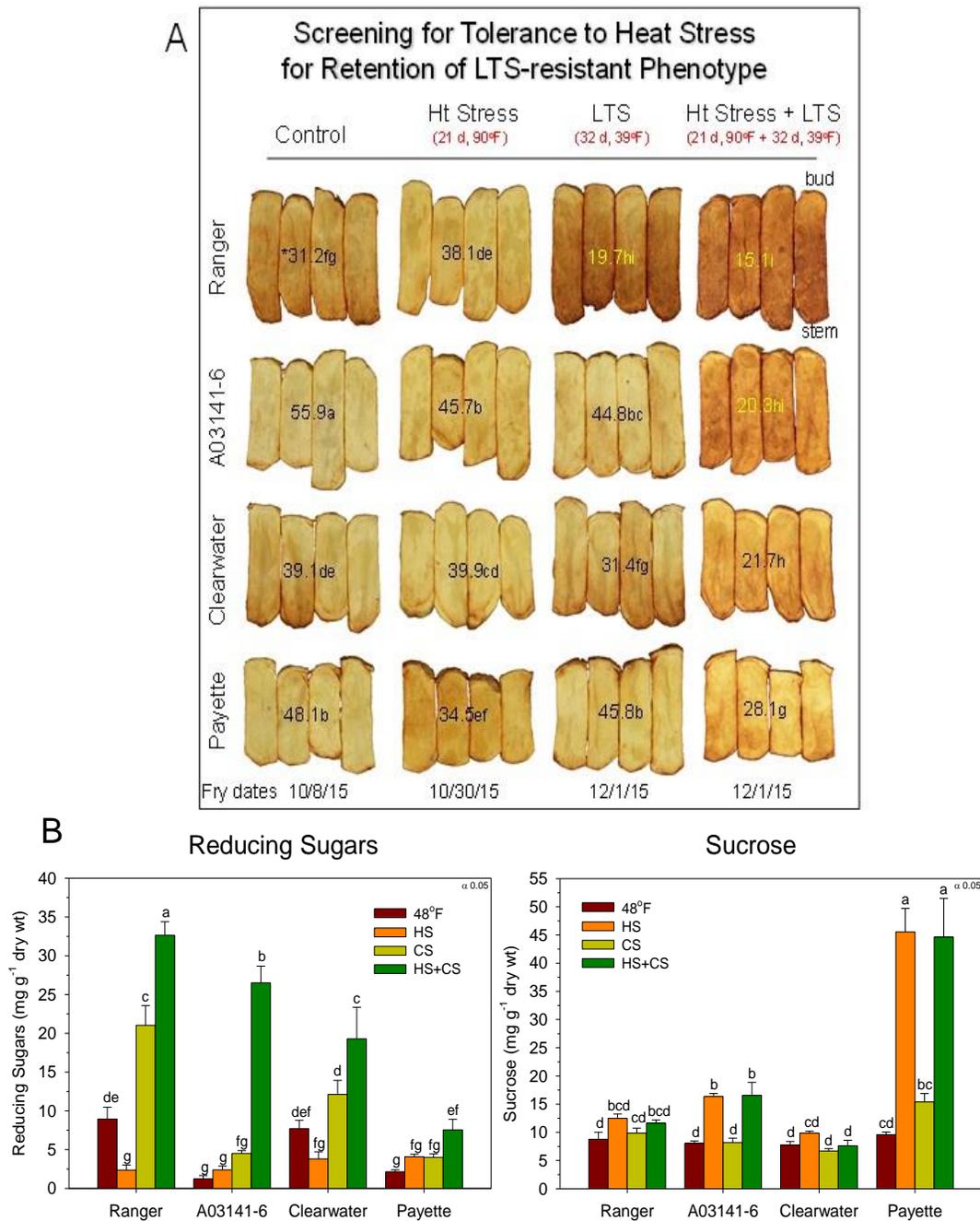
- (1) Compared with control (no heat stress), specific gravities were lower in tubers exposed to elevated temperature during early bulking (80 to 120 DAP). Moreover, 40 days of heat during early bulking produced lower gravity tubers than 20 days of heat in all years. Heat stress during late bulking/maturation (120 to 160 DAP) had less effect on gravities than heat stress applied during bulking regardless of duration (20 or 40 days).
- (2) Sensitivity to early vs late season heat applied for 20 or 40 days depended on cultivar. For example, relative to Ranger Russet; Clearwater, Payette and A03141-6 tolerated 20 days of early season heat for retention of process color when stored at 48°F, but fries were noticeably darker from tubers exposed to 40 days of early season heat. Late season heat stress had little effect on fry color following 24 days' storage at 48°F.
- (3) **Collectively, the heat cable studies demonstrated that the LTS-resistant trait could be compromised by exposure of tubers to high soil temperatures at various developmental stages during the growing season.** Most LTS-resistant cultivars lost some degree of their resistance to cold sweetening during storage as a consequence of prior exposure to heat stress during the growing season. The exception was Payette Russet, which showed robust resistance to heat stress for retention of the LTS-resistant trait.

- (4) A postharvest heat stress (PHHS) protocol was developed to more efficiently screen a greater number of clones for tolerance to heat stress for retention of process quality. This protocol produced similar results to the in-field heat cable procedure but with less variability, and facilitated further evaluation of the effects of heat on retention of LTS-resistant phenotype. Tubers were subjected to a heat priming (stress) period of 21 days at 90°F directly following harvest. This treatment alone had no deleterious effect on fry color (Fig. 4). Heat-primed or control tubers were then placed at 39°F to sweeten for an additional 32 days and changes in fry color (Fig. 4) and sugars were evaluated.
- (5) Heat stress prior to cold storage exacerbated cold-induced sweetening of the LTS-susceptible cultivars, Russet Burbank and Ranger Russet, resulting in high reducing sugar concentrations and unacceptable dark colored fries (Figs. 2 and 3). Consistent with their LTS-resistant phenotypes, non-heat stressed tubers of Sage Russet, POR06V12-3, A02138-2, A03141-6, Clearwater, and GemStar Russet (data not shown) maintained relatively low reducing sugar concentrations and produced light colored fries when stored for 32 d at 39°F (Figs. 4 and 5). However, heat stress prior to cold storage abolished the LTS-resistance of these cultivars/clones, resulting in significant deterioration of process quality. **In contrast, heat-stressed tubers of Payette Russet, its maternal parent, EGA09702-2, and Innate<sup>®</sup> Russet Burbank (W8) maintained their LTS-resistant phenotypes, producing light color fries in response to the HS+CS treatments.** This was not the case for Payette's paternal parent, GemStar Russet, which as described above lost its inherent ability to resist LTS when subjected to heat stress. Therefore, it is likely that Payette Russet inherited its robust tolerance to heat stress from EGA09702-2.
- (6) Further work demonstrated that the tolerance of Payette (and likely EGA09702-2) to heat for retention of LTS-resistant phenotype and thus process quality (Fig. 4) was conferred by reduced sensitivity of invertase to cold induction (Herman et al., 2016), resulting in the buildup of sucrose in heat-primed tubers during cold-sweetening (Fig. 5B). Indeed, heat-primed tubers of Innate<sup>®</sup> Russet Burbank (W8) in which acid invertase is silenced (Clark et al. 2014) displayed a sucrose-accumulating/low reducing-sugar phenotype similar to Payette Russet tubers during LTS (Herman et al., 2016).
- (7) The PHHS and in-field heat cable studies facilitated classification of ten conventionally bred cultivars/clones and the genetically engineered Innate<sup>®</sup> Russet Burbank (W8) cultivar (provided by the J.R. Simplot Co., Boise, ID) into one of three categories: **'LTS-susceptible', 'LTS-resistant but non-heat tolerant', or 'LTS-resistant and heat-tolerant'** (Fig. 4A). Subsequent evaluation of the LTS phenotypes, invertase activities and starch phosphorylase activities of a subset of these cultivars/clones in response to heat and cold treatments demonstrated that heat stress altered how LTS-resistant but heat susceptible clones perceive cold to induce invertase activity and the accumulation of reducing sugars during storage at low temperature. By contrast, retention of the LTS-resistant phenotype in heat tolerant cultivars/clones was conferred by the resistance of invertase to cold induction.

- (8) These studies inform in-season and postharvest management for the cultivars/clones and are fundamental to breeding for more robust tolerance of heat stress for retention of process quality during storage.



**Fig. 4.** (A) Changes in process quality (color) of French fry planks from LTS-susceptible and resistant cultivars/clones as affected by storage for 32 d at 39°F (CS) or the combination of HS (21 days at 90°F) plus CS. Control tubers were stored at 48°F. Fry planks are oriented with the stem end down. The four fry planks for each treatment are from different tubers and represent the average color observed from a 12-tuber sample. Numbers on fries depict USDA color ratings for the average stem end Photovolt reflectance. (B) Changes in stem end Photovolt reflectance values (fry color) as affected by the storage treatments (n=12, ±SE). Letters indicate LSD (P<0.05) for comparison across storage treatments and cultivars. Adapted from Herman et al. (2016).



**Fig. 5. (A)** Effects of postharvest heat stress on LTS at 39°F (2015 crop). Tubers were subjected to a heat stress (HS) treatment at 90°F for 21 days prior to storing for an additional 32 days at 39°F to stimulate LTS. Control tubers were stored continuously at 48°F. A03141-6, Clearwater Russet and Payette Russet (A02507-2LB) are highly resistant to LTS at 39°F, as indicated by light (USDA 0) colored fries. However, A03141-6 and Clearwater lost their LTS-resistant phenotype if heat stressed prior to storage at low temperature. In contrast, Payette was more tolerant of heat stress for retention of LTS-resistant phenotype, producing a USDA 1 fry color when heat stressed tubers were stored at 39°F for 32 days. The susceptibility of Ranger to LTS was enhanced in tubers exposed to prior heat stress. Darker fries indicate higher buildup of reducing sugars (shown in B). Numbers are the stem end photovolt reflectance values of 12 tubers. Letters indicate LSD  $P < 0.01$  across all treatments. **(B)** Reducing sugar (left) and sucrose (right) concentrations of tubers depicted in (A). Letters indicate LSD  $P < 0.05$

### **Development of techniques to alter tuber shape of superior cultivars from the NWVDP.**

Tuber length to width (L/W) ratio and size distribution interact to dictate yield of raw product for processing into frozen French fries. Payette Russet, Alturas and several other clones from the NWVDP are superior in many traits of interest (yield, pack out, dormancy, low temperature sweetening resistance, resistance to key diseases and physiological disorders); however, tuber shape tends to be round (i.e. low L/W ratio of 1.4), especially when grown in warmer areas (e.g., Columbia Basin). L/W ratio should be  $\geq 1.8$  for maximum yield of 3-inch or longer French fries. This project demonstrated that treatment of cut seed with gibberellin (GA) effectively increased tuber L/W ratio, but the effects were cultivar- and concentration-dependent. GA treatment of Payette Russet seed hastened emergence, increased tuber L/W ratio, and recovery of raw product (3-inch or longer French fries, percent by weight). However, GA also decreased apical dominance and shifted tuber size distribution toward smaller tubers that yield less fries (despite the tuber elongation effect), which limited the potential increases in fry yield. Further proof-of-concept studies demonstrated that naphthalene acetic acid (NAA) in combination with GA decreased the GA-induced shift in tuber size distribution, thus confining the effect of GA to tuber shape. This approach significantly increased fry yield when compared with GA only treatments for Payette Russet, Alturas and Shepody tubers. The combination GA and auxin treatments attenuated the undesirable effect of GA on shifting tuber size distribution while still maintaining the desirable effects on plant emergence and tuber shape.

This project did not involve research partners from other states. Cooperators included personnel from Lamb Weston, Simplot, and PVMI (Potato Variety Management Institute) who helped in procuring seed of numbered clones and newly released cultivars. Agri Northwest provided extensive in-kind nutrient analyses of soil and petiole samples throughout the project. Portions of the project also constitute part of the thesis work of Derek Herman (PhD), Cody Dean (MS), Kathryn Bolding (MS), Graham Ellis (PhD), and Chandler Dolezal (PhD), graduate students in the Horticulture program at WSU.

This project benefitted specialty crops, specifically potatoes.

### **GOALS AND OUTCOMES ACHIEVED**

Multi-year trials were conducted to identify potato clones and cultivars that are truly more efficient in their use of agronomic inputs and tolerance of various stresses. Activities included determining the:

- relative performance (yield and quality) of advanced clones and cultivars to conventional and low fertility (N and P) regimes and water stress;
- optimum row-width, in-row spacing, and directional planting to maximize land-use efficiency and profitability;
- N use efficiency, optimum N rates, and petiole nitrate levels to guide fertigation for maximum economic returns of selected clones/cultivars in the Columbia Basin;
- effects of N regime and genotype on tuber physiological maturity in relation to retention of process quality, including acrylamide forming potential, during full-season storage;
- efficacy of commercial products for enhancing P use efficiency;
- tolerance of clones and cultivars to in-season and postharvest heat stress for retention of process quality; and
- identifying commercially feasible and practical approaches to hastening emergence and altering tuber shape to increase the yield of raw product for frozen processing from selected cultivars.

Detailed descriptions of these activities along with results and selected outcomes are described above under Project Approach. Measurable outcomes and impacts include the identification and ultimately the adoption by industry of cultivars that are more tolerant of stress and efficient in their use of agronomic inputs than standard cultivars, along with the best management practice recommendations needed to maximize production efficiency and retention of postharvest quality of each cultivar in WA. Additionally,

commercially feasible and practical techniques were identified for increasing the yield of French fries from cultivars with delayed emergence and round tuber phenotype. These plant growth regulator-based methods are undergoing further study to develop application techniques and define optimum concentrations for specific cultivars.

The longer-term outcome of greater adoption of more sustainable cultivars by industry will occur over time and will be facilitated by some of the best management practices (BMPs) developed in this project. Extension of the results to stakeholders is currently ongoing to encourage adoption of these cultivars and implementation of associated BMPs. A major challenge remains convincing the quick service restaurant (QSR) industry and other end users to incorporate and adopt more efficient potato cultivars into their businesses. Much of the long-term economic impact of this project therefore depends on the extent to which the stress tolerant and more efficient cultivars identified in this project (along with the BMPs needed to grow them) are adopted by stakeholders.

The activities in this project contributed directly to the main goals of quantifying the tolerance of selected advanced clones and cultivars from the NWVDP to nutrient, water, heat and plant population stresses; evaluating planting designs to optimize plant population, inter-plant competition and land use efficiency; and developing techniques for enhancing yield of raw product from round but otherwise superior russet selections from the NWVDP. Accomplishing these goals also facilitated the development of cultivar-specific BMPs. As indicated above, dissemination of these BMPs to stakeholders is ongoing.

Except for the original variety performance data from the NWVDP, Baseline data for performance of many of the newly released cultivars (e.g., Mtn Gem Russet, Targhee, POR06V12-3) under varying levels of management inputs and stress in WA was non-existent prior to this project. Water stress studies demonstrated that many of the cultivars can be grown profitably with significantly less water. The evapotranspiration models upon which irrigation decisions have traditionally been based require revision to reflect the improved use efficiency of many of the new cultivars. Optimum N rates to maximize profitability of selected cultivars were defined and were often less than the N rate needed to produce maximum yield. Cultivars with moderate to high tolerance to heat stress for retention of process quality were identified (e.g., Clearwater, Payette) and the metabolic basis for this tolerance determined. Land-use efficiency studies resulted in the recommendation that growers switch from planting at 34-inch to 32-inch between-row spacing. Early adopters are making the adjustment this year. Growers are also beginning to adopt various plant growth regulator treatments to manipulate tuber set and size distribution in accordance with end-use specifications and premiums for various tuber size classes, and to enhance yield of raw product for frozen processing. The research-based BMP recommendations from this project represent an improvement over the dispersed, often intuition-based management ‘trial-and-error’ approaches currently used by stakeholders as they adopt new cultivars for production. Results from the N, P, water, land use efficiency, and heat stress trials provide growers and industry quantitative information that will inform adoption and management decisions for these cultivars into the future.

### **BENEFICIARIES**

Because the project was only just completed, potato growers and industry have not yet had an opportunity to fully assimilate and implement the findings. However, as explained above, it is expected that extension of the results will lead to further adoption of selected cultivars and best management practices. The beneficiaries of this project will be potato growers, including seed and commercial growers of fresh pack and frozen processing potatoes, as well as processors, consultants, fertilizer, chemical and equipment manufacturers and applicators. Extension of the results has already begun. Results were reported to stakeholders at the WA/OR annual Potato Conference and Trade Show and the Western WA Potato Growers meetings (2015-17). Articles containing results from the project have been published in the

Proceedings of the WA and OR Potato Conference and Trade Show (see Additional Information below). Results have also been summarized in presentations at the annual potato industry field days (2015-17, Othello, WA) and annually during the WA Potato Commission research reviews.

Much of the quantitative data and economic impact was described above in the Project Approach section of this report. Results from the project defined best management practices and sustainability parameters for selected production inputs (e.g., N, P, water, land) for each cultivar. The data provide a direct measure of the resource utilization efficiency and potential economic and environmental impact of producing each cultivar in the highly productive Columbia Basin. This information is essential to enable stakeholders to choose cultivars that maximize profit margins and environmental stewardship and will lead to increased adoption of more sustainable cultivars and competitiveness of the WA potato industry.

Approximately 85% of the 115 potato producing operations in Washington will be able to save at least \$300/A (+15% increase in net revenues) by tailoring their planting and management practices to match the needs of specific varieties as determined in this project. These savings will accrue by adopting project recommendations for closer between-row and in-row spacing according to variety and in relation to harvest maturity, and reducing nitrogen and water inputs to more closely match use, which varies by variety.

### **LESSONS LEARNED**

The most significant lessons learned from this project include the following:

- The levels of agronomic inputs (N, P, water) needed to produce maximum yield are often greater than those required for maximum profitability. Tailoring management inputs to achieve maximum profitability thus contributes to conservation of resources and increased sustainability in potato production.
- Tolerance to heat stress for retention of process quality is conferred by inherently low invertase activity along with insensitivity of invertase to induction during cold storage of heat stressed tubers. This information is relevant to selection of parental material for breeding for tolerance to heat stress.
- Yield of raw product for frozen processing (i.e. French fries) is dictated by an interaction between tuber size distribution and shape, both of which can be manipulated with commercially available plant growth regulators.
- While in-row spacing recommendations depend largely on cultivar and tuber size distribution goals, between-row spacing can be reduced for a direct increase in yield and land-use efficiency for most cultivars.
- Many of the newest cultivar releases from the NWVDP produce higher yields, quality, and greater economic returns than the traditional cultivars when grown under conditions optimized for the traditional cultivars; however, many of the newer cultivars have the capacity to produce even higher economic returns with lower agronomic inputs and optimized management, reflecting their increased efficiencies. However, because of the costs associated with many of the inputs, economic returns are optimized at levels specific to each cultivar.

There were no unexpected outcomes as a result of this project.

The activities, goals and Expected Measurable Outcomes of this project were met.

### **ADDITIONAL INFORMATION**

A final financial report will be provided by WSU's Office of Research Support and Operations - Sponsored Program Services. Cash match and in-kind support for this project were provided by the Washington Potato Commission, WSU, and AgriNorthwest as outlined in the original proposal.

The following publications and presentations contain results pertinent to or directly from many of the trials conducted during the course of this project:

1. Bolding, K, M. Pavek, R. Knowles, Z. Holden, L. Knowles, C. Dolezal, R. Garza and J. Rodriguez. 2016. Clearwater Russet cultural management. WSU Annual Potato Field Day, IAERC, Othello, WA, June 23 (presentation by KB).
2. Bolding, K.R., Z. Holden, C.J. Dolezal, N.R. Knowles and M. J. Pavek. 2016. Cultural management of Clearwater Russet. Proceedings of the 100<sup>th</sup> Annual Meeting of the Potato Association of America. **Am J Pot Res** (abstract in press).
3. Dolezal, C., M. Pavek, N.R. Knowles, Z. Holden, L. Knowles, R. Garza, and J. Rodriguez. 2016. Phosphorus Management in the Columbia Basin: Are Current Strategies Practical? WSU Annual Potato Field Day, IAERC, Othello, WA, June 23 (presentation by CD).
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13. Knowles, N.R., D. Herman, Cody Dean, Graham Ellis, Lisa Knowles and Mark Pavek. 2016. Use of growth regulators to optimize plant growth, tuber set and shape of new varieties. Proceedings of the Annual Washington and Oregon Potato Conference, Jan. 27-28, Kennewick, WA. pp. 55-62.
14. Knowles, N.R., L.O. Knowles, C. Dean, D. Herman, G. Ellis, and M.J. Pavek. 2016. Manipulating plant establishment, tuber set, size and shape with growth regulators. WSU Annual Potato Field Day, IAERC, Othello, WA, June 23 (presentations by NRK, CD, GE).
15. Knowles, N.R., L.O. Knowles, G. Ellis, D. Herman, and M.J. Pavek. 2016. In-season stress and retention of postharvest quality. WSU Annual Potato Field Day, IAERC, Othello, WA, June 23 (presentations by NRK, LOK, GE).

16. Knowles, N.R., L.O. Knowles, G.N.M. Kumar, M.J. Pavek. 2016. Effects of in-season management and stress on retention of postharvest quality. *In Northwest Potato Consortium Progress Reports for the year 2015*, 20 pages.
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27. Stark JC, Novy RG, Whitworth JL, Knowles NR, Pavek MJ, Thornton MK, Spear RR, Brown CR, Charlton BA, Sathuvalli V, Olsen N, andTL Brandt. 2016. **Mountain Gem Russet**: a medium to late season potato variety with high early and full season yield potential and excellent fresh market characteristics. **Am J Pot Res** 93:158-171.
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## **PROJECT #14**

**Project Title:** Rapid Detection Technologies for Apple Bitter Pit Management

**Partner Organization:** Washington State University – Lav Khot

### **PROJECT SUMMARY**

Washington State is top ranked in fresh market US apple production. Undeniably, growers prefer to grow cultivars having high economic returns and ‘Honeycrisp’ is one such variety with wholesale value of \$60 to \$100/box. However, ‘Honeycrisp’ and other high value cultivars (‘red delicious’ and ‘granny smith’) are susceptible to bitter pit, a disorder that reduces the marketability and utilization value of apples. Conservatively about 15 to 20% of stored (and packaged) fruits get affected by bitter pit disorder annually [U.S. Apple Association]. Therefore, non-contact rapid sensing techniques are needed for in-field and at the postharvest stage to detect and sort bitter pitted apples in fruit lots destined for the fresh market. WSU synergic team thus proposed to evaluate rapid non-contact apple bitter pit detection technique(s) that will be able to identify the disorder during early to asymptomatic stages. Overall, successful development, evaluation and adaptation of one (or more) of the techniques could reduce costs associated with produce storage, packaging materials, and labor. Improved efficiency has the potential to minimize considerable economic losses associated with packaging and storing fruit affected with bitter pit disorder. Additionally, WA state apple industry export around a quarter of produced fresh market apples. Thus, through use of sensing tools to identify and remove bitter pitted apples, quality produce can be delivered to the international consumers with continued good reputation of the American apple industry.

Bitter pit is a physiological disorder in apples which develops inside the fruit before or after harvest (in the storage facility). Bitter pitted fruits can be better utilized in domestic fresh market or for value-added production if such symptoms are detected at early stages. This will reduce the economic losses for the growers and the packaging industry through packing line time, costs and labor involved during packing, marketing, and post-harvest crop management.

Overall, proposed was the development of one or more rapid non-contact sensing technique(s) for use on packaging lines such that only disorder free fruits are packaged for sale. Team proposed evaluation of computer tomography (CT)-based imaging, visible-near infrared (VIS-NIR) spectroscopy, and Fourier transform infrared (FTIR) spectroscopy techniques. Motive on choosing above sensing techniques was: 1) the VIS-NIR spectroscopy based analysis would have lead towards identification of cultivar specific spectral bands. Spectral bands identified using the non—contact sensing would help develop a rapid and field portable bitter pit disorder detection systems and in development of cultivar specific crop management practices, 2) successful evaluation of CT-imaging would have lead towards using similar methods for bitter pit detection on fruit packaging lines. Expectedly, such technology can also be able to detect other internal fruit defects (bruising and handling injuries) and grade fruits based on consumer expected indices than just based on color; ultimately grower getting higher dollar value/box, and 3) FTIR technique would help in understanding variety specific Ca and Mg nutrient imbalances in fruit that can be associated with bitter pit. It could be a basis for future research (variety development) and developing appropriate farm management practices.

This project was not built on a previously funded SCBGP project.

**PROJECT APPROACH**

Activity 1: Evaluate and identify sensing techniques suitable to detect bitter pit disorder at post-harvest stages (for use on packaging lines).

Activity 2: Evaluate and identify sensing techniques suitable to detect bitter pit disorder at pre-harvest stages.

*Activity 1 Task 1a:* healthy and bitter pitted apples were harvested (see table 1) at commercial maturity from two different orchard field sites, Prescott and Burbank in first season, Burbank and Quincy in second season, and Burbank and Prescott in third season, all in Washington State.

**Table 1.** Sampling details from each field location for evaluating proposed sensing modules.

Season	Location (within WA State)	Cultivar	# of samples pit	Healthy	Bitter
2014	Prescott	Honeycrisp	20	20	
		Golden Delicious	20	20	
		Granny Smith	10	10	
2015	Burbank	Honeycrisp	20	20	
	Prescott	Golden Delicious	30	30	
2015	Burbank	Honeycrisp	30	30	
		Golden Delicious	30	30	
	Quincy	Honeycrisp	30	30	
2016	Prescott	Golden Delicious	30	30	
		Honeycrisp	30	30	

Burbank	Honeycrisp	30	30
	Golden Delicious	30	30

*Activity 1 Task 1b:* Visible-near infrared spectral reflectance data was collected with a spectroradiometer (Spectra Vista Corporation, SVC HR-1024i, Poughkeepsie, NY, USA) from all of the apples (Table 1) on days 0, 7, 14, 35 and 63 after harvest in standard laboratory conditions. Apples were stacked in boxes one per field site for storage. Apple boxes were also scanned using CT imaging technique (Aquilion<sup>®</sup>, Toshiba, Shimoishigami, Tochigi-ken, Japan) on the same days as Vis-NIR spectral reflectance data.

The FTIR spectrometer was used for apple flesh and peel sample analysis (season 2014, 2015). For the elemental analysis, calcium, magnesium and potassium analysis was performed in analytical chemistry lab for peel and flesh of the apples.

Additionally, X-ray fluorescence (XRF) measurements were performed on apples from 2014 season.

The near infrared spectra were processed to identify spectral bands associated with classification of healthy and bitter pit apples. Feature extraction techniques (Partial Least Square Regression and Stepwise Discriminant Analysis) were applied to select spectral features and then classify fruits using these features. The spectra could successfully classify healthy and bitter pitted apples. Also, a strong relationship was observed between the chemical content and the spectra indicating that NIR spectral features can be useful in predicting the changes in some chemical content (magnesium to calcium ratio) as an indicator of apple bitter pit development. Peer-reviewed publications 1 & 2 discuss the pertinent methods and results in details.

CT imaging showed great potential for detecting bitter pit specifically inside apples. CT analysis algorithm was developed in MATLAB, using image processing toolbox. The algorithm was modified and applied to 2015 and 2016 datasets. CT imaging revealed that bitter pit incidence starts from inside the fruit and later it appears on the cuticle. Further analysis for pit distribution along each apple set showed 54% of pit located at calyx-end of apples in comparison with middle and stem-end. The bitter pit distribution within a fruit revealed that on an average 42-66% of the bitter pits in the bitter pit affected apples were present inside the fruits. In the healthy apples, 85% of newly developed bitter pits were inside the fruit and were not emerged on the surface during the 63 DAH storage, signifying importance and need of CT or similar technology on packaging lines. Also, CT-based images indicated that bitter pit development increased from 0.1x to 7x in mildly and severely infected samples during 63 storage period. Data showed that bitter pit incidence increased during storage and potential to detect other internal injuries.

The FTIR spectral analysis on the flesh and peel of the fruit indicated the key wavelengths that could be associated with bitter pit related nutrients. To determine specific nutrient peaks, standards of Calcium and Magnesium were analyzed by FTIR device. Peaks for Calcium were found in 1440 wavenumbers ( $\text{cm}^{-1}$ ), peaks for Magnesium were found in 1280 wavenumbers ( $\text{cm}^{-1}$ ). Analysis of peel and flesh in two locations showed peaks in same wavenumbers and in general the health samples had lower absorbance than bitter pitted samples. Similar to Vis-NIR spectroscopy, water peaks were dominant and had distinct signatures for healthy and bitter pitted apples. Results confirmed that the peel samples had higher prediction accuracies, i.e. chemical imbalance, compared to flesh samples. The XRF technique was able to detect bitter pit and the results were matching with ground-reference elemental analysis. In a latter case, the result of flesh tissue and peel analysis in Honeycrisp apples data showed higher Ca concentration, and lower Mg/Ca and K/Ca ratio for healthy apples compared to bitter pit apples. Further analysis of Ca concentration for flesh of healthy and bitter pit Honeycrisp apples and peel of healthy and bitter pitted apples showed 28 and 19, and 132 and 96 mg/kg fresh wt., respectively.

*Activity 2 Task 2a and 2b:* apples were harvested 1 and 2 weeks before the commercial harvest date in the 2015 season. The harvested varieties were: Honeycrisp and Golden Delicious. Harvested apples were kept in cold storage during the experiment. Data collection was performed on the samples using CT imaging and Vis-NIR spectroradiometer.

The samples 1 and 2 weeks before commercial harvest showed bitter pit symptoms. The results of the classification according to the Vis-NIR spectra showed accuracy range of 97-100% in Honeycrisp and 80-91% in Golden

Delicious apples. The reason for higher accuracy in Honeycrisp may be because of the high bitter pit incidence on and underneath the fruit cuticle. The CT imaging data confirms that Honeycrisp apples were highly bitter pitted compared to Golden Delicious apples and the bitter pit was identifiable in both weeks 1 and 2 before harvest.

*Activity 1 Task 1e and 1f:* To accomplish these tasks, hyperspectral imaging sensor (Hyperspec® extended VNIR, Headwall Photonics Inc., Fitchburg, MA, USA) was procured and configured to capture ‘hypercube’ images to validate the spectral features identified in previous seasons on the samples of the 2016 season. The results of feature selection from NIR spectra were used to extract an image of one of the selected wavelengths. This image was used for the spatial analysis of the ‘hyper cube’. To further evaluate this sensing system, more apple samples were collected from a commercial apple storage facility (Spring, 2017). These samples included Honeycrisp and Golden Delicious apples and each cultivar was coming from two different locations. The algorithm used for analyzing the hyperspectral images is summarized in Fig. 1(left).

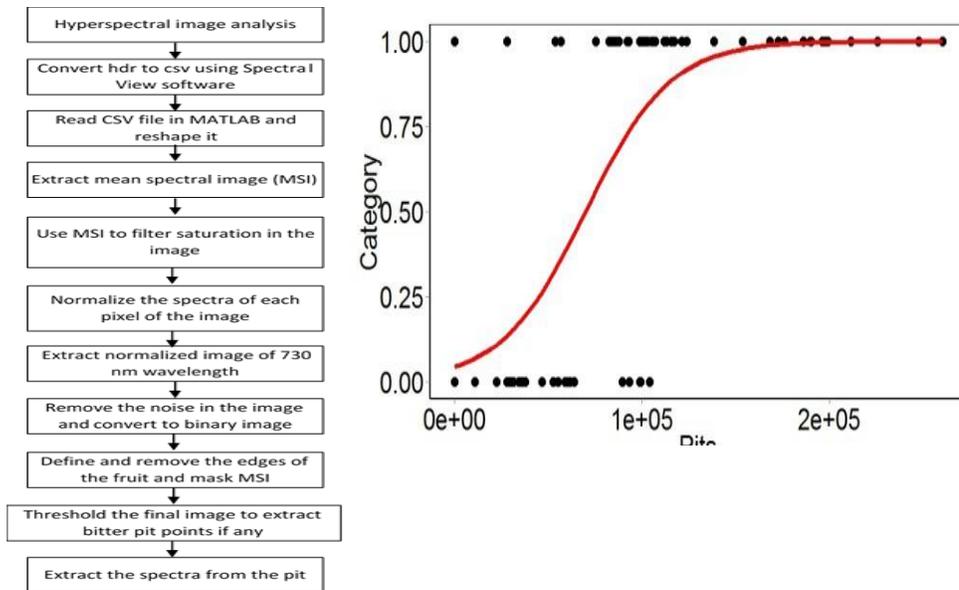


Fig. 1. Algorithm for analyzing the hyperspectral images (left) and logistic regression between the bitter pit area and apple category (0 and 1 represent healthy and bitter pit apples, respectively) (right).

The hyperspectral image processing algorithm, custom developed in MATLAB®, was able to automatically find bitter pits, count them and calculate the total area of the pits. In order to classify bitter pitted and healthy apples, the area of the pits was utilized. Thirty healthy and thirty bitter pit Honeycrisp apples from each of two locations (Bengnoff, WA and Jump, WA) were imaged using hyperspectral imaging sensor. To define the appropriate threshold of pit area for classification, logistic regression was applied on the data (Fig. 1 right). During the analysis, the odds of apples being healthy or bitter pit were considered 0.5 and the associated area was extracted. Using this threshold, the fruit classification accuracy was 83% with false negative of 3% and the false positive of 14%. This sub-objective study results are being written as peer-reviewed publication, reported as in preparation in section 17.

- Visible-near infrared (Vis-NIR) spectroscopy was performed on the harvested apples in 2014, 2015 and 2016. Two graduate research assistants (GRAs) worked on the data acquisition and later data analysis that resulted in a publication. A postdoctoral research associate also analyzed data using different statistical methods and published second peer-reviewed publication on this part of the study.
- Computed tomography (CT) was performed on all the three year harvested apples and two GRAs developed (and refined) an algorithm to analyze images through automated processing steps. Two peer reviewed papers were published as a result.

A visiting professor (sponsored by China Scholarship Council) also worked on the quantifying aspect of bitter pit in CT images and published the work with one of the PIs.

- Four GRAs worked in-part on Fourier Transform Infrared Spectroscopy (FTIR) data acquisition for three years of data collection. Chemical analysis was also performed on first year harvested apples. Two GRAs and a postdoctoral research associate worked on this part of the project. The outcome was presented in technical conferences and was published in a credible peer-reviewed journal.
- During the period of October 1, 2014 through September 30, 2017; Borton Fruits has made in-kind and cash contributions to the above referenced project as an industry cooperator.

The study was only performed on different varieties of apples, however it is possible to apply the methods to other fruits such as pears and also other specialty crops. Specifically, CT imaging technique and associated image processing algorithms can be used by tree-fruit breeders as one of the ‘high throughput Phenomics’ tool that can aid in understanding storage quality traits of new cultivars under investigation.

### **GOALS AND OUTCOMES ACHIEVED**

The overall goal of this project was to evaluate techniques that can be used for in-field and on packaging lines to detect bitter pit in apples. In some varieties such as Honeycrisp, bitter pit affects around 15-30% of apples depending on the growing season climate variation. Therefore, early bitter pit detection is essential to reduce growers’ economical losses in packing fruits with this disorder. This project aimed at providing sensing solutions to identify bitter pit apples, and prevent storing and packaging of the affected apples. As reported in section 4, during the project period, five different sensing techniques (see Fig. 2 below) were evaluated and associated data mining algorithms were developed to achieve the performance goals and expected measurable outcomes. Specific activities were conducted as in section 4 of this report.

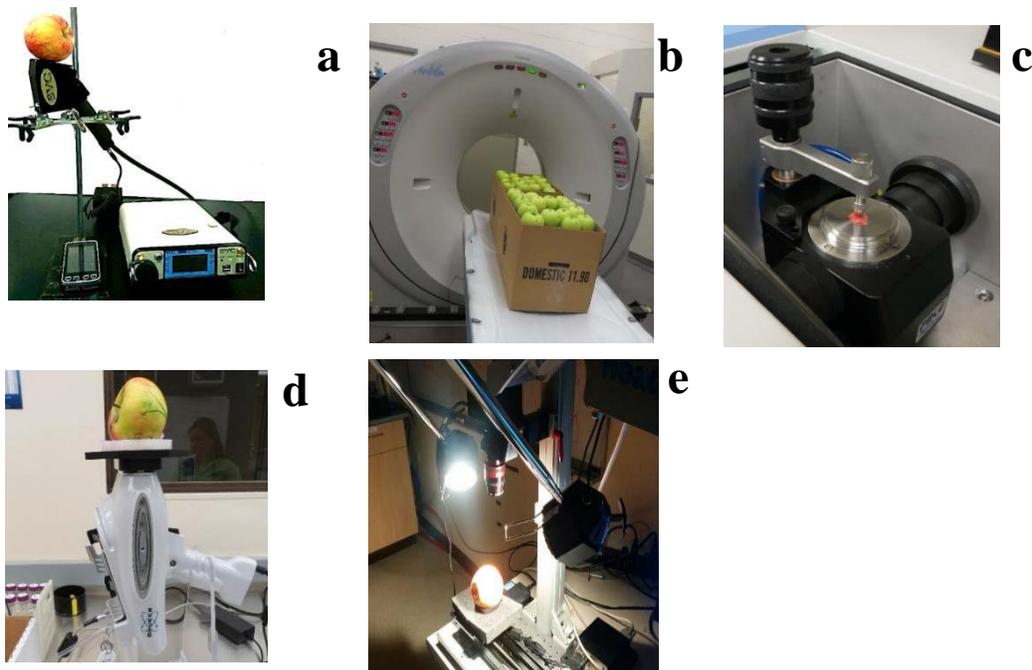


Fig. 2. Different sensing techniques used in the project: a. Vis- NIR spectroradiometer. b.

Computed tomography imaging. c. Fourier transform infrared spectrometer. d. X-ray fluorescence

Overall, one or more rapid non-contact sensing technique(s) for use on packaging lines were to be developed such that only disorder free fruits are packaged for sale. Towards this goal, the team had conducted scientific research and identified key techniques that can be modulated for this purpose. For example, CT-imaging has emerged as a promising method to detect bitter pits and additional efforts are needed to translate this technology on packaging lines. The team has already developed the CT image processing algorithms and tree fruit breeding program is using some of those for CT-imaging based fruit quality traits mapping and for data driven variety selection. The Vis-NIR spectroradiometer & Hyperspectral imaging based data analytics has resulted in identification of key spectral bands and additional commercialization efforts are needed to develop and validate the prototype in-field fruit sensing system for rapid, non-contact apple bitter pit detection.

Pertinent to the project activities following were the accomplishments:

Activities	Accomplishments
<p>Activity 1. Evaluate and identify sensing techniques suitable to detect bitter pit disorder at post-harvest stages</p>	<p>Vis-NIR spectroscopy and CT imaging were able to detect bitter pit in apples. The NIR spectroscopy analysis assisted in identifying wavebands that were the most important in the classification. These bands were further validated using hyperspectral imaging and can be used towards developing a multi-band imaging device.</p> <p>CT imaging and custom algorithms were able to detect bitter pit inside the fruits and associated progression during the storage period. It can also detect other injuries or defects as well as bitter pit.</p> <p>Ground-truth elemental analysis was performed to estimate calcium, magnesium, and potassium concentrations in Honeycrisp, Golden Delicious and Granny Smith apples. Calcium content was higher in peel than in flesh, and calcium difference between healthy and bitter pit affected apples was higher in Granny Smith and Golden Delicious compared to Honeycrisp cultivar.</p> <p>The FTIR spectral analysis, indicated the presence of three wavelength regions in flesh (2840- 2980 <math>\text{cm}^{-1}</math>; 1750–1790 <math>\text{cm}^{-1}</math>; 1290–1350 <math>\text{cm}^{-1}</math>) and two in peel (1150–1450 <math>\text{cm}^{-1}</math>; 1700–1800 <math>\text{cm}^{-1}</math>) that could be associated with bitter pit development in ‘Honeycrisp’, ‘Golden Delicious’, and ‘Granny Smith’ apples. FTIR spectral features was able to identify bitter pit development.</p> <p>This project also demonstrated the applicability of FTIR and XRF techniques as rapid and precise tools in bitter pit detection in apples.</p>
<p>Activity 2. Evaluate and identify sensing techniques suitable to detect bitter pit disorder at pre-harvest stages</p>	<p>Cultivar specific field (fruits) sampling at pre-harvest stage and analysis using CT-imaging and VIS-NIR spectroradiometer was performed for two seasons. It revealed that CT imaging could be a rapid method to detect apple bitter pit progression at different field sites and can be an alternative to conventional bitter pit testing methods.</p> <p>Vis-NIR based spectral data analysis and hyperspectral imaging based validation activities have identified few key spectral bands (730±10, 980±10, 1135±10, 1250±50 and 1405±10 nm) that can be used to develop a prototype in-field fruit sampling technique.</p>

The project outcomes have resulted in five peer reviewed journal publications and 9 presentations made in different meetings and conferences such as ASABE Annual International Meeting, and Annual Meeting of the WSHA.

As illustrated in the sections above, the identification of sensing technologies to detect bitter pit was performed successfully in this project. Vis-NIR, CT and FTIR sensing techniques were able to identify this disorder (outcome 1); CT imaging allowed to identify internal injuries in apples (outcome 2); Results in chemical composition were analyzed to understand its relationship to bitter pit disorder, results showed imbalances in calcium and magnesium content in bitter pit apples.

Honeycrisp, Golden Delicious and Granny Smith showed similar trends in those imbalances (outcome 3): Calcium and magnesium composition were statistically different in healthy and bitter pit apples, however it was difficult to establish a threshold in chemical content for those conditions because of the complexity of this disorder (outcome 4); hyperspectral imaging system procured, based on the information coming from the results, was evaluated in detecting bitter pit. With HSI system successfully identifying the disorder, similar system can potentially be used for post-harvest management. In this case, a suitable platform should be developed in packaging facilities (outcome 5); six research articles were written during this period, increasing the knowledge of scientific community and of stakeholders (through 9 presentations at regional and international meetings) about bitter pit and pertinent detection techniques. The findings of this research will allow exploration of new horizons in apple bitter pit detection (outcome 6). These results translate beyond the scope of this project and WSU researchers (not part of this project) are using pertinent CT imaging techniques and developed image processing software in high throughput phenotyping of apple cultivars, and in evaluating role of calcium in bitter pit development & progression.

## **BENEFICIARIES**

WA State apple growers, associated packaging industry, and national & international research community are the direct beneficiaries of this project.

The project outcomes are beneficial to WA State apple growers who produce 68% of total US fresh market and 73% of the nation's certified organic apples. Scientific data driven oral presentations ideally would have resulted in 800 direct industry contacts and 1200+ indirect contacts through written documents. Moreover, the ASABE meeting draws 1400+ international researchers and the team has shared these project outcomes with them through oral/poster presentations. Furthermore, the project PI was invited to share study outcomes at 1<sup>st</sup> International Apple Symposium, Shaanxi, China, which was attended by several (120+) key apple industry representatives and researchers in global arena. Economically, project addressed industry need that can have about \$96 million dollar losses to growers and processors conservatively through harvest and storage of bitter pit disorder fruits. Costs associated with such produce packaging material and labor (\$10 to 15/box), and transportation can amalgamate to have considerable economic losses as well.

## **LESSONS LEARNED**

PIs had a very positive experience working with grower cooperator, Borton Fruit. PIs and project staff had meaningful interactions with industry and understood gravity of practical solution needed to identify and sort bitter pitted fruits. In particular, GRAs learned practical usability case scenario side of doing the quality research in a land-grant university setting. As this was first WSDA-SCBG project for the PI to lead, he has learned several aspects of project and fund management that can be applied to upcoming projects. WSDA staff's assistance to PI in solving some of the grant fund management issues was amicable.

CT imaging to quantify bitter pit in apples: This goal is accomplished and two manuscripts are published. The technique and refined methods were made available to the WSU researchers working in the plant breeding area for high throughput phenotyping based rapid selection of the new cultivars.

Developing a multi-band imaging system: PIs realized that this particular project objective was over-commitment for funded amount, nonetheless, this situation was worked through to have a deliverable that can help the industry. The spectral bands for such prototype system have been identified according to the results of feature selection of first and second year Vis-NIR data. The HSI imaging system with selected bands was procured and used to capture images of apples in 2017 season. Custom algorithms have been developed to analyze the images to quantify the bitter pit disorder in apples and to reconfirm those bands. Although, a multi-band camera was not able to be developed, industry can use such information to develop or retrofit existing packaging line imaging systems for defect sorting of fruits on lines.

## **ADDITIONAL INFORMATION**

During the period of October 1, 2014 through September 30, 2017; Borton Fruits has made contributions to the above referenced project as an industry cooperator. The cash (\$10,000) and in-kind contribution (\$21,480) helped team towards successful implementation of this project. The annual in-kind contribution of \$7,160 was made through access to orchards, fruit samples & packaging material cost, harvest labor cost and time contribution by participating on-field research, crop expertise and data interpretation.

The WSU indirect costs for the project period were waived, thus at 20% rate, \$31,079 are the cost-match for this project through WSU-CAHNRS. Also, PI matched his salary (FTE 2%) \$2,153.

The in-cash contribution from Borton Fruit (\$10,000) and WSU PIs contribution match from start-up packages was used towards the proposed task of developing a multi-band camera. The bands for this camera were selected according to the results of feature selection of first and second year Vis-NIR data. After a thorough research on the available hyperspectral (HSI) imagers in market, Hyperspec<sup>®</sup> SWIR (Headwall Photonics Inc., Fitchburg, MA, USA) was procured as imaging system on this project. Originally, \$7,000 was budgeted for such sensor development

but as PI's could get some support from Visiting Scholars supported by China Scholarship Council, it was decided to procure the high-end HSI imaging system.

Cost of this sensor was about \$66,403; WSDA project funded \$26,938 and PIs put additional funds (\$39,491) from their programs to procure this sensor. Original quoted cost of this HSI sensor was \$95,600 but a deep academic discount was received (\$29,196 + \$20,000 in-kind accessories). Overall, this equipment will serve as a base to test similar concepts as technologies for crop loss management are developed.

Peer-reviewed Publications:

- 1) Kafle, G.K., Khot, L.R., Jarolmasjed, S., Yongsheng, S. and Lewis, K., 2016. Robustness of near infrared spectroscopy based spectral features for non-destructive bitter pit detection in honeycrisp apples. *Postharvest Biology and Technology*, 120, pp.188-192.
- 2) Jarolmasjed, S., Zúñiga Espinoza, C., Sankaran, S., 2016. Near infrared spectroscopy to predict non-invasive bitter pit development in different varieties of apples. *Journal of Food Measurement and Characterization*, pp. 1-7.
- 3) († Equal authors) Jarolmasjed, S.†, Zúñiga Espinoza, C.†, Sankaran, S., Khot, L.R. 2016. Postharvest bitter pit detection and progression evaluation in 'Honeycrisp' apples using computed tomography images. *Postharvest Biology and Technology*, 118, pp.35-42.
- 4) Si, Y. †, and Sankaran, S.†. 2016. Computed tomography imaging-based bitter pit evaluation in apples. *Biosystems Engineering*, 151, pp. 9-16.
- 5) Zúñiga, C.E., Jarolmasjed, S., Sinha, R., Zhang, C., Kalcsits, L., Dhingra, A. and Sankaran, S., 2017. Spectrometric techniques for elemental profile analysis associated with bitter pit in apples. *Postharvest Biology and Technology*, 128, pp.121-129.
- 6) Jarolmasjed, S., Khot, L.R., Sankaran\*, S. 2017. Detecting bitter pit development in apples using hyperspectral imaging [In preparation].

Conference Papers/Abstracts/Posters: (\* Presenter)

- 1) Khot\*, L. R., S. Sankaran, and L. Kalcsits. 2016. Role of sensing technologies in apple bitter pit management. 1st International Apple Symposium, Shaanxi, China. October 10-16, 2016 (Oral Presentation).
- 2) (Invited/sponsored) Khot\*, L. R., Presentation on "Advanced technologies for 'decision and precision' agriculture", College of Mechanical and Electronic Engineering, Northwest A&F University, Shaanxi, China October 15, 2016.
- 3) Jarolmasjed, S.\* Khot, L.R., Sankaran, S. 2017. Detecting bitter pit development in apples using hyperspectral imaging, Paper No. 1700741, ASABE 2017 Annual International Meeting, Spokane, WA, July 16-19, 2017.
- 4) Jarolmasjed, S.\*, Zúñiga C. E., Sankaran, Kalcsits, L.A., Khot, L.R. 2015. Assessment of high throughput sensing techniques for pre- and postharvest apple bitter pit detection. 2015 Washington State Tree Fruit Association (WSTFA) 111th Annual Meeting, December 7-9, 2015, Yakima, WA (Poster).

- 5) Jarolmasjed, S.\*, Zúñiga Espinoza, C., Sankaran, S., Kalcsits, L.A., Khot, L.R. 2015. Sensing technologies in apple bitter pit management. Center for precision and automated agricultural systems (CPAAS) open house, September 17, 2015 (Poster).
- 6) Jarolmasjed, S.\*, Zúñiga Espinoza, C., Yongsheng S., Sankaran, S., Kalcsits, L., Khot, L. Assessment of high- throughput sensing techniques for pre and postharvest apple bitter pit detection. 111<sup>th</sup> Annual Meeting of the WSHA, December 7-9, 2015, Yakima, WA. (Poster Presentation).
- 7) Jarolmasjed, S.\*, Zúñiga, C. E., Khot, L.R., Sankaran, S. 2015. Visible-near infrared spectroscopy for bitter pit detection in apples, Paper No. 152190895, ASABE 2015 Annual International Meeting, New Orleans, LA, July 26-29, 2015.
- 8) Zúñiga Espinoza, C.\*, Jarolmasjed, S., Sankaran, S., Khot L., 2015. Calcium evaluation in healthy and bitter pit apples using Fourier transform infrared (FTIR) spectroscopic technique, Paper No. 152191056, ASABE 2015 Annual International Meeting, New Orleans, LA, July 26-29, 2015.
- 9) Jarolmasjed, S.\*, Zúñiga C. E., Khot, L.R., Sankaran, S., Dhingra, A., and Lewis, K. M. 2014. X-ray computer tomography imaging and visible-near infrared spectroscopy for non-destructive apple bitter pit detection, 110<sup>th</sup> Annual Meeting of the WSHA, December 1-3, 2014, Kennewick, WA (Poster).

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## **PROJECT #15**

**Project Title:** Grappling with Emerging Soil-borne Virus Diseases in Washington Vineyards

**Partner Organization:** Washington State University – Naidu Rayapati

### **PROJECT SUMMARY**

Virus diseases are one of the significant constraints to sustainable growth of the grape and wine industry in Washington State. Therefore, management of virus diseases was identified by the Grape Industry Research Task Force as one of the highest research priorities for mitigating negative impacts of viruses on vine health and fruit yield and grape quality. Although grapevine leafroll and red blotch diseases have received greater attention in recent years due to their significant economic impacts to growers, viruses spread by soil-inhabiting nematodes, known as nepoviruses, have received less attention. Ignoring emerging diseases caused by nepoviruses could derail the growth trajectory of Washington's grape industry. Previously, grapevine fanleaf virus (GFLV), the causal agent of grapevine fanleaf disease, was reported in two wine grape (*Vitis vinifera*) cultivars in two commercial vineyards in the State. Based on previous research, GFLV was considered as of no serious threat due to absence of the dagger nematode vector (*Xiphinema index*) in Washington State soils. During 2013 crop season, a disease with symptoms mimicking grapevine fanleaf disease was observed in a commercial vineyard in Yakima Valley. Symptomatic vines showed poor vigor with stunted growth and produced small clusters containing shot berries. Since samples from symptomatic vines tested negative for GFLV, it was suspected that a nepovirus(es) distinct from GFLV may be present in vineyard blocks showing 'fanleaf-like' symptoms.

If preemptive and preventive measures are not implemented, soil-borne diseases caused by nepoviruses could derail the growth trajectory of Washington's grape and wine industry that is currently contributing an estimated \$5 billion to the State's economy. Consequently, the project was developed to generate research-based knowledge for advancing the understanding of the nature of nepoviruses and nematode vectors present in affected vineyard blocks. This knowledge will provide a foundation for implementing appropriate strategies to negate deleterious impacts of nepoviruses in vineyards and prevent introduction of 'alien' nepoviruses and nematode vectors into Washington vineyards via planting stock imported from outside the State.

Several nepoviruses are known to infect grapevines worldwide. However, none of these viruses, except GFLV, have so far been documented in Washington vineyards. Although fallowing, cultural practices, growing cover crops and soil disinfestation methods have been advocated to control nematodes, these measures are seldom used successfully for controlling nepoviruses due to the remarkable ability of viruliferous nematodes to survive in the soil for long periods of time under adverse conditions. Soil fumigation with methyl bromide to reduce nematode vector populations is prohibited due to environmental and human health concerns. Soil fumigation is also prohibited under Salmon Safe and LIVE (Low Input Viticulture and Enology) programs implemented in several Washington vineyards. The use of grafted vines with suitable rootstocks resistant/tolerant to root-feeding ectoparasitic nematode vectors has shown little success in limiting virus spread. Moreover, nepoviruses are known to cause graft-incompatibility problems. In addition, growers have little experience with rootstocks due to the fact that grapevines are planted as own-rooted plants in eastern Washington. In view of these practical challenges, accurate identification of virus(es) and nematode vectors present in affected vineyard blocks would provide a solid foundation for designing appropriate strategies to manage diseases caused by nepoviruses in Washington vineyards.

This is a new project funded by the WSDA SCBGP. However, the project activities were carried out synergistically with projects funded, in part, by the WSU Agricultural Research Center, the Wine Research Advisory Committee, the Washington Wine Commission, the Washington State Grape and Wine Research Program, for complementarity and maximizing impacts.

### **PROJECT APPROACH**

The overall goal of the project was to identify viruses and nematode vectors associated with soil-borne diseases in Washington vineyards and disseminate research-based knowledge to stakeholders and regulatory agencies for advancing sustainable growth of the grape and wine in industry in Washington State.

#### ***Activity: Collect samples from vineyards and test for nepoviruses and other viruses.***

In 2014 and 2015 seasons, a commercial vineyard planted with a red-fruited wine grape cultivar (*Vitis vinifera* cv. Grenache) was identified showing fanleaf degeneration and decline symptoms. Symptomatic Grenache vines showed severe stunting, degeneration and decline symptoms, and flower abortion leading to poor fruit set compared to non-symptomatic vines. Leaves from symptomatic and non-symptomatic vines were collected and tested for candidate nematode-transmitted viruses (Grapevine fanleaf virus, Arabis mosaic virus, Tobacco ringspot virus, Tomato ringspot virus, Tomato black ring virus, Peach rosette mosaic virus, and Strawberry latent ringspot virus) known to cause fanleaf-like symptoms by serological (ELISA) assays. All symptomatic vines tested positive only for Tobacco ring spot virus (TRSV). To further confirm ELISA results, total nucleic acids were extracted from leaves of symptomatic and healthy vines and subjected to molecular diagnostic assays using reverse transcription-polymerase chain reaction (RT-PCR). DNA fragments specific to a portion of the coat protein gene and a portion of the replicase gene of TRSV were amplified in RT-PCR only from symptomatic samples. The amplified DNA fragments were cloned and nucleotide sequence determined. A comparison of the derived sequences with corresponding nucleotide sequences of nematode-transmitted viruses reported from other countries confirmed the presence of TRSV in symptomatic Grenache vines. As far as the project manager's knowledge goes, this is the first report of the occurrence of TRSV in Washington vineyards. This finding was published in a peer-reviewed scientific journal (<https://apsjournals.apsnet.org/doi/10.1094/PDIS-02-15-0140-PDN>). During 2015 crop season, fanleaf degeneration and decline symptoms were observed in cvs. Syrah and Tempranillo planted adjacent to the Grenache block mentioned above. Symptomatic samples from vines in Syrah and Tempranillo blocks tested positive for TRSV in molecular diagnostic (RT-PCR) assays. These results confirmed the presence of TRSV in all three cultivars planted within the same commercial vineyard.

In 2016 season, Cabernet franc vines planted in a commercial vineyard block located in a different appellation was observed showing fanleaf degeneration and decline symptoms. Samples from symptomatic vines were tested positive in RT-PCR assays only for GFLV.

In 2016 season, fanleaf degeneration and decline symptoms were observed in the wine grape cultivar Merlot in a third commercial vineyard block located in a geographic area distant from the two commercial vineyards mentioned above. Leaf samples from symptomatic vines tested positive only for GFLV in RT-PCR assays. No fanleaf degeneration and decline symptoms were observed in other vineyard blocks during surveys conducted in 2017 season.

In summary, data obtained during the project period revealed the presence of two nepoviruses (TRSV and GFLV) in five wine grape cultivars planted in three geographically distant commercial vineyards in Washington State. TRSV was found in three red-fruited wine grape cultivars (Grenache, Tempranillo and Syrah) in a single commercial vineyard. In contrast, GFLV was detected in two red-fruited wine grape cultivars (Cabernet franc and Merlot) planted in two commercial vineyards located in distinct geographic locations in the State.

***Activity: Characterization of nepoviruses using biological assays and molecular biology techniques (including next-generation sequencing technology, if warranted).***

Since TRSV is a newly reported virus in Washington vineyards, genome sequence of the virus was analyzed by molecular biology methods, including the next-generation sequencing (NGS) using the Illumina HiSeq 2500 platform. The quality filtered NGS reads (120-bp paired-end reads) were assembled *de novo* into contigs using the CLC Genomics workbench software and annotated against the viral RefSeq database in GenBank by BLASTx program to assemble viral genome sequences present in symptomatic samples. Using these approaches, the complete sequence of RNA-1 and RNA-2 genome segments of TRSV was determined to be 7,519 nucleotides (nt) and 3,927 nt, respectively. Phylogenetic analysis of RNA-1 and RNA-2 sequences with corresponding sequences of TRSV reported from other regions within and outside the USA indicated that TRSV from the cultivar Grenache showed high similarity with TRSV isolates infecting soybean from South Korea and USA. In host-range studies, *Nicotiana occidentalis* was identified as a suitable herbaceous indicator host for biological indexing of TRSV.

***Activity. Characterization of Grapevine fanleaf virus from cv. Merlot using next-generation sequencing technology.***

The presence of GFLV in cvs. Merlot and Cabernet franc (mentioned above) was further confirmed by subjecting RNA samples extracted from symptomatic vines to NGS technology using the Illumina HiSeq 2500 platform described above. The NGS results showed the presence of RNA-1 and RNA-2 sequences related to GFLV, confirming the RT-PCR results. Sequence analysis of RNA-1 and RNA-2 of GFLV from both cultivars showed high similarity with GFLV previously reported from Washington vineyards. Further in-depth sequence analyses revealed the presence of two distinct strains of GFLV in symptomatic Merlot vines, but not in symptomatic Cabernet franc vines. This is a new finding and additional research will be conducted in future to better understand implications of co-infections of distinct strains of GFLV on vine health and fruit yield and quality as well as their spread in the Merlot vineyard.

***Activity: Validation of molecular diagnostic assays for discrimination of two nepoviruses (TRSV and GFLV).***

Since fanleaf degeneration and decline symptoms are produced by two distinct viruses (TRSV and GFLV), symptom-based detection of these two viruses in vineyards was found to be difficult. Therefore, PCR-based diagnostic assays were optimized to test individual samples to determine whether a symptomatic vine is infected with TRSV or GFLV. To ensure high level of specificity and reliability in detection, a multiplex RT-PCR assay was optimized, where samples from each symptomatic vine can be tested simultaneously for the two genomic RNAs (RNA-1 and RNA-2) of each virus, to distinguish TRSV from GFLV. These multiplex assays were optimized for simultaneous amplification and detection of the two genomic RNAs of TRSV or GFLV. A ‘house-keeping’ RNA sequence of host origin was included as a co-amplification template in each RT-PCR assay for the detection of TRSV or GFLV. The DNA band specific to the ‘house-keeping’ RNA sequence amplified in each sample, irrespective of whether the sample has a virus or not, ensured reliability of the RT-PCR assay and assisted in accurate interpretation of test results, in terms of whether samples from symptomatic vines had TRSV and/or GFLV. This assay is currently being used for field indexing of grapevine samples in grower vineyards as part of preventing the spread of TRSV and GFLV through plant material and in registered nurseries to maintain virus-free vines.

***Activity: Collect soil samples, identify nematodes and conduct virus transmission studies using cucumber baiting assay.***

Since GFLV and TRSV are known to be transmitted by dagger nematode species, studies were conducted to examine whether dagger nematode species present in commercial vineyards can serve as vectors for these two viruses. In year 1 of the project, subsurface soil samples were collected close to symptomatic Grenache

vines tested positive for TRSV. Individual nematodes were isolated from soil samples and separated into distinct nematode categories in collaboration with WSDA Nematology laboratory at Prosser. Using morphological characters, spiral nematode (*Helicotylenchus* spp.), lesion nematode (*Pratylenchus* spp.), ring nematode (*Criconebella* spp.) and dagger nematode (*Xiphinema* spp.) were identified in these soil samples. Individual nematodes from each category were subsequently tested for the presence of TRSV using RT-PCR. TRSV was detected in individual dagger nematodes, but not in other nematode types collected from the same soil samples. Sequence analysis of the DNA amplified in RT-PCR confirmed the presence of TRSV in dagger nematodes, indicating that dagger nematode could be the vector of TRSV. Subsequently, molecular studies were conducted using nematode genomic DNA to identify the dagger nematode at the species level. For this purpose, DNA extracted from a group of dagger nematodes was used in PCR to amplify the D2-D3 expansion segment of the 28S RNA and internal transcribed spacer (ITS) region of 18S RNA. An approximately 800 base pair (bp) and 1,000 bp fragments specific to D2-D3 and ITS regions, respectively, were amplified, cloned and sequenced. The derived nucleotide sequences were highly identical to the corresponding 18S and 28S of *Xiphinema rivesi* reported from other countries. These results supported morphological characteristics in identifying the dagger nematode present in soil samples as *X. rivesi*.

**Transmission of TRSV by nematodes:** In 2015 and 2016, cucumber baiting assay was carried out to examine whether *X. rivesi* can transmit TRSV from symptomatic grapevines to healthy cucumbers. For this purpose, cucumber seedlings were planted in June each season in close proximity to symptomatic vines in Grenache and Tempranillo vineyard blocks. These cucumbers served as a bait to attract soil-inhabiting nematodes and transmit TRSV from symptomatic grapevines to healthy cucumbers. Leaf samples from individual cucumber plants were collected in October 2015 and 2016 and tested by RT-PCR for the presence of TRSV. Samples from 38/86 cucumber plants tested positive for TRSV, indicating that the virus can be transmitted from grapevines to cucumbers likely by *X. rivesi*.

In 2014 season, 24 healthy Cabernet franc cuttings were planted in close proximity to symptomatic Grenache vines to examine whether TRSV can be transmitted from virus-infected Grenache vines to healthy Cabernet franc vines. Leaf and cane samples were collected from these Cabernet franc vines in October 2015, 2016 and 2017 and tested by RT-PCR for the presence of TRSV. None of the vines tested positive for TRSV in 2015. However, 5/24 vines were tested positive in 2016 and an additional 4 vines tested positive in 2017. The cumulative data indicated that transmission of TRSV occurred from symptomatic grapevines to 9/24 (37%) healthy Cabernet franc vines. The remaining 15 Cabernet franc vines will be monitored in the following seasons for virus infection.

Overall, the above studies have shown that TRSV can be transmitted from virus-infected grapevines to healthy cucumber plants and grapevines by soil-inhabiting nematode vectors. The dagger nematode (*X. rivesi*) was identified as the likely vector transmitting TRSV. Further studies (beyond the scope of this project) will be continued to better understand transmission of TRSV by *X. rivesi*.

**Activity: Collect soil samples from Merlot block, identify nematodes and conduct virus transmission using cucumber baiting assay.**

In 2016 season, soil samples were collected from Cabernet franc block affected with GFLV for the presence of nematode species. Based on morphological characteristics, most of the nematodes found in soil samples (100 cc soil sample, with three replicates) from the Cabernet franc block were root-lesion (*Pratylenchus* spp.) and pin nematodes (*Paratylenchus* spp.) and a few were root-knot (*Meloidogyne* spp.) nematodes. However, no dagger nematodes were found in soil samples collected from this vineyard block. These observations suggest that there is little risk of GFLV spread in the Cabernet franc block due to the absence of dagger nematodes and the virus might have been introduced into this vineyard block via compromised planting stock. In contrast, an analysis of soil samples from the Merlot block during 2017 season revealed the presence of root-knot (*Meloidogyne* spp.), stubby-root (*Pratrichodotus* spp.), ring (*Mesocriconema* spp.) and dagger (*Xiphinema* spp.) nematodes. Based on morphological features, two

species of dagger nematodes (*X. rivesi* and *X. pachtaicum*) were identified in these soil samples. Virus transmission studies using cucumbers as a bait showed that GFLV was not transmitted to healthy cucumbers planted in close proximity to symptomatic grapevines. This could be due to the absence of *X. index*, the known vector of GFLV, and inability of the other two dagger nematode species (*X. rivesi* and *X. pachtaicum*) present in the vineyard soil to spread GFLV. Like in Cabernet franc block, it is likely that GFLV might have been introduced via contaminated cuttings into the Merlot block.

**Activity: Measure impacts on fruit yield and quality of berries in one wine grape cultivar.**

Impacts of TRSV on fruit yield and quality were measured in three wine grape cultivars (cvs. Grenache, Tempranillo and Syrah) during 2015, 2016 and 2017 seasons. Fifteen to twenty symptomatic and an equal number of non-symptomatic vines from each cultivar were selected to study impacts of TRSV on fruit yield and quality. The data collected from cv. Grenache in 2015 season indicated that symptomatic vines produced significantly less fruit (a reduction of 49.64% fruit yield) due to reduced number of clusters and smaller size berries, compared to non-symptomatic vines. The fruit soluble solids or sugars, measured as °Brix, in berries harvested from symptomatic vines were decreased by 11.52% compared to sugar levels in berries of non-symptomatic vines. Interestingly, no differences were observed in juice pH and titratable acidity (TA) as well as berry anthocyanins in grapes harvested from symptomatic and non-symptomatic vines. The data collected from cv. Grenache in 2016 season from the same block showed similar results with fruit yield reduced by 56.25% in symptomatic vines compared to non-symptomatic vines. The reduction in yield in symptomatic vines was largely due to smaller size berries in individual clusters than reduction in number of clusters per vine. The fruit soluble solids or sugars, measured as °Brix, in berries harvested from symptomatic vines were decreased by 7.90% compared to sugar levels in berries of non-symptomatic vines. Interestingly, no significant difference was observed in juice pH and TA between symptomatic and non-symptomatic vines, whereas berry anthocyanins were decreased by 10.44% in grapes harvested from symptomatic compared to non-symptomatic vines. It should be noted that both symptomatic and non-symptomatic vines tested positive for TRSV in RT-PCR assays suggesting that virus-infected vines can perform well as long as they don't express fanleaf degeneration and decline symptoms.

During the 2017 season, twenty symptomatic vines tested positive for TRSV and an equal number of non-symptomatic vines tested negative for TRSV were selected from cv. Tempranillo and cv. Syrah to study impacts of TRSV on fruit yield and quality. Symptomatic vines of the cv. Tempranillo produced significantly less fruit (66.6% reduction in yield) due to reduced number of clusters and smaller size berries in individual clusters compared to non-symptomatic vines. However, no significant differences were found in soluble solids, juice pH and TA. In contrast, grapes of virus-infected vines had nearly 15% higher berry anthocyanins than those produced by healthy vines. Syrah vines infected with TRSV gave 22.9% less fruit yield compared to healthy vines. Interestingly, no significant differences were observed in soluble solids, juice pH and TA and berry anthocyanins of grapes produced by healthy and virus-infected vines.

Overall, these results suggested that TRSV can cause substantial crop losses (reduced fruit yield) in infected vines. However, impact of TRSV on fruit quality attributes appears to be variable in a cultivar-dependent manner.

**Activity: Post-plant nematicide treatment to suppress nematode vector populations in infested soils.**

In the commercial Grenache block, the grower has applied Cordon (2.5 gal/acre) through drip irrigation in spring 2015 as a post-plant measure to suppress nematode vectors. Half of the block was treated with Cordon and the other half left untreated. Soil samples were collected randomly from both treated and untreated areas in fall 2015, 2016 and 2017 to examine dagger nematode (*X. rivesi*) populations. For each treatment, three biological replicates and three technical replicates for each biological replicate were used to count number of dagger nematodes per 250 cc soil sample. The data from 2015 season showed 76.5% reduction in number of dagger nematodes per 250 cc soil in Cordon-treated portion of the vineyard block compared to nematodes in soils from untreated portion of the block. This result suggested that Cordon could be used as an effective agent in suppressing nematode vectors for management of nepoviruses. However,

comparison of dagger nematode populations in soil samples between Cordon-treated and untreated portions of the block during 2016 and 2017 seasons showed gradual increase in nematode populations in treated portion of the block in 2016 and 2017 seasons. For example, the data from 2016 season showed only 37.5% reduction in number of dagger nematodes in Cordon-treated portion of the vineyard block compared to nematodes in soils from untreated portion of the block. The data from 2017 season showed only 12.9% reduction in number of dagger nematodes in Cordon-treated portion of the vineyard block compared to nematodes in soils from untreated portion of the block. It can be concluded from these results that dagger nematode populations have increased over time in Cordon-treated soil and a one-time soil fumigation with Cordon may be transient in suppressing dagger nematode populations but may not be effective for long-term sustained suppression of dagger nematodes in vineyards. This study will be continued beyond the project period to test a combination of control strategies for suppressing vector nematode populations in vineyards.

**Activity: Present results at grape industry annual meetings for the benefit of stakeholders.**

In order to bring awareness about soil-borne virus diseases in vineyards, the following presentations were made at grower-sponsored industry meetings and professional scientific meetings. These presentations provided science-based information on symptoms, diagnosis, spread and impacts of soil-borne diseases, with emphasis on *Tobacco ring spot virus*. Several growers and other industry stakeholders attending these meetings visited posters to learn the current status of soil-borne virus diseases in Washington vineyards.

- **Presentations at grape and wine industry meetings:**

- i. Natra, N., Ryan, J., Bernal, M., Akinbade, S., Swamy, P., Schultz, A., and Naidu, R.A. 2017. Beware and be aware of soil-borne viral diseases in Washington vineyards. Washington Association of Wine Grape Growers Annual Meeting, Convention and Trade Show, February 7-9, 2017, Kennewick, WA.
- ii. Naidu, R.A., Natra, N., Akinbade, S., Bagewadi, B., Swamy, P., Adiputra, J., Hottell, D., Garza, M., Ocampo, C. and Schultz, A. 2016. Tackling emerging soil-borne virus diseases in Washington vineyards. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA. Among the several posters displayed at the WAWGG meeting, this poster won second prize under Professional category. This recognition is a reflection of the high value information shared with wine grape industry stakeholders. **A copy of the poster is attached (Exhibit #1).**
- iii. Walker, L., Bagewadi, B., Swamy, P., Schultz, A. and Naidu, R.A. 2015. A new soil-borne virus disease in Washington vineyards. Washington State Grape Society Annual Meeting and Trade Show, November 12-13, 2015, Grandview, WA.
- iv. Walker, L., Bagewadi, B., Swamy, P., Schultz, A. and Naidu, R.A. 2015. A new soil-borne virus disease in Washington vineyards. Washington Association of Wine Grape Growers 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA.

- **Presentations at professional scientific meetings:**

- i. Natra, N., Akinbade, S., Schultz, A., and Naidu, R.A. 2017. Epidemiology of Tobacco ringspot virus causing fanleaf degeneration and decline symptoms in wine grape (*Vitis vinifera*) cultivars. 2017 American Phytopathological Society Annual Meeting, August 5-9, 2017, San Antonio, TX. **A copy of the poster is attached (Exhibit #2).**
- ii. Natra, N., Akinbade, S., Bagewadi, B., Swamy, P., Schultz, A. and Naidu, R.A. 2016. The current status of nepoviruses in Washington vineyards. APS Pacific Division Meeting, La Conner, WA. June 28-30, 2016.
- iii. Naidu, R.A., Bagewadi, B., Walker, L., Swamy, P., and Schultz, A. 2015. *Tobacco ringspot virus* in a wine grape (*Vitis vinifera*) cultivar in Washington State. Proceedings of the 18<sup>th</sup> Congress of the International Council for the Study of Virus and Virus-like Diseases of the Grapevine (ICVG), Ankara, Turkey, September 7-11, 2015, 24-25.

- iv. Walker, L., Bagewadi, B., Schultz, A., and Naidu, R.A. 2015. The occurrence of *Tobacco ringspot virus* in a wine grape (*Vitis vinifera* L.) cultivar in Washington State. 2015 American Phytopathological Society Annual Meeting, August 1-5, 2015, Pasadena, CA.
- **Publication in a peer-reviewed scientific journal:**  
Walker, L., Bagewadi, B., Schultz, A., and Naidu, R.A. 2015. First report of *Tobacco ringspot virus* associated with fanleaf disease in a Washington State vineyard. *Plant Disease* 99:1286.
- **News outlets:**
  - i. Soil-borne virus stunts crop growth; causes concern for farmers. KNDO/KNDU Right Now (NBC affiliate based in Yakima and Tri-Cities, WA). July 12, 2017. (<http://www.nbcrightnow.com/story/35872486/soil-borne-virus-stunts-crop-growth-causes-concern-for-farmers>).
  - ii. Tobacco ring spot virus found in Washington wine grapes. Capital Press, June 23, 2017. (<http://www.capitalpress.com/Washington/20170623/tobacco-virus-found-in-washington-wine-grapes>).
  - iii. WSU study finds virus threaten grape crops. KING 5 (NBC affiliate based in Seattle, WA) June 15, 2017. (<http://www.king5.com/tech/science/environment/wsu-researchers-find-harmful-worms-in-wine-growing-soil/449413104>).
  - iv. Vineyard, WSU scientists team up to battle orchard virus threat. WSU News. June 14, 2017. (<https://news.wsu.edu/2017/06/14/plant-virus-major-threat-to-growers/>).
- Activity: Contribute to field days and/or tail-gate meetings for information dissemination.**
  - i. Information was disseminated during one-on-one meetings with 25 growers, 2 nurseries and five WSDA nursery inspectors during field visits in 2015, 2016 and 2017 seasons.
  - ii. The project results were shared with St. Michelle Wine Estates Viticulture Team (15 people) at a meeting held at 14 Hands Winery, Prosser on May 4, 2017.
  - iii. The project results were shared with about 75 wine industry stakeholders at the WAVE 2017 Washington Advancements in Viticulture and Enology meeting held on April 19, 2017.
  - iv. The project results were shared with 20 participants in the Viticulture Certificate program offered by Washington State University (WSU) on September 10, 2017.
  - v. A poster “An overview of nematode-transmitted viruses in Washington vineyards” was displayed at Washington State Grape Society annual meeting. November 10-11, 2016, Grandview, WA.
  - vi. The project results were shared with about 60 wine industry stakeholders at the WAVE 2016 Washington Advancements in Viticulture and Enology meeting held on July 14, 2016.
  - vii. The project results were shared with 30 participants in the Viticulture Certificate program offered by Washington State University (WSU) on September 11, 2016.
  - viii. The project results were shared with 77 students enrolled in WSU course “PIP 300: Diseases of Fruit Crops” during field visits on October 7<sup>th</sup> and 8<sup>th</sup> and during class lectures in 2016 Fall semester.
  - ix. The project results were shared with the Departments of Agriculture in Washington, Oregon and Idaho during a workshop “Harmonizing grapevine nursery certification program across the Pacific Northwest” held on July 19, 2016, at The Dalles, OR. Eight members from the Departments of Agriculture and 12 industry stakeholders learned about the status of nepoviruses in Washington vineyards.

The project was led by the PI (Naidu Rayapati) and assisted by a post-doctoral research associate and other personnel in Rayapati’s program. The PI has coordinated project activities, conducted outreach and educational activities and submitted quarterly and annual reports. The project personnel carried out proposed activities. Rayapati and post-doctoral associate made oral and poster presentations describing the project results at grape industry and professional scientific meetings. Wine grape growers have provided access to vineyards for sample collections and conduct certain activities of the project. One grower has

provided in-kind contributions (personnel to help sample collections, planting cucumbers and grapevines as well as watering during the season, fruit harvesting and yield estimations, and donation of grapes for measuring fruit quality) for successful implementation of the project. WSDA nematology laboratory at WSU-IAREC, Prosser, provided technical support and microscope facilities for identification of nematode species present in soil samples. Commercial services were used for next-generation sequencing and identification of nematodes in soil samples.

This project addressed a specific biotic constraint affecting wine grapes. Thus, outcomes of this project benefited Washington’s wine and juice grape industry. The project outcomes have no potential benefits to producers/processors of non-specialty crops.

**GOALS AND OUTCOMES ACHIEVED**

As described above, proposed activities were completed during the project period. Using molecular biology techniques and other science-based approaches, two nematode-transmitted viruses (TRSV and GFLV) were documented in Washington vineyards and their genomes characterized to establish phylogenetic relationships with nepoviruses currently reported in other grapevine-growing regions. Molecular methods were developed for reliable detection of TRSV and GFLV in vineyards. This diagnostic capacity is vitally important, since both viruses can produce fanleaf degeneration and decline symptoms and symptom-based diagnosis is difficult to differentiate them in infected vines. Techniques were optimized for nematode collections from soil samples and testing individual nematodes for the presence of TRSV and GFLV by RT-PCR. Impacts of TRSV on fruit yield and quality attributes were measured in three red fruited wine grape cultivars. The spread of TRSV was demonstrated from symptomatic grapevines to healthy cucumbers and Cabernet Franc vines that were used as transmission bait plants. Using morphological characteristics and sequence analysis of specific portions of the nematode genome, the dagger nematode present in the vineyard soil was identified as *Xiphinema rivesi*. In addition, *X. rivesi* was identified as a likely vector for the spread of TRSV but not GFLV in vineyards. Science-based knowledge was shared with stakeholders, state regulatory agencies and research and extension faculty and students via a wide range of dissemination pathways for increased awareness of nematode-transmitted viruses in vineyards.

In summary, the project met targets and benchmarks listed in the project proposal to fulfil the goal “To identify viruses and nematode vectors associated with soil-borne diseases emerging in Washington vineyards and disseminate research-based knowledge to stakeholders and regulatory agencies for advancing sustainable growth of Washington’s grape and wine industry.”

It is anticipated that the project data will be published in a peer-reviewed scientific journal during 2018. In addition, a fact sheet on nematode-transmitted viruses in Washington vineyards is being developed with an anticipated publication in 2018. The fact sheet will be distributed widely among the industry stakeholders for implementing best practice guidelines to manage nematode-transmitted viruses in grower vineyards.

<b>Project Activity</b>	<b>Timeline (month and year)</b>	<b>Accomplishments</b>
Collect samples from vineyards and test for nepoviruses and other viruses by serological and molecular assays.	Oct-Dec 2014; Jun-Oct 2015 & 2016.	Completed
Characterization of nepoviruses using biological assays and molecular biology techniques (including next-generation sequencing technology, if warranted).	Jan 2015-Dec 2016	Completed
Optimize sampling and diagnostic protocols for the detection of nepoviruses in grapevine and nematode vectors.	Jul 2015-Oct 2016	Completed
Collect soil samples, identify nematodes and conduct virus transmission studies using cucumber baiting assay.	May 2015 – Dec 2016	Completed

Measure impacts on fruit yield and quality of berries in one wine grape cultivar	Sept-Oct 2015 & 2016	Completed
Develop and distribute bilingual field guide on nematode-transmitted viruses.	July 2016 - March 2017	On-going, expected to complete in 2018.
Contribute to field days and/or tail-gate meetings for information dissemination.	Jun-Sept 2015 & 2016	Completed
Present results at grape industry annual meetings and scientific meetings.	Jul/Aug & Nov 2016; Feb 2017	Completed
Submit quarterly and annual reports	Jan 2015 - Mar 2017	Completed

The amended work plan for year 3 of the project:

<b>Project Activity</b>	<b>Timeline (month and year)</b>	<b>Accomplishments</b>
Collect samples from vineyards and test for nepoviruses by serological and molecular assays.	Jun - Sept 2017	Completed
Validation of molecular diagnostic assays for discrimination of two nepoviruses (TRSV and GFLV)	Oct 2016 - Jul 2017	Completed
Characterization of Grapevine fanleaf virus from cv. Merlot using next-generation sequencing technology.	Jan - Apr 2017	Completed
Collect soil samples from Merlot block, identify nematodes and conduct virus transmission using cucumber baiting assay.	Oct 2016 - Sept 2017	Completed
Measure impacts on fruit yield and quality of berries in one wine grape cultivar	Aug - Sept 2017	Completed
Develop a fact sheet/field guide on nematode-transmitted viruses	Jan - Sept 2017	On-going, expected to complete in 2018.
Present results at grape industry annual meetings and scientific meetings.	Feb 2017, Jun-Aug 2017	Completed

The presence of GFLV was documented a few years ago in two commercial vineyards. Prior to this project, no additional information was available on the importance of nematode-transmitted virus diseases to the health of vineyards. As described above, this project generated science-based knowledge for practical applications in managing two important nematode-transmitted viruses and strengthening state-wide clean plant campaigns and grapevine certification programs. The project outcomes have laid a foundation to continue monitoring vineyards for nepoviruses and implementing measures to prevent their spread in vineyards. The knowledge of the presence of TRSV in vineyards is helping regulatory agencies to strengthen grapevine certification programs for preventing the introduction and spread of the virus via planting materials supplied by registered nurseries in Washington State.

### **BENEFICIARIES**

As listed under the activities “Contribute to field days and/or tail-gate meetings for information dissemination” and “Contribute to field days and/or tail-gate meetings for information dissemination” above, outcomes of the project benefited the following stakeholders:

- i. The Departments of Agriculture in Washington, Oregon and Idaho in harmonizing and strengthening grapevine nursery certification programs across the Pacific Northwest.
- ii. Grape and wine grape industry stakeholders (consisting of grape growers, wine makers, crop consultants, vineyard managers and farm workers) in the Pacific Northwest.

- iii. Research and extension faculty working on grapes, and research associates, graduate students and undergraduate students specializing in Viticulture & Enology Programs at Washington State University and in community colleges.

As detailed above, dissemination of research-based knowledge generated from the project activities provided latest information with regard to nematode-transmitted viruses to the grape and wine industry that is currently contributing an estimated \$5 billion to Washington State's economy. Since managing virus diseases affecting vine health and fruit yield and quality is recognized by the grape and wine industry as one of the highest priorities, the project outputs have contributed to implementation of science-based best practice guidelines to manage nematode-transmitted virus diseases in vineyards for long-term sustainability of the wine grape industry. Additionally, the project contributed to the WSDA SCBGP priority "Controlling Pests and Diseases" impacting Washington State's agriculture.

**Benefit to industry stakeholders:** An estimated 750 grower and winery members of the Washington Winegrowers (<https://www.wawinegrowers.org/>) and the Washington State Grape Society (<http://www.grapesociety.org/>) benefited with research-based knowledge shared via educational and outreach events. With an estimated 5 percent increase in wine grape acreage annually from the current 60,000 acres, the project has contributed to sustainable growth of the \$5 billion wine grape industry in Washington State. Since managing virus diseases affecting vine health and fruit yield and quality is one of the top priorities for the grape and wine industry as one of the highest priorities, the project has contributed to implementation of science-based best practice guidelines to manage nematode-transmitted virus diseases in vineyards for long-term sustainability of the wine grape industry in Washington State.

**Benefit to the next-generation of viticulturists:** About 75 undergraduate students (with most of them majoring in Viticulture & Enology) at Washington State University enrolled in the course "PIP 300: Diseases of Fruit Crops" gained knowledge about impacts of nematode-transmitted viruses in wine grapes and management of soil-borne viral diseases in commercial vineyards.

**Benefit to regulatory agencies:** Eight members of the Departments of Agriculture in Washington, Oregon and Idaho gained knowledge about the status of nematode-transmitted viruses towards strengthening grapevine quarantine and certification rules and regulations in the Pacific Northwest.

**Benefit to the scientific community:** Scientific publications (<https://apsjournals.apsnet.org/doi/10.1094/PDIS-02-15-0140-PDN>) and presentations at professional scientific meetings benefited an estimated 50 research and extension faculty associated with viticulture and enology programs and about 10 graduate students majoring in viticulture and enology across the United States.

## **LESSONS LEARNED**

Changing viticulture practices and replacing other crops with wine grape cultivars are creating many opportunities for plant viruses to 'jump' from one crop to the other with devastating consequences. It is likely that TRSV could cause latent infections with no apparent impact in other crops (such as fruit trees), but could cause serious problems in wine grapes with severe consequences to grower's income. Historically, nematode-transmitted viruses, such as GFLV, are known to be a constraint to wine grape production in many grape-growing regions around the world. For the first time, the project outcomes highlighted that TRSV could become a major impediment to the expansion of wine grape acreage in Washington State. Thus, testing soils for the presence of nematode vectors and testing nematodes for the presence of TRSV before planting wine grapes could help growers make informed decisions about risks associated with nematode-transmitted viruses. Understanding the genome characteristics and epidemiological properties of TRSV and GFLV has shed new light on modes of their spread in vineyards.

For example, it is clear from the project outcomes that TRSV can be spread by dagger nematode species (*Xiphinema rivesi*) present in Washington soils. In contrast, transmission of GFLV is unlikely to occur by *X. rivesi*. The absence of *X. index* in Washington soils also makes the spread of GFLV less likely in vineyards. Thus, a combination of planting virus-tested cuttings and nematode vector management are key for minimizing the spread of TRSV in vineyards. In contrast, removing infected vines and planting virus-tested cuttings can be adopted for preventing the spread of GFLV in vineyards. Participatory collaborative approaches with industry stakeholders and growers as well as state regulatory agencies is critical for effective dissemination of research-based knowledge in a timely manner to contain emerging virus diseases.

Fanleaf degeneration and decline symptoms can be caused by different nematode-transmitted viruses. Thus, symptoms are not a reliable indicator of a specific virus and sensitive and specific diagnostic methods have to be used for the discrimination of viruses present in symptomatic vines. In essence, accurate diagnosis of a virus is the first critical step in deploying appropriate management strategies for controlling viral diseases in vineyards.

Project activities were completed according to the proposed timeline in the project. Due to the extended nature of grape season, no-cost extension until end of September 2017 helped to successfully complete proposed activities. Team work between project personnel and productive collaborations with wine grape growers and regulatory agencies was found to be critical for achieving project goals and making tangible impacts.

#### **ADDITIONAL INFORMATION**

Total cash or in-kind match obligated for the project: \$109,344.

Total cash or in-kind match utilized for the project: \$118,804.42. This includes Salaries (\$60,514.34), Employer contributions (\$21,481.01) and Facilities & Administrative costs (\$36,806.07).

In 2015, a research article was published in a peer-reviewed scientific journal (Walker, L., Bagewadi, B., Schultz, A., and Naidu, R.A. 2015. First report of *Tobacco ringspot virus* associated with fanleaf disease in a Washington State vineyard. Plant Disease 99:1286. <https://apsjournals.apsnet.org/doi/10.1094/PDIS-02-15-0140-PDN>). Another publication is anticipated during 2018 based on the data generated from this project. A fact sheet is being developed on nepoviruses and their detection with an anticipated publication in 2018/2019. Funding support from the SCBGP will be duly acknowledged in all of these publications.

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## **PROJECT #16**

**Project Title:** Integrated Management of Botrytis on Ornamental Geophyte Cut Flower Crops

**Partner Organization:** Washington State University – Gary Chastagner

### **PROJECT SUMMARY**

Diseases caused by species of *Botrytis* are the most economically destructive diseases of peonies, lilies, and tulips grown as cut flowers, both in the field and post-harvest. *Botrytis* species are common in fields of these cut flowers, and include, *B. cinerea*, a generalist pathogen of over 1,400 host species, as well as host-specific *Botrytis* species that tend to be more aggressive. A combination of *B. cinerea* and host-specific *Botrytis* can cause total destruction of above-ground plant parts and a 50-60% reduction of growth of the perennial root or bulb structure. Management of *Botrytis* diseases in cut flowers is heavily reliant on the use of traditional chemicals at high rates and intervals, as well as a number of cultural management strategies. On tulips and lilies, 10 to 20 applications of fungicides per season are applied by some growers to limit the development of *Botrytis*. The high number of applications used in these systems is costly for growers, increases the risk of fungicide resistance problems, and raises concerns about potential environmental impacts associated with grower disease management programs. A number of approaches are being used to try to reduce the number of applications of fungicides to control Botrytis on tulips and lilies. In the Netherlands, the development of the BoWaS: Botrytis Warning System has been shown to potentially reduce overall fungicide use on tulips and lilies, but some growers have been reluctant to switch from calendar-based spray schedules. Another approach to reduce the number of fungicide applications is to integrate crop phenology into the disease management program. In some crops, the continuous emergence of new foliage necessitates the continued applications of fungicides during the growing season to protect foliage from infection. However, in tulips and lilies, all of the foliage that is going to develop is present at the time of flowering. Given the residual activity of many fungicides, it may be possible to reduce or eliminate applications of fungicides once flowering has occurred. It may also be possible to integrate bio-fungicides, which are generally not as effective as conventional products, with conventional fungicides into a disease management program. One of the goals of this project was to assess alternatives to traditional chemically-intensive cropping systems, including testing biopesticides and monitoring weather conditions to help growers better predict high-risk conditions for disease development.

Although Botrytis gray mold on peonies has been known for over 100 years, very limited information is available relating to factors that affect the development of *Botrytis* on peonies. With the support of a SCBG from the Alaska Department of Agriculture, a collaborative research project was initiated between Washington State University and the University of Alaska Fairbanks to improve the management of *Botrytis* on peonies. During 2013, a preliminary study was done to better understand the prevalence of the host-specific *B. paeoniae* and *B. cinerea* in AK and WA fields. *Botrytis* species were identified using a combination of traditional morphological and newer molecular DNA techniques. The results indicate that there is a complex of *Botrytis* species that are occurring on peonies in these states, many of which have never been described by science. Recent advancements in molecular identification using genomic sequencing have indicated immense variability in spatial and temporal distribution and fungicide resistance among and within species of *Botrytis*. Therefore, the presence of previously unknown *Botrytis* species in the peony production systems warrants a thorough investigation into the species present in peony fields to provide growers with the necessary tools to manage gray mold.

The specialty cut flower (CF) industry has grown in the United States as production of traditional cut flowers, such as tulips, carnations, and chrysanthemums, has moved abroad. The Pacific Northwest of the

United States, including WA, OR, and AK alone have over 300 peony, tulip, and lily growers for cut flowers and rootstock/bulbs, grown on over 2,000 acres in WA or alone. The peony industry in Alaska has experienced a tremendous increase since 2004. In just 10 years, Alaska has become the 7<sup>th</sup> most important cut peony producing state in the nation as measured by value of the industry. According to the 2012 USDA Ag Census, Oregon is #1 and Washington is #5 in the United States in terms of peony cut flower sales. Producers range from large-scale wholesale producers that ship bulbs/rootstocks and CF throughout the U.S., to increasing numbers of small farms that are providing freshly-harvested CFs to local markets. In WA, CFs are sold at over 150 local farmers' markets and a group of growers has recently established the Seattle Wholesale Growers Market that sells CFs from local growers and AK. A 2012 WSU survey of WA CF growers indicated that 98% of current CF growers had less than 10 acres in production and 51% had less than 1 acre. In addition to CFs, there are a number of large growers who also sell planting stock to CF growers throughout the region and nation. Many of the growers in AK obtain their planting stocks from peony producers in WA and OR. Locally, there are also a large number of display gardens and festivals, such as the Skagit Valley Tulip Festival which generates in excess of \$40 million in revenue that adds to the economic vitality of local communities through agro-tourism. It is difficult to estimate the total economic benefit of this project to growers: however, the economic benefit can be estimated on an acre-by-acre basis. Growers have reported losses of 50 to 60% due to *Botrytis*. Conservatively, an acre of peonies, tulips and lilies could yield 50,000 stems per acre. At a very conservative price of \$2 per peony stem, even a 10% loss due to *Botrytis* equates to \$10,000. Thus, even a small improvement in disease control has the potential to have a large economic benefit. In addition, growers such as those associated with the Seattle Wholesale Growers Market and many of the growers in AK are interested in organic production of these CF crops. The proposed biopesticide work will benefit them and potentially increase the integration of biopesticides into other growers' disease management programs which would result in a number of environmental and worker benefits.

This project builds on a previously funded (\$10,000) Alaskan SCBGP project that provided one year of funding to conduct initial disease surveys of peony fields in Alaska. The limited survey conducted as part of that project indicated that there was a greater diversity of *Botrytis* spp. on peony in AK than had been previously reported on this crop. This project expanded the survey work to obtain a better understanding of the diversity of *Botrytis* species on peonies in AK, WA, and OR.

### **PROJECT APPROACH**

*Activity 1. Maintain geophyte plant material at WSU Puyallup* - A total of approximately 0.4 acres of field-grown geophytes (peonies, tulips, lilies, etc.) were planted and maintained at the Puyallup Research and Extension Center in Puyallup, WA. 800 potted peonies were also maintained and up to 50 peony roots were held in cold storage for use in root-inoculation or pathogenicity studies throughout the course of the project.

*Activity 2. Contact growers to obtain disease samples and set up disease progression study sites* - Two growers in WA, one in OR, and 4 in AK were contacted during the first and second years of this project to identify sites for installation of environmental monitoring equipment, disease monitoring studies, and collection of disease samples. With the exception of one site in Alaska, the same fields were monitored in each season during the course of this project.

*Activity 3. Collect samples from grower sites* - Samples were collected from 24 grower sites in 2015 and isolates of *Botrytis* were identified to species. More than 400 samples were collected, and hundreds of *Botrytis* samples isolated, however, due to difficulties in molecular tools used to identify them to species, not all were identified past the genus level. For those isolates for which molecular identification was not possible, *Botrytis* isolates were identified morphologically. Furthermore, many of the samples collected were infected with organisms other than *Botrytis*. All *Botrytis* isolates were archived. From 2014 to 2015, a total of 179 *Botrytis* isolates were identified from WA, OR, and AK.

*Activity 4. Monitor progression of Botrytis infection on peonies* - Eight weather stations were deployed in 7 commercial peony fields throughout the Pacific Northwest and at WSU Puyallup during the 2015 and 2016 growing seasons. Of the weather stations at commercial fields, four were in Alaska, three in Washington and one in Oregon. The weather stations in Alaska represented the major peony production regions of the state: the Interior (Fairbanks) region, the Matanuska-Susitna Valley, and the Soldotna and the Homer regions of the Kenai Peninsula. Weather stations were deployed in February in WA and OR and in April in AK. All weather stations were taken down by September in all locations. Data was collected during the peony growing season on temperature, rainfall, and leaf wetness for all locations. Average environmental conditions for 2016 at all locations are reported in (**Figure 1**).

Disease progression was monitored in all sites, either by WSU or remotely using photos supplied by growers. Samples were taken at three (3) times during the year in Washington and Oregon, including during the end of the growing season, and one (1) time in Alaska at the end of the growing season. Final disease evaluations were made on unsprayed plants of the cultivar ‘Sarah Bernhardt’ in all locations by WSU. Linear regression analyses were performed to determine any relationship of disease development to the environmental parameters measured (**Figure 2**). Temperature, rainfall, and leaf wetness, individually and in combinations of parameters, were plotted against final disease ratings for each location. For all individual parameters and combinations, no apparent correlation between environmental conditions and disease development was identified for the 2016 data due to lack of significant p-values. In an attempt to give the test more power, 2015 and 2016 data from WA and OR were combined with 2015 and 2016 data from Alaska and the most biologically relevant parameters associated with *Botrytis* biology. Final disease ratings were tested against the data most likely to contribute to disease development because the conditions are favorable for *Botrytis* spore germination and infection. The environmental parameters assessed were as follows: the number of leaf wetness periods greater than or equal to 4 hours; the average temperature during leaf wetness periods greater than or equal to 4 hours; and the number of instances of leaf wetness to occur when temperatures were 53.6-86°F. The results of those linear regression analyses are shown below with r-squared and p-values, none of which are significant. The failure to identify a correlation likely is not due to the irrelevance of the environmental data collected in disease development, rather the prevalence of confounding and uncontrolled factors in the systems observed such as: differences in patterns of fungicide use; the prevalence of fungicide resistance; the presence of a diversity of *Botrytis* species present among fields; initial inoculum loads present in fields; differences in phenological development in periods conducive to disease development; planting density; and irrigation practices. In vitro tests to assess variability among *Botrytis* species to infect peonies under various environmental conditions could lead to better understanding of conditions favorable to disease.

*Activity 5. Isolate and identify Botrytis species obtained from peony samples* - 178 isolates of *Botrytis* from peony were identified from 23 fields in AK, 8 fields in WA, and 4 fields in OR. All isolates were identified using PCR and sequencing of the glyceraldehyde-3-phosphate dehydrogenase (G3PDH) gene. Using this gene alone, 136 isolates were identified as either *B. cinerea*, *B. paeoniae*, or *B. pseudocinerea*. The remaining 42 isolates that were not identified as one of these three species were subjected to additional PCR and sequencing of the heat-shock protein 60 (HSP60), DNA-dependent RNA polymerase subunit II (RPB2), and necrosis and ethylene-inducing proteins 1 and 2 (NEP1 and NEP2) genes. Phylogenetic analysis using all genes indicated that the isolates represented at least 13 distinct clades, many of which could be species. Up to 13 new species could potentially be described using molecular techniques. **Figures 3 and 4** are phylogenetic trees showing the relatedness of these 42 isolates to known *Botrytis* species based on sequence data. The diversity of *Botrytis* species varied by the region where isolates were obtained from (**Figure 5**). In short, the majority of isolates from Washington and Oregon were identified as being either *B. cinerea* or *B. paeoniae*, whereas 35% of the isolates from Alaska were species other than *B. cinerea*, *B.*

*paeoniae*, or *B. pseudocinerea*. Many of these isolates represented new species, including the species that was described as *B. euroamericana* as a result of this project (See 7.1 below).

*Activity 6. Conduct pathogenicity and rootstock infection studies on peonies* - Sixty peony roots were inoculated with *Botrytis paeoniae* in the fall of 2015 to determine the potential for commercial rootstocks to become infected by *Botrytis*. Roots were inoculated in three locations on the root with agar plugs that had been colonized by *B. paeoniae*. The inoculated locations included: a cut root surface, an area below the next year's developing bud, and on a basal stem piece that remained intact on the root. Only the cut root surface became infected with *B. paeoniae* as confirmed by isolations after incubation in the greenhouse (**Figure 6**). Twenty additional plants were inoculated to determine if above-ground infections have the potential to travel down into the roots. Roots were then potted and left outside to vernalize over the winter. In the spring of 2016, plants were routinely observed for above ground *Botrytis* disease development; no infection appearing to originate from the root tissue was observed in any of the treatments. At the end of the season, roots were washed clean of soil and observed for lesion development. Lesions were not observed on any of the tissue and *B. paeoniae* was not able to be re-isolated from any root tissue. Isolations were made from the inoculation site that had been marked by a pin: however, *Botrytis* was not recovered from any of the inoculation sites on any of the treatments. Furthermore, there was no increased disease development in above-ground tissues on inoculated plants versus control plants. These results suggest that the method of root inoculation to test the potential for movement of *B. paeoniae* with rootstock is either ineffective or the pathogen is not very aggressive on peony root tissue. Alternatively, development of disease may not occur in the field as was tested during this project: rather, disease development could occur largely in storage. This hypothesis is based on the observation of severe *B. paeoniae* infection seen on peony root tissue that had been held in cold storage during the 2017 season.

Microsatellite markers were developed by WSU to determine the presence of *B. paeoniae* movement on rootstock. A total of 16 *B. paeoniae*-specific microsatellite markers were developed, 15 of which are polymorphic in the isolates that have been tested from WSU collections. Development of these markers was aided by two draft genome sequences of *B. paeoniae*, one that WSU developed using funding from this grant and one that was provided by a Dutch university. The results of this marker development have been published, including primer sequences and allele sizes. The microsatellite markers were tested on 68 *B. paeoniae* isolates collected by WSU from across the United States and The Netherlands. Although 15 of the loci are polymorphic, not enough overall variability exists to determine movement or relatedness of the individual genotypes. Statistical tests to determine the number of populations represented in these 68 samples are inconclusive, suggesting either they represent one population or more information is needed to elucidate differences. The markers should be tested on a larger collection of *B. paeoniae* isolates to improve clarity of its population structure.

*Activity 7. Conduct fungicide resistance studies* - A total of 50 isolates of *B. paeoniae* and 50 isolates of *B. cinerea* were tested in-vitro for their resistance to 7 fungicides (iprodione, thiophanate-methyl, fenhexamid, boscalid, pyraclostrobin, fludioxonil, and cyprodinil). Each isolate was grown on potato dextrose agar (PDA) amended with three rates of each fungicide (0.1, 1.0 and 10 ppm ai) to determine the concentration required to inhibit the growth of each isolate on PDA alone by 50% (EC50). The 50 isolates of each species represented collections from Alaska, Washington and Oregon.

There was very little difference in the sensitivity of the isolates from the different states. Overall, all of the *B. cinerea* and *B. paeoniae* isolates were very sensitive to fenhexamid with EC50 values of <0.1 ppm. About 2% of the *B. cinerea* and *B. paeoniae* isolates had EC50s >10 ppm of iprodione. The addition of thiophanate-methyl, even at 10 ppm had very little effect on the growth of any of the isolates included in the tests. It is unclear if the lack of sensitivity to this fungicide is due to resistance or a problem with the testing method. The percentage of *B. cinerea* isolates with EC50s >10 ppm for boscalid, pyraclostrobin,

and cyprodinil was 67.3, 49.0, and 98.0%, respectively. For *B. paeoniae* isolates the percentages with EC50's >10 ppm for the same fungicides were 31.9, 2.1, and 78.7%, respectively. These data suggest that strains of *B. cinerea* and *B. paeoniae* from peony fields in Alaska, Oregon, and Washington are resistant to a number of commonly used Botrytis fungicides. This indicates that grower disease management programs need to include practices such as fungicide rotations to manage fungicide resistance problems.

*Activity 8. Conduct integrated disease management field trials* - Over the course of this project 23 fungicides were tested in one or more of 11 trials (**Table 1**). The purpose of these field trials was to evaluate the effectiveness of biopesticides, such as F9111, Proud 3, Botector, BW165N, and MRI110; reduced-risk fungicides such as, BAS 703 01F (Orkestra), S2200, and NUP 09092, to three industry standards (Pageant, Daconil WS and Chipco 26019) in controlling Botrytis on tulips, lilies and peonies crops. In general, the biopesticides tested over the 3 years of trials did not perform well in WSU field trails.

Six trials were conducted on tulips. Results showed that several of the newer reduced risk products were effective in controlling *Botrytis*, particularly on the foliage. In 2015, Orkestra, NUP0902, and S2200 were as effective as both Pageant and Chipco in controlling disease on the foliage (**Figure 7**). Inadequate disease developed in 2016; however, in 2017, one trial was conducted to determine what effect application frequency had on the development of *Botrytis* on tulips. Results showed all of the fungicide treatments reduced foliage dieback compared to the non-sprayed checks. In addition, applications of Orkestra, NUP 09092, S2200 were as effective as Pageant when applied at both low and high rates and on 14 or 28 day intervals (**Figure 8**).

In 2015 and 2016, field trials were conducted to determine what effect adoption of a crop phenology-based spray program that stopped sprays after flowering had on the control of *Botrytis* on lilies and tulips. Two conventional fungicides (Pageant 38WG and Daconil Weather Stik) and one biopesticide (F91101) were included in the trials. These trials showed that limiting applications to the period of time up to flowering were as effective as spraying fungicides to plants during the whole season on lilies and tulips (**Figures 9 & 10**). The results from these trials indicate that limiting applications of Pageant 38WG to the period of time from emergence to flowering was as effective as applications throughout the whole season in controlling fire on tulips and lilies. This was also true with Daconil Weather Stik on tulips and during one of the two trials on lilies. These results suggest that sufficient residues of these fungicides persisted on the foliage to protect the leaves during the period of time from flowering to the end of the growing season. The effectiveness of these fungicides in limiting disease development early in the growing season also probably reduced inoculum levels, which would also help limit disease development later in the growing season. Ceasing applications at flowering resulted in a 40 to 66% reduction in fungicide applications in WSU trials. The results with F9110, which contains a 20% extract of *Lupinus*, indicates that this biopesticide has limited ability to control fire on tulips and lilies, even when it is integrated into a spray program with conventional fungicides.

Two trials were conducted on peonies. Limited disease developed on plants maintained outdoors in both 2016 and 2017. Given the limited disease that developed on the plants, on May 22, 2017 leaves were harvested from the plants after the last treatment application and inoculated with mycelia plugs of *B. cinerea* and *B. paeoniae* to assess the residual activity of the fungicide treatments. Checks consisted of non-sprayed leaves that were inoculated with mycelial plugs of *B. cinerea* and *B. paeoniae* or plugs of just plain media. Lesion development on the treated leaves was compared to the size of lesions that developed on inoculated checks. No lesions developed on the non-inoculated checks (**Figure 11**).

After 96 hours incubation at 18C, lesion size on the *B. paeoniae* inoculated leaves ranged from 0.0 to 4.37 cm and ranged from 0.0 to 5.15 cm on the *B. cinerea* inoculated leaves (**Figures 12 & 13**). Several fungicides either reduced or eliminated the growth of lesions compared to the inoculated checks in the *B.*

*paeoniae* inoculated leaves. The most effective treatments were Daconil WS, S2200, Kenja 400 SC, Orkestra, Pageant 38 WG, NUP 09092, and Medallion WDG. Fewer fungicides were effective against *B. cinerea*. Treatments of Medallion and NUP09092 were the only treatments that had lesions that were significantly smaller than the inoculated checks in the *B. cinerea* test.

To assess the effect of the preharvest applications of fungicides during the growing season on the postharvest development of gray mold on the foliage and flower buds on stems during cold storage, three flower stems were harvested from each plant in the 2017 trial and held in cold storage for 4 weeks at 1 to 5C. Just prior to storing, the bundles of flowers were sprayed with *Botrytis cinerea* spores and then wrapped in paper to encourage disease development. The foliage was rated for disease severity on a scale of 0 to 10 scale, where 0 = no dieback and 10 = 91 to 100% of the foliage is dead. Disease development on the flowers were rated on a scale of 0-3 where 0 = none, 1 = slight infection (< 25% of flower infected), 2 = moderate infection (25-50%), 3 = severe (>50% of flower infected). Flowers that were held in cold storage for 4 weeks had high levels of disease on both the foliage and flowers (**Figures 14 & 15**). Disease ratings on the foliage ranged from 0.1 to 7.4 and treatments with MBI110, Badge X2, Daconil WS, S2200, NUP 09092, Pageant 38 WG, Kenja 400 SC, Orkestra, Palladium, and Medallion WDG had significantly lower disease ratings on the foliage than the inoculated check (**Figure 15**). However, compared to the inoculated check, none of the fungicides significantly lowered disease ratings on the flower buds.

To determine if the limited effectiveness of some of the fungicides in the spray trials was due to inadequate fungicide coverage on the leaves, leaves were collected from field-grown ‘Sarah Bernhardt’ peonies that had not been treated previously with fungicides. The leaves were then dipped in fungicides solutions at the same concentrations used in the spray trial. The surface of the leaves were allowed to dry before placing mycelia plugs of *B. cinerea*, *B. paeoniae*, and two other pathogens of peonies (*Sclerotinia sclerotiorum*, and *Graphiopsis chlorocelphala*) on the upper surfaces of the leaf sections, which were then incubated for 4 days (*Graphiopsis* leaves were incubated for 15 days) at 18C. Inoculated and non-inoculated checks consisting of leaves that had not been treated with a fungicide were included in this test.

Compared to the inoculated checks, a total of 12, 9 and 9 fungicides treatments significantly reduced the size of *B. paeoniae*, *B. cinerea*, and *Sclerotinia sclerotiorum* lesions respectively (**Figures 16, 17, and 18**). Eight fungicides, Orkestra, NUP 09092, Pageant, Chipco 26019, Medallion, Palladium, Decree, and Kenja significantly reduced lesion development of all three pathogens. With respect to *B. paeoniae*, three additional fungicides had significantly lower lesion size development. These were as follows: Daconil Weather Stik, Badge X2, and Fore. Far fewer fungicides controlled lesion development on the leaves inoculated with *Graphiopsis*. Only treatments of NUP 09092 and Medallion had lesions that were significantly smaller than the inoculated checks (**Figure 19**). The increased number of fungicides that were effective in controlling the *Botrytis* lesions in this dip test illustrates the importance of having good coverage on plants when applying fungicide sprays.

*Activity 9. Analyze data, prepare quarterly and annual reports* - Data have been analyzed as it has been collected and all progress reports have been completed and submitted on time.

*Activity 10. Organize yearly grower conference and field day and present update progress report to industry* -

Grower conferences and field days were attended or organized as specified in the grant proposal in January of 2015, 2016, and 2017 and in May of 2015 and 2016. In January 2015, a growers’ conference was held in Auburn, WA and in May 2015, a growers’ field day was held in Mt. Vernon, WA. In January 2016, a growers’ conference was held in Auburn, WA and in May 2016, a growers’ field day was held at WSU Puyallup. At each event, 30 growers from Washington and BC attended. In January 2017, a growers’ conference was held in Puyallup, WA; 20 growers from WA and BC attended. At all meetings, growers

were updated with research project activities related to the present WA SCBG. Furthermore, presentations relating to this project were given in January 2015-2017 at the Alaska Peony Grower's Association (APGA) annual conferences by the PI and Graduate Student. With support from a Western SARE grant, the PI and Ph.D. Graduate organized a 4 hour workshop on the identification and management of diseases of peonies that was attended by about 30 growers preceding the annual APGA conference in Fairbanks on January 26<sup>th</sup> 2017. Two presentations providing information from this project were also provided to 40 growers at this conference on January 28<sup>th</sup>. The PI also participated in a panel discussion before 50 growers on research needs relating to the postharvest management of *Botrytis* during storage and shipping. In previous years (2015 and 2016), both the PI and Graduate Student participated in the conference by giving presentations about the environmental monitoring and fungicide testing portions of this project to the estimated 200 attendees at these conferences. During February of 2017, the PI and Graduate Student hosted the annual meeting of the Northwest Peony Society and provided a tour and updates on this project to the 30 growers that attended this meeting.

*Activity 11. Prepare final report, grower Botrytis disease management guides, and manuscripts for publication* - The current document satisfies the requirement for a final report. During the course of this project, the PI and Graduate Student have authored or co-authored chapters on diseases of lilies and peonies in the new Plant Disease Management Handbook of Florists' Crops Diseases, including information on *Botrytis* diseases. The Graduate Student and PI also co-authored a paper describing a new *Botrytis* species found during this study, *B. euroamericana*, from peony in Alaska that was published in the journal Mycologia and a paper describing the development of microsatellite markers to detect *B. paeoniae* was published in Acta Horticulturae. A grower Fact Sheet relating to the identification and management of Tobacco Rattle Virus, which was commonly observed during WSU peony surveys, was prepared and published by Washington State University. The PI and Graduate Student have prepared growers' guides and journal articles describing *Botrytis* species, management, and other diseases of peonies discovered throughout the course of this project; the submission of these manuscripts is anticipated to occur by the end of the calendar year.

Dr. Pat Holloway, Professor of Horticulture at the University of Alaska, Fairbanks provided guidance in crop production, serves on the graduate student's research committee, and help coordinate research activities in AK that are also being supported by funding from the State of Alaska Department of Natural Resources Division of Agriculture.

This project only benefitted peony, tulip, and lily cut flower and bulb/rootstock producers.

### **GOALS AND OUTCOMES ACHIEVED**

There were two stated measureable outcomes for this project as described below:

- 1) *Goal: Characterize for the first time, Target: the diversity of new Botrytis species associated with gray mold development on peonies. Benchmark: which is unknown, Performance Measure: as measured by the identification of a minimum of three new species from 15 grower fields and publication of results in WSU extension grower guides and peer-reviewed journals.* As indicated in the Project Summary section of this report, up to 13 potential new species on peonies have been described using molecular techniques. One species from Alaska, *B. euroamericana*, was discovered during this project and formally described using both molecular and morphological characterization in the peer reviewed journal Mycologia (DOI: 10.1080/00275514.2017.1354169).
- 2) *Goal: Educated growers via disease management guides, Target: inform 300+ growers of approaches to integrate biopesticides into their disease management programs. Benchmark: no current benchmark exist, Performance Measure: as measured by the number of downloaded on-line English and Hmong versions of guides for peonies, tulips and lilies.*

Over 300 growers were informed of the results on the biopesticide trials at the growers' field days and growers' conferences described in the Project Summary section of this report.

The two stated measurable outcomes for this project are below:

- 1) *Goal: Characterize for the first time, Target: the diversity of new Botrytis species associated with gray mold development on peonies. Benchmark: which is unknown, Performance Measure: as measured by the identification of a minimum of three new species from 15 grower fields and publication of results in WSU extension grower guides and peer-reviewed journals. A draft extension grower guide has been prepared and will be reviewed and published by WSU early next year.*
- 2) *Goal: Educated growers via disease management guides, Target: inform 300+ growers of approaches to integrate biopesticides into their disease management programs. Benchmark: no current benchmark exist, Performance Measure: as measured by the number of downloaded on-line English and Hmong versions of guides for peonies, tulips and lilies.*

Publications are still in preparation to fulfill the performance measure of a WSU extension growers' guide. A draft has been prepared and will be submitted for review by the end of 2018. A Hmong language version of a bulletin will not be produced as reported in the quarterly progress report for the Oct-Dec 2016 reporting period. A modification to the work plan was made at that time to reflect that WSU eliminated Bee Cha's Hmong Farmer Program Coordinator position. Mr. Cha was going to aid in the development of the Hmong language version of the bulletin. Without his assistance, it was not be possible to produce Hmong versions of the grower publications.

All of the activities and goals of this project have been or will be achieved upon the completion of extension growers' guides.

As indicated above, up to 10 possible new undescribed *Botrytis* species were associated with gray mold on peonies. This represents a four-fold increase in the number of species that were previously known on peonies. One species from Alaska, *B. euroamericana*, was formally described using both molecular and morphological characterization in the peer reviewed journal *Mycologia* (DOI: 10.1080/00275514.2017.1354169). While information from this project describing ways to improve grower disease management programs has been shared with more than 300 growers at various grower meetings and field days and the publication of one Fact Sheet, none of the biopesticides tested during this project were effective in controlling *Botrytis* development on tulips, lilies or peonies. This was true even when a biopesticide was integrated into a spray program with conventional fungicides.

### **BENEFICIARIES**

As indicated above, more than 300 peony, tulip, and lily cut flower growers in the Pacific Northwest have benefitted from the completion of this project. The PI and Graduate Student have directly presented the information to growers at field days and conferences and, upon completion of the bulletin, additional peony, lily, and tulip growers from around the United States will benefit.

The potential economic impact of *Botrytis* development of tulip, lilies, and peony is described in the Project Summary section of this report. As indicated, fungicides play an important role in grower disease management programs. As indicated in No. 4 above, extensive studies were conducted during this project relating to the effectiveness of new reduced risk fungicides and biopesticides in limiting disease development, the prevalence of fungicide resistant strains of *Botrytis* on peonies, and the potential of using a crop phenology-based spray program to reduce the number of fungicide applications needed to provide season-long control of *Botrytis* on tulips and lilies. Results from these trials indicated that 1) at least three

new fungicides (Orkestra, NUP0902, and S2200) were shown to be as effective as industry standards in controlling disease development, 2) none of the six biopesticides tested were effective in controlling *Botrytis*, even when they were integrated into a spray program with conventional fungicides, 3) Zerotol, a common product used by “organic” growers, was ineffective in controlling disease development of tulips, lilies and peonies, even when applied on a 7 day application schedule, 4) the adoption of a crop phenology-based spray schedule has the potential to reduce the number of fungicide application on tulips and lilies by 40 to 66%, and 5) that there are high levels of resistance to at least five classes of *Botrytis* fungicides in isolates of *B. cinerea* and *B. paeoniae*.

### **LESSONS LEARNED**

One of the key lesson learned during this project was the need to be flexible. There were a number of instances where activities had to be delayed or changed due to unexpected findings or events (See below). Despite these factors and negative results, the activities performed to accomplish project objectives yielded important and unexpected discoveries. Many of the negative results are discussed in more detail in other sections, as are the unexpected findings as a result of project activities. Some examples include the inability to use molecular markers to track movement of *B. paeoniae*, however, the markers revealed an important aspect of *B. paeoniae* biology, namely that it is likely not undergoing sexual recombination. As a result of collecting *Botrytis* isolates for this study, multiple new species of this fungal genus were identified. Furthermore, environmental data could not be correlated with disease development. However differences could be elucidated between Alaskan peony production regions in terms of temperature, rainfall, and leaf wetness, and how these parameters change throughout the season. Initiation of the fungicide resistance studies had to be delayed due to the extra time needed to complete the identification of the isolate of *Botrytis* collected from grower fields due to the unexpected diversity of *Botrytis* spp. that were detected. It was also not possible to meet with Hmong growers and produce a Hmong version of grower guides due to the unexpected elimination of the WSU Hmong Farmer Program Coordinator position prior to the start of the 2016 season. One of the best lessons learned was how valuable interactions with growers are and how essential it was to make personal visits to farms. Grower meetings and visits allowed for a better understanding of the production systems that take place in Alaska and the agronomic issues that result. Furthermore, this allowed for an identification of diseases, their prevalence in the field, and making recommendations that fit with production systems.

The sheer diversity of *Botrytis* species was unexpected. Although the PI and Graduate Student believed that at least 3 new species of *Botrytis* would be discovered, up to 13 were actually identified based on molecular phylogenetics. Furthermore, although the microsatellite markers developed to track movement of *B. paeoniae* were not able to conclude if movement was occurring, the results of the microsatellite analysis indicated that *B. paeoniae* is not likely sexually recombining in peony fields which may have ramifications on the biology and epidemiology of this pathogen in peony fields. The limited effectiveness of virtually all of the biopesticides tested was also unexpected, as was the limited ability of a number commonly used *Botrytis* fungicides in protecting peony leaves from infection by *B. cinerea* and *B. paeoniae*. The identification of several previously unreported pathogens on peonies was also unexpected. Specifically, there were five genera of fungal pathogens found on peonies that have never been reported before in the United States: *Mycocentrospora acerina*, three *Colletotrichum* spp., *Pilidium concavum*, a *Botryosphaeria* sp., and a *Phoma* sp. New host-pathogen-state combinations were also revealed for fungal pathogens *Graphiopsis chlorocephala*, *Sclerotinia sclerotiorum*, *Sclerotium rolfsii*, *Phytophthora cactorum*, and at least one *Alternaria* sp.

The goal of determining the movement of *B. paeoniae* using microsatellite markers was likely not achieved due to a small sample size of *B. paeoniae* isolates for which a population genetics analysis can be performed. Sampling revealed that *B. paeoniae* exists at a relatively low frequency in Alaska peony farms; therefore, successful completion of this objective would likely require collecting many more isolates than occurred

during the course of this study. Although hundreds of isolates of *Botrytis* were collected from peony with positive identification of 98 of them to species, only 22 were *B. paeoniae*. The microsatellite markers that were developed during this project could still be used for further studies.

The goal of providing growers with information on approaches to integrate biopesticides into their disease management program was not achieved because none of the biopesticides included in field trials over the three years of this project were effective in reducing disease development, particularly under high disease pressure. The development of Hmong versions of disease management guides was not achieved because the WSU Hmong Farmer Program Coordinator's (Bee Cha) position was eliminated during the first year of this project.

### **ADDITIONAL INFORMATION**

#### **Cash Support**

- The Northwest Agriculture Research Foundation/Wally Statz Foundation provided a total of \$39,176 in support of the WSU Puyallup cut flower research program, of which \$25,000 represents the proposed cash match for this project. This funding was used to help support staff and cover the cost of some travel and supplies associated with this project.
- Additional support for the WSU Puyallup cut flower research program included:
- \$44,999 from the State of Alaska Department of Natural Resources Division of Agriculture to help support travel and peony work done in Alaska.
- \$85,310 from the USDA Floriculture and Nursery Research Initiative to support staff and cover the cost of some travel and supplies.
- \$40,000 from the IR-4 Ornamental Crop Program to help support studies to determine the effectiveness of new bio and reduced risk fungicides in controlling *Botrytis* diseases on tulips, lilies and peonies.
- \$1,500 from the Alexander A. Smick Scholarship in Rural Community Service and Development to support travel AK to participate in the 2017 Arctic Alaska and Mat-Su Peony Farm Tours.
- \$3,400 from the Chiconia Endowment to purchase a peristaltic dispense pump to improve the efficiency of purpose of pouring agarose plates, slants, and other culture containers and a gradient thermal cycler to enhance molecular work relating to the identification of *Botrytis* species.

#### **In-Kind Support**

- Knutson Farms in Sumner, WA provide space, site preparation and hilling for a fungicide integration plot on tulips. This grower also donated 400 assorted peony roots for planting in research trials at Puyallup. \$4,000
- Our American Roots in Woodland, WA donated 460 'Monsieur Jules Elie' peony roots and lily bulbs for planting in research plots at Puyallup. \$7,860
- DeGoede's Bulb Farm, Mosseyrock, WA donated peony roots for use in trials. \$300.
- Washington Bulb Co. in Mount Vernon, WA donated bulbs for experimental trials during each year of this project. \$2,880
- LRI in Puyallup, WA donated 125 cubic yards of compost to amend soil in the peony field plots. 125 yds. @ \$25/yd. = \$3,125.
- Tagro in Tacoma, WA donated 20 cubic yards of potting mix that was used to pot up container grown peonies. 20 yds. @ \$35/yd. = \$700
- The following growers provide space, helped maintain the environmental monitoring equipment, and collected disease data in the disease development studies: Boreal Peonies, Two Rivers, Arctic Sun Peonies, Hoffman Acres, Echo Lake Peonies, and Alaska Perfect Peony in AK; the American Roots, and DeGoede's Bulb Farm in WA; and Oregon Perennial in OR.
- The following companies provided products that were used in some of the trials conducted during this project: BASF, BioHumanetics, BioSafe Systems, BioWorks, FMC, ISK, LAM International, Marrone Bio Innovations, NuFarm, OHP, Syngenta, and Westbridge Agricultural Products.

- The unrecovered WSU Indirect – 51% MTDC on Campus Research which was capped at 20% totaled \$28,172.

### **CONTACT INFORMATION**

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**See Attachment D- 2014 SCBGP-FB**

### **PROJECT #17**

**Project Title:** Grafting Watermelon: Sustainable Practice and Value-added Enterprise

**Partner Organization:** Washington State University

### **Project Summary**

Watermelon production in WA is valued at ~\$5 million, but production has declined more than 30% in the past 10 years, to 550 A. Decline in watermelon production has been due primarily to crop losses of 25-75% from Verticillium wilt (caused by *Verticillium dahliae*), even after soil fumigation. Watermelon does not have resistance to *V. dahliae*, and grafting with disease resistant rootstocks is effective and economical in Asia, Europe and Canada. In a 2-year field study at Mount Vernon and Eltopia, grafting watermelon with two commercial rootstocks provided improved resistance to *V. dahliae* but did not improve yield. These initial results are promising, but follow-up is needed to: 1) identify *V. dahliae*-resistant rootstocks that are compatible with watermelon and WA growing conditions; 2) validate disease tolerance, yield and fruit quality of grafted plants in field trials; 3) develop a reliable healing regimen for grafted watermelon transplants; and 4) train transplant producers (commercial companies and watermelon growers) in WA to graft watermelon. Results from this project will be relevant to both conventional and organic growers, and will help jump-start a grafted vegetable transplant industry in WA.

Watermelon production declined from 750 A in 2007 to approximately 550 A in 2013, representing ~\$1.8 million loss in revenue for WA growers and stakeholder industries. This decline is due primarily to Verticillium wilt (caused by *V. dahliae*), a soilborne disease causing 25-75% crop loss, even after soil fumigation. Soil fumigation has become more difficult and costly for growers to implement and has negative environmental and human health effects. More than 60 crops commonly grown in WA are susceptible to Verticillium wilt, inoculum of *V. dahliae* can remain viable for as long as 14 years in field soil, and there are no known watermelon varieties with resistance to Verticillium wilt. Hence, alternative approaches for managing Verticillium wilt in watermelon production systems are urgently needed. Grafting watermelon onto disease-resistant rootstocks is a promising approach for controlling Verticillium wilt and is widely used throughout Asia, Europe, and Canada for managing soilborne diseases. In Japan and Korea, over 90% of cucurbitaceous crops are produced using grafted plants.

In a 2-year field study in WA, grafted watermelon showed significantly lower disease severity than non-grafted plants, however effects were rootstock-dependant. There is a need to evaluate rootstocks for Verticillium wilt resistance in WA. Further, there is a need to develop grafting and healing regimens that provide a reliably high rate of survival of grafted watermelon transplants in order to reduce the costs of grafted transplants.

This project does not build on a previously funded SCBGP project.

## **PROJECT APPROACH**

Activities performed and tasks achieved during this project period are as follows:

- 1) Data from 2016 experimental field trials at WSU Mount Vernon NWREC were statistically analyzed, compiled into a report, and published.
- 2) Results on resistance of cucurbit rootstocks to *V. dahliae* were included in a new Vegetable Grafting Manual that will be published on-line, for distribution to growers and vegetable grafting industry members.
- 3) MS graduate student Sahar Dabirian submitted her thesis entitled “Optimizing watermelon grafting to control Verticillium wilt in Washington” for on-line archiving.
- 4) Three research papers that summarize findings from this project were published in horticultural journals.
- 5) Recruited a new PhD graduate student, Pinki Devi, who started Spring 2017 semester, to continue research studies to further optimize watermelon grafting and rootstock selection, with the goal of providing new Washington business opportunities both for growing grafted transplants and identifying new domestic-sourced rootstocks (currently all rootstocks are imported); continued funding for the student is provided by a national SCRI grant for vegetable grafting.

### **Scientific Publications:**

1. Dabirian, S., and C. Miles. 2017. Antitranspirant application increases grafting success of watermelon. HortTechnology 27: in press
2. Dabirian, S., and C. Miles. 2017. Increasing survival of grafted watermelon seedlings using a sucrose application. HortSci. 52:579–583. 2017. doi: 10.21273/HORTSCI11667-16
3. Dabirian, S., D. Inglis and C. Miles. 2017. Grafting watermelon and using plastic mulch to control Verticillium wilt caused by Verticillium dahliae in Washington. HortSci. 52:349–356. 2017. doi: 10.21273/HORTSCI11403-16

Dr. Debra Inglis, Plant Pathologist, provided critical support of this project by testing pathogenicity of isolates from field studies, mentoring the graduate student, and coauthoring research papers. Alan Schreiber hosted on-farm trials.

This project did not benefit non-specialty crops.

## **GOALS AND OUTCOMES ACHIEVED**

Activity 1) Identify rootstocks that are compatible with watermelon and resistant to different strains of *V. dahliae* commonly found in WA - This goal was accomplished and one scientific paper was published on the results.

Activity 2) Validate disease resistance, yield and fruit quality of grafted plants - This goal was accomplished and one scientific article was published on the results.

Activity 3) Develop a successful healing regimen for grafted watermelon - 2 scientific papers were published that describe components of a successful healing regimen, and this is new information generated by this project.

Activity 4) Train transplant producers (commercial companies and watermelon growers) to graft watermelon. Training was provided at 2 national events as well as annual workshops at WSU Mount Vernon NWREC, where this project was based.

Identifying rootstocks that are compatible with watermelon and resistant to *V. dahliae* is an on-going goal as there are hundreds of potential rootstocks to test. In this project the most commonly available rootstocks were evaluated as well as 20 entries from the USDA national plant germplasm system (NPGS), but there are hundreds more to test. In this project two key components of a successful healing regimen for grafted watermelon were identified: increasing carbohydrate reserves in the rootstock and reducing transpiration

from the scion. Future research will focus on testing a combination of these treatments in combination with different rootstocks. Efforts to train transplant producers (commercial companies and watermelon growers) to graft watermelon were met with marginal success due to lack of interest that in turn was due to lack of commercial demand for purchasing grafted vegetable transplants. Interest in training will begin when customers request grafted plants.

Target 1)  $\geq 5$  rootstocks resistant to *V. dahliae* - More than 5 cucurbit rootstocks with resistance to *V. dahliae* were identified.

Target 2) Complete year 2 (2015) of field trials at 3 locations (year 1 was funded by WSU ERI grant in 2014) - Year 2 of the field trial was completed and both years were published as 2 separate research papers.

Target 3) 90% survival of grafted watermelon transplants - Greater than 90% survival of grafted watermelon transplants was achieved under test conditions, and 2 scientific papers were published with the results; now the methods need to be scaled up to test under larger-scale transplant production conditions.

Target 4)  $\geq 4$  transplant producers will receive training - Training was provided to more than 4 transplant producers nationally; in Washington, training was targeted to growers who had an interest in grafting their own plants, and at least one of these growers (near Cle Elum) has increased his production of grafted plants based on this training.

Measureable outcome 1) Acceptable resistance will be considered as less than 20% disease severity; successful watermelon compatibility will be considered as greater than 80% grafted transplant survival; results will be published - rootstocks were found that had less than 20% disease severity and grafting compatibility was greater than 80%, and results were published.

Measureable outcome 2) Disease incidence and severity will be rated every 2 weeks, and fruit will be harvested at optimal maturity; 5 fruit per plot will be assayed for Brix, firmness, and internal quality and color; results will be published - Data collection and analysis were completed, and results were published.

Measureable outcome 3) Transplant survival will be assessed during acclimation to the greenhouse environment; results will be published - 2 greenhouse studies were carried out to increase transplant survival, success was achieved with both studies, and results were published.

Measureable outcome 4) Participating transplant companies and watermelon growers will be surveyed within 1 year of trainings to assess production of grafted transplants, and this will be compared to target value - Potential vegetable transplant producers in Washington were informally surveyed and none are commercially grafting vegetable plants as the demand is not great enough due to lack of knowledge/demand on the part of customers. Additionally, established companies in California and Arizona are currently shipping grafted transplants into the region at below cost for transport thereby cornering the market. However, new data shows that energy costs for producing grafted transplants is lowest in Washington and this information may incentivize grafted transplant producers to open an operation in Washington.

### **BENEFICIARIES**

A total of 38 farmers growing watermelon in Washington, on a total of 488 acres, benefited from this research. The value of watermelon production in Washington is approximately \$2,098,400 (based on \$4,300 gross per acre). One MS student was trained on this project, Sahar Dabirian, and she is now employed in plant nursery development/sales. One PhD student, Pinki Devi, initiated her research program as part of this project and will continue with the research with funding provided by a national SCRI project for vegetable grafting. More than 50 people in Washington were trained in vegetable grafting, including one

commercial tomato grower in Cle Elum. Currently PI Miles is editing and authoring a vegetable grafting manual that will be available on-line, and narrated PowerPoint presentations will be updated so that producers who are interested in receiving training can do so at their convenience.

One Masters student was trained on this project, Sahar Dabirian, and she is now employed in plant nursery development/sales. One PhD student initiated her research program as part of this project and will continue with the research with funding provided by a national SCRI project for vegetable grafting. More than 50 people in Washington were trained in vegetable grafting, including one commercial tomato grower in Cle Elum. Currently PI Miles is editing and authoring a vegetable grafting manual that will be available on-line, and narrated PowerPoint presentations will be updated so that producers who are interested in receiving training can do so at their convenience.

It can be said with confidence that grafting watermelon onto resistant rootstocks can reduce disease severity and increase yield when disease is present in the soil at greater than 8 cfu per gram soil. Extension publication <http://cru.cahe.wsu.edu/CEPublications/TB08E/TB08.pdf> provides a cost-benefit analysis of using grafted transplants compared to non-grafted transplants in WA. There is the potential to use commonly available cucurbit seed as rootstocks, which will significantly reduce cost of grafted transplants; this is an area of continuing research. Guidelines have been developed for watermelon grafting that lead to grafting success of >80%, and these methods are summarized in the watermelon chapter of the new Vegetable Grafting Manual that PI Miles is editing along with colleagues Kubota at Ohio State University and Zhao at University of Florida, and will be available nationally.

### **LESSONS LEARNED**

For growers to be interested in purchasing grafted watermelon transplants, the cost of grafted transplants needs to be lower. Cost can be lowered if the rootstock seed cost is lower, which can be achieved if transplant growers are using domestic seed rather than imported seed. With this end in mind, research is on-going to screen cucurbit germplasm from the USDA NPGS for *Verticillium* wilt resistance and grafting compatibility with watermelon. Additionally, newly grafted watermelon can be difficult to heal successfully, and research is on-going to develop more fool-proof methods that lead to healing success when environmental factors such as temperature, light and humidity fluctuate slightly, as is common in a greenhouse setting. Attracting transplant growers to grafting training was difficult, and so the future focus will be on developing resources that reside on the internet and are available on demand (e.g., on-line grafting manual, narrated PowerPoint slides, Extension publications).

Watermelon yield is negatively impacted when the level of disease in the soil is above a certain threshold. While much research is needed to develop a threshold for *V. dahliae* for watermelon in Washington, results from this project indicate this threshold is likely around 8 cfu per gram soil. As a result of this project growers are recommended to test the soil prior to planting and to use grafted plants if the disease level is greater than 8 cfu per gram soil.

The only Measurable Outcome that was difficult to achieve in Washington was training transplant producers. Training was presented at local, state, regional and national events, however no commercial WA operations are offering grafted vegetable transplants for sale at this time. Currently PI Miles is editing and authoring a vegetable grafting manual that will be available on-line, and narrated PowerPoint presentations will be updated so that producers who are interested in receiving training can do so at their convenience.

### **ADDITIONAL INFORMATION**

Total cash match for this project was exceeded. Cash match in the form of salaries and benefits totaled \$85,207.59.

[Vegetable Grafting: Watermelon](#). WSU Extension Fact Sheet FS100E 7 pages. Revised June 2016.

All publications and presentations are available on the WSU website:

<http://vegetables.wsu.edu/graftingVegetables.html>

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## **PROJECT #18**

**Project Title:** Aphid Pest Management and Soil Quality on Apple Orchards

**Partner Organization:** Washington State University – David Crowder

### **PROJECT SUMMARY**

Over the past decade, economic damage to Washington apple orchards from the woolly apple aphid (WAA) has increased considerably, especially for organic producers. Aphids feeding in the tree canopy can distort leaf, shoot, and fruit growth. In addition, they secrete honeydew that can drip on fruit and act as substrate for a disfiguring fungus called sooty mold, which greatly reduces the fruit's market value. Management of WAA is difficult, however, because it colonizes both above- and below-ground portions of apple trees. Aerial colonies cause the economic damage described above and decrease production, while subterranean colonies are protected from severe winter temperatures and pesticide applications and thus act as a reserve population that can move up to the canopy throughout the season. In addition, feeding by WAA on roots causes tissue distortion or death, reduces tree vigor, and in young trees can even cause tree death. Currently, the insecticide diazinon is used to control aerial colonies of WAA in conventionally managed orchards, but there are no effective options for organic orchards. The use of diazinon, however, may be restricted or eliminated as it undergoes the EPA re-registration process and even conventional growers have nothing to control belowground WAA colonies. Clearly, both organic and conventional growers in Washington State require new management options for WAA.

The project originated based on discussions between the research team, growers, and members of the Washington Tree Fruit Commission (WTFRC) about improving the understanding of WAA dynamics and control options. Sustainable aphid management requires a broad knowledge of how pest biology, orchard management practices, natural enemies, and environmental factors interact. For many aphids, soil fertility and fertilization practices can greatly affect aphid population growth. For example, excessively fertilized soils, particularly with nitrogenous materials (both organic and synthetic), can lead to vigorous plant growth that enhances aphid reproduction and makes their control more difficult. For WAA, soil quality might also affect belowground aphid colonies feeding on roots, making soil management essential for WAA aphid control. There is also some evidence that more pesticide-intensive practices in both organic and conventional orchards exacerbate economic damage caused by aphids. This is important because there is high variability among Washington growers in their pesticide management practices. While growers can be broadly classified as "organic" or "conventional," each of these groups can be further subdivided into two categories representing "less pesticide-intensive" and "more pesticide-intensive" management practices. Thus, robust information on optimal management programs must be provided in a clear set of recommendations useful in either organic or conventional orchards.

This project sought to (i) explore how WAA pest densities are affected by soil quality, plant nutrient content, and natural enemies in organic and conventional apple orchards; (ii) conduct in-depth interviews with orchard operators to evaluate how they make management decisions and link management practices with the field measurements of WAA pest densities, soil quality, and economic returns; and (iii) develop enterprise budgets to determine optimal strategies for aphid management and soil quality for organic and conventional apple producers in Washington State. Through these objectives, the goal was to develop a more comprehensive understanding of the factors that affect WAA. This could lead to improved management of this pest in both conventional and organic orchards.

As mentioned above, WAA causes severe problems for both conventional and organic apple producers, who have limited control options for this emerging pest. The project sought to develop a systems-level understanding of the processes and orchard management factors that affect WAA populations. As WAA and other aphid pest problems continue to rise, increasingly more sophisticated and expensive management practices will be required. The project provided growers with new, practical information on linkages between the intensity of organic and conventional management practices, aphid control, soil quality, and economic returns. This information will form the basis for better recommendations for growers on practices to manage WAA while enhancing soil quality and economic returns. Moreover, the information gathered from interviews is allowing WSU to understand how specific management practices affects the entire orchard system, and how to apply this information to reduce management costs, crop damage, and environmental impacts.

The project was appropriate for the WSDA Specialty Crop Block Grant program by directly addressing the ***Funding Priority - Control Pests and Diseases*** by improving management of WAA in Washington apple orchards. Moreover, by optimizing management strategies for aphids, soil quality, and economic returns for organic and conventional apple orchards, and extending this information to growers through an innovative extension program (including DAS in the future), the project also directly addressed ***Funding Priority - Improve Production Practices through Innovative Technologies***. By providing specific recommendations to organic and conventional orchards to enhance economic returns, the project can also enhance the competitiveness of apple growers which addressed ***Funding Priority - Enhancing Domestic Markets***. Finally, the WAA was recently reported as a quarantine concern for China and Taiwan, two countries that are important export markets for Washington apples. Thus, by limiting WAA populations, the project may indirectly reduce barriers to trade with these and other countries that addressed ***Funding Priority – Reducing Regulatory Barriers***.

Although this project did not directly build on any previous SCBGP project, co-PI Jones has received previous funding from WSDA SCBGP to support development of the WSU Decision Aid System (DAS) (<http://das.wsu.edu>). The DAS is a web-based IPM decision support system for Washington tree fruits that integrates weather data, forecasts, and site-specific model predictions for pests, diseases, and horticultural stresses. The system is easy to use, has integrated help features (both animated video help and text-based feature guide), and can be readily accessed by growers and crop consultants using laptops, desktop computers, and smartphones. Beyond the life of the proposed grant period, the results will be incorporated into the DAS. This will provide organic and conventional apple growers with timely and effective recommendations for management of WAA and ensure sustained impact of the project.

### **PROJECT APPROACH**

(A) Over the course of the project a large-scale sampling effort for WAA was carried out and natural enemies on organic and conventional apple orchards throughout Washington State that had varying pesticide intensity. This generated a three year observational dataset at 8 conventional, 9 certified organic and 3 transitional organic orchards. The density of WAA was sampled in the spring months by observing crawler movement from the soil into the tree canopy; populations were also assessed regularly throughout the summer months (at least 4 times per site). Natural enemies were sampled at each time point as well. Data were analyzed as a function of various factors on each farm (see C below).

(B) In addition to the data on insect populations, soil and plant quality were sampled in each orchard. In July of each year soil quality and plant nitrogen levels were sampled in each of the study orchards. Soil was sampled by taking soil cores in each orchard. Soil was then analyzed for the following: total carbon and nitrogen; microbial biomass carbon and nitrogen; nitrate and ammonium-nitrogen; Olsen phosphorous; extractable potassium, calcium, magnesium, sulfur, sodium, boron, zinc, manganese, copper, and iron; soil pH; cation exchange capacity; and particle size (% sand, silt, clay). Bulk density, water content, aggregate

stability, and earthworm populations were also determined. These values are being used to determine a composite index of soil quality on each orchard. Leaf tissue from each orchard was collected four times and tested for plant nitrogen content. These samples are providing the project team with an estimate of the variation in soil quality and plant nitrogen levels across organic and conventional apple orchards (see C below).

(C) Using the datasets mentioned above, factors such as orchard management, soil quality, and plant nutrition were evaluated to determine the affect on WAA. The data suggest three factors are most important for WAA management: (1) pesticide use intensity, (2) soil texture, and (3) natural enemies (see Figures and Tables below). Farmers can incorporate mulches and conservation of earwigs to improve WAA management. Moreover, farms with reduced pesticide intensity had both higher natural enemy numbers and reduced WAA.

(i) Data showing average woolly apple aphids, leaf N %, earwigs, and soil quality at each of 20 orchard sites. Data were averaged across sampling dates.

Site	Management	Average woolly aphid count	Average leaf N (%)	Average earwig count	Soil Quality Index
a. McD-C	Conventional	0	3	15.5	0.63
b. Ro-C	Conventional	14.4	2.5	25.7	0.51
c. Mo	Conventional	11	2.7	17.5	0.43
d. Pie	Conventional	21	2.8	11.1	0.62
e. Sk-C	Conventional	2	2.6	9.8	0.5
f. MM-C	Conventional	0.2	2.3	11.3	0.65
g. Cl-C	Conventional	1.3	2.3	16.5	0.48
h. Ae	Conventional	0	2.1	0.09	0.48
i. Bu-T	Transitional	4.8	2.3	0.48	0.51
j. MM-T	Transitional	46.4	2.7	3.2	0.62
k. W	Transitional	5.6	2.5	0	0.59
l. McD-O	Organic	4.6	2.8	0.3	0.47
m. Ro-O	Organic	9.4	2.2	7.3	0.49
n. Ta	Organic	6.2	2.6	13.3	0.65
o. TT	Organic	31.6	2.4	3.5	0.5
p. Sk-O	Organic	1	2.6	23.5	0.58
q. Bu-O	Organic	25.6	2.4	36.4	0.51
r. Ru	Organic	9.4	2.3	11	0.64
s. Cl-O	Organic	1.5	2.2	6.9	0.52
t. Sa	Organic	0	2	5.3	0.38

(ii) Summary data of woolly apple aphid counts on organic, conventional, and transitioning orchards

Management	N	Mean	SE
Conventional	8	6.2	2.9
Transitional organic	3	18.9	13.7
Certified organic	9	9.9	3.7

(iii) Summary data of earwig counts on orchards

Management	N	Mean	SE
Conventional	8	13.4	2.6
Transitional organic	3	1.2	1.0
Certified organic	9	11.9	3.8

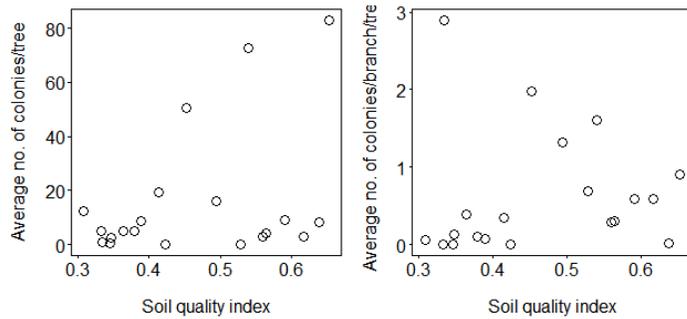
(iv) Summary data of the soil quality index on orchards of different types

Management	N	Mean	SE
Conventional	8	0.54	0.03
Transitional organic	3	0.57	0.03
Certified organic	9	0.53	0.03

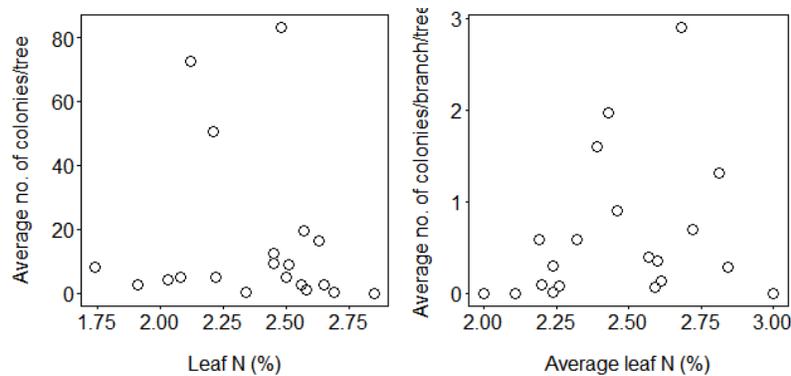
(v) Summary data of leaf nitrogen (%) on orchards of different types

Management	N	Mean	SE
Conventional	8	2.5	0.11
Transitional organic	3	2.5	0.12
Certified organic	9	2.4	0.08

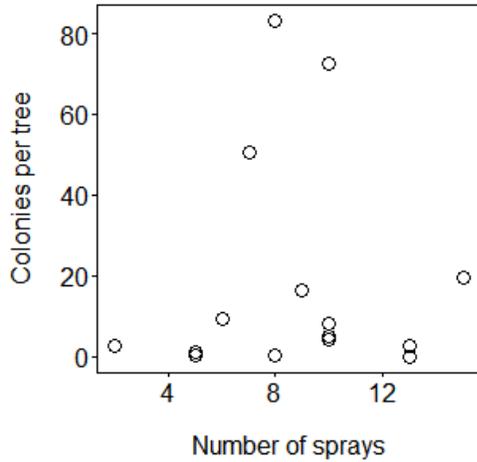
(vi) There was not a strong relationship between soil quality and WAA.



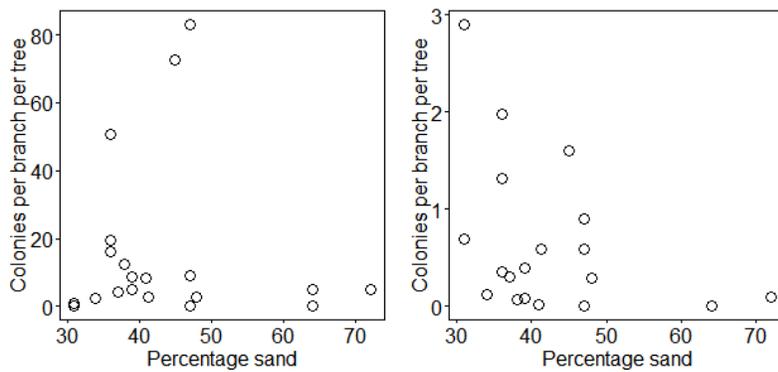
(vii) There was not a strong relationship between leaf nitrogen and WAA.



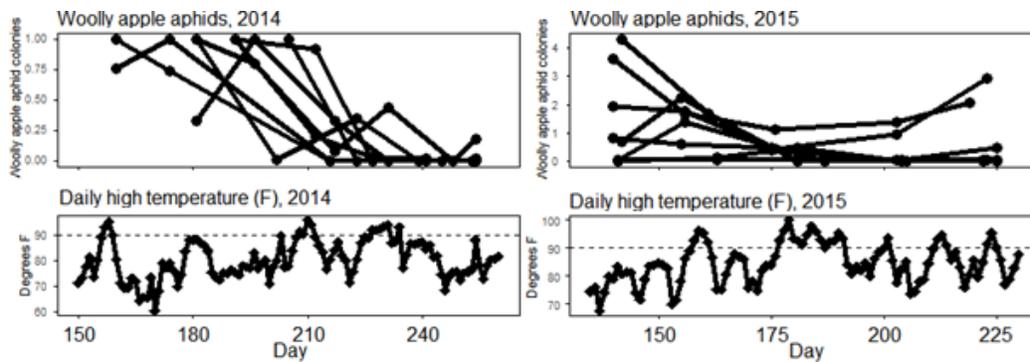
(viii) A marginally significant positive relationship between pesticide intensity and WAA was found.



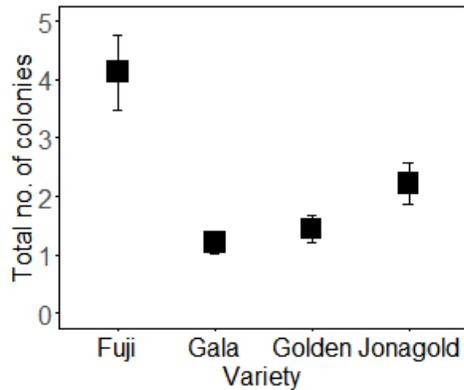
(ix) A significantly negative relationship between % sand and WAA was found.



(x) Temperature appeared to be an important predictor of WAA population dynamics. Consistently, when summer temperatures reached over 90 F for summer days, woolly apple aphid populations declined.



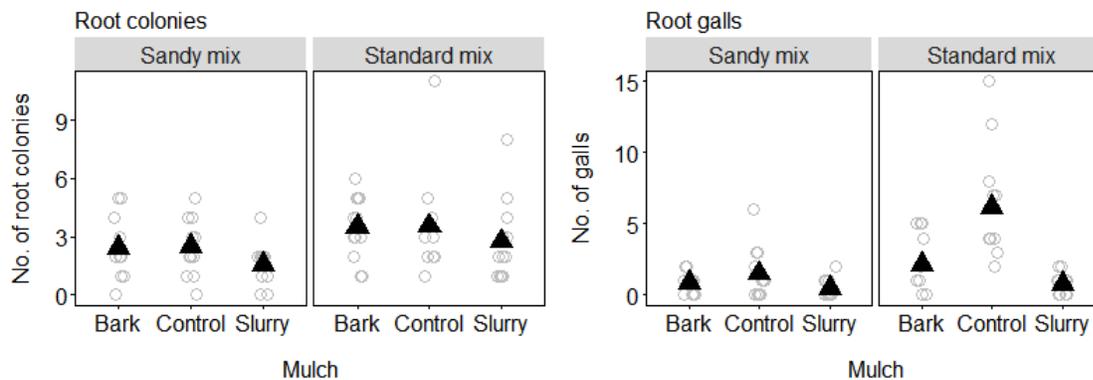
(xi) WAA counts averaged about twofold higher in Fuji orchards compared to Galas. Because of this, and because growers sometimes mentioned that they thought Fujis are more susceptible, WAA colonies were counted in mixed plantings in the WSU Sunrise Research Orchard. The results suggest that Fujis are indeed more susceptible to WAA.



(D) Several outreach events were conducted to share results of the project. Findings were presented at the North Central Washington Tree Fruit Apple Day in Wenatchee on January 21, 2016; the Washington State Tree Fruit Research Commission apple crop protection review in Wenatchee on January 28, 2016; and an article on earwigs was published for WSU's Fruit Matters Newsletter on July 11, 2016. An article on earwigs by the Good Fruit Grower magazine was published in March 2017, and two different radio stations offered to interview Robert Orpet about earwigs after a second set of grower interviews are completed this winter. Other materials such as future newsletter articles, handouts, and updates to WSU's Tree Fruit Research and Extension website are forthcoming, in addition to additional public talks

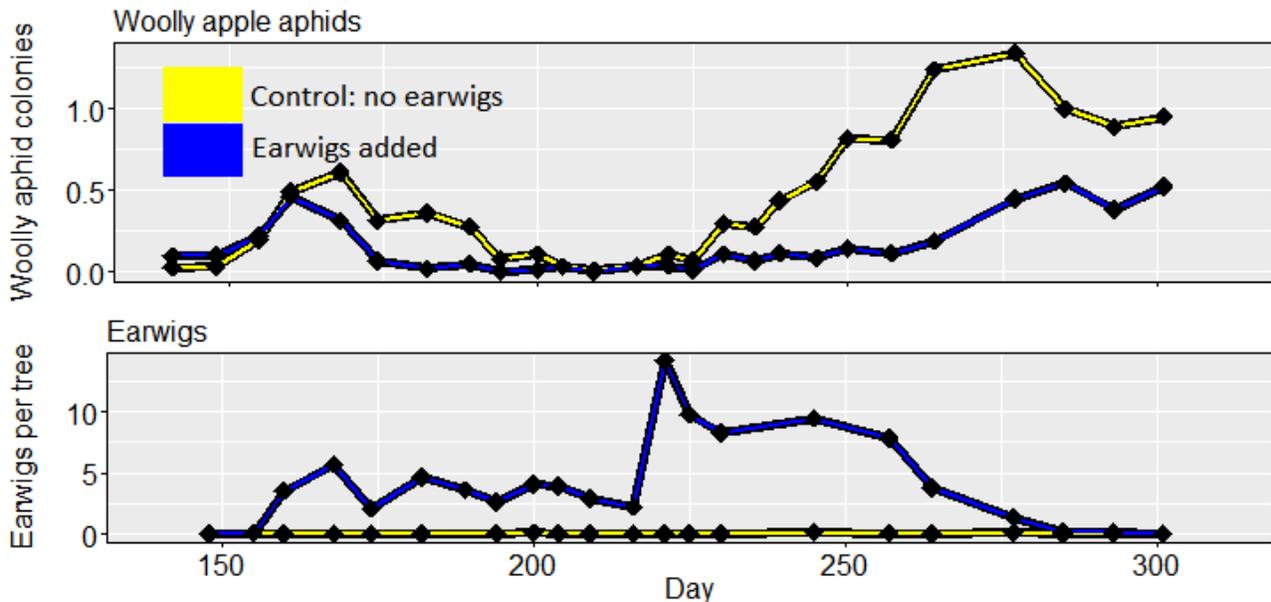
(E) Preliminary analyses suggested that soil texture was an important determinant of WAA densities in orchards. The scope of the original proposal was expanded by examining the potential importance of soil texture on WAA experimentally. In this experiment, mulches were analyzed to see whether they might also serve as a barrier to WAA entering the soil. The experiment involved a factorial design with two soil types: sandy or clay and three mulches (control, paper slurry, wood chips), to determine whether these factors affect WAA movement from tree canopies into the soil. Sandy potting media (60% sand content), wood chip mulch, and paper slurry mulch only slightly reduced the number of aphid colonies observed feeding on roots 2 months after aboveground infestation. However, there were significantly fewer galls (which form where woolly apple aphids feed) on roots in sandy soil (75% reduction), under bark mulch (65% reduction), and under paper slurry mulch (88% reduction) compared to a potting mix control (equal parts perlite, vermiculite, and peat). Therefore, mulches in the field may partially disrupt woolly apple aphid movement in and out of soil.

(i) Root galls were lower with mulches. Sandy soils also had lower root galling than non-sandy soils.



(F) Preliminary data also suggested a potentially important role of earwigs in providing biological control of WAA. Earwigs have not previously been considered as a major biological control agent in Washington, although a wide body of literature from other regions reports that earwigs are important predators of WAA. A biological control experiment was initiated to clarify the role of earwigs in Washington State apple orchards. In an orchard block where no earwigs were found over two years of observation, approximately 2,000 earwigs were introduced to each of five 10 X 10 meter sections and were monitored in addition to five unmanipulated 10 X 10 meter control sections. Woolly apple aphid counts averaged around 400% higher in the sections without earwigs during the second half of the summer, when woolly apple aphid populations peaked. Moreover, there was no evidence of any earwig-caused damage to apples. This study shows that earwigs have promise as biological control agents for Washington apple growers.

(i) Results showed that woolly apple aphid densities were significantly lower with earwig introductions than without



(G) During interviews, interviewees were asked to rate from 1-5 (1 = not important, 5 = very important) the role of some factors in the dynamics of woolly apple aphid populations. Ratings were obtained separately for conventionally and organically managed apples (N = 7 for both styles, with 6 individuals answering for both categories, 1 answering for conventional only, and 1 answering for organic only because they had no apples in the other management style). Some growers managed multiple orchards in the study. Results are shown below.

Factor	Mean rating (no. of “don’t know” responses)	
	Conventional apples	Organic apples
Insecticides	3.7 (0)	1.5 (1)
Biological control	3.8 (0)	4.5 (0)
Soil quality	3.3 (3)	2.0 (2)
Tree nutrition	3.5 (1)	3.4 (0)

Next, interviewees were asked to consider only biological control agents and rate them from 1-5 (1 = not important, 5 = very important) in importance for suppressing woolly apple aphid populations.

Natural enemy	Mean rating (no. of “don’t know” responses)	
	Conventional apples	Organic apples
Earwig	1.5 (5)	2.0 (4)
<i>Aphelinus mali</i>	4.0 (1)	4.2 (2)
Ladybug	3.5 (3)	3.6 (2)
Lacewing	3.4 (1)	3.3 (1)
Syrphid	4.0 (1)	3.8 (2)

(H) Perennial cankers. Cankers were found at only one of the twenty study orchards, but they were rare (32 perennial cankers out of 4,500 trees inspected). While 90% of the perennial cankers were infested with WAA, there was overall a weak connection between WAA and perennial canker because of the lack of perennial cankers at other orchards. The high infestation rate of perennial cankers suggests that they are great feeding sites that are preferred by aphids. This may cause some growers to conclude falsely that aphids are vectors of perennial canker. However, WAA do not spread or cause first-year cankers. It was previously demonstrated that WAA do not transmit the perennial canker fungus. Yet, trees with canker may provide suitable feeding sites for aphids, and it is possible that incidence of canker in an orchard could amplify aphid outbreaks.

(A) David Crowder, an Assistant Professor of Entomology at Washington State University (WSU) served as the lead investigator on the project. Crowder was the co-advisor of the graduate student, Robert Orpet, who was the primary “on the ground” person collecting data and conducting the interviews for the project. Crowder aided with all aspects of the research and outreach objectives on the grant, and oversaw the overall execution of the grant and the budget. Crowder also facilitated collaboration between the entire project team and oversaw publication of research results.

(B) Co-PIs Elizabeth Beers and Vincent Jones (Professors of Entomology at WSU) served as co-advisors of graduate student Orpet. Both Beers and Jones contributed to all of the Entomological aspects of the grant, including developing and executing WAA sampling and analysis of the research results. Beers and Jones also helped develop research questions concerning biological control of WAA. Both Beers and Jones helped identify research sites to conduct the project, and aided in coordinating interactions between the project team, WTFRC, and participating growers.

(C) Co-investigator Jessica Goldberger (Associate Professor, Department of Crop and Soil Sciences, WSU) advised Robert Orpet on the design and execution of the grower interviews, and assisted with the interpretation and analysis of resulting sociological data. Goldberger worked closely with Orpet on this part of the project, both for the first and second round of grower interviews.

(D) Co-investigator John Reganold (Professor of Soil Science, WSU) advised Robert Orpet on the analysis of soil quality data and impacts of variation in soil quality for WAA. Reganold helped design the soil collection protocols and was in the field with Orpet helping collect and interpret data.

(E) Graduate student Robert Orpet, who was co-advised by Jones and Crowder, served as the primary data collector on the project. Orpet conducted the WAA surveys, grower interviews, and biological control studies. Orpet also served as the lead on outreach for the project, and will be the first author on resulting publications.

(F) Primary industry partner Jim McFerson (currently director of WSU-Tree Fruit Research and Extension Center, formerly of the Washington Tree Fruit Research Commission) helped identify grower contacts and provided overall support for the project.

(G) The project would not have been possible without the efforts of the grower collaborators, who allowed use of their orchards for the project and agreed to participate in a series of interviews about management practices

The project did not provide benefits to commodities other than specialty crops

### **GOALS AND OUTCOMES ACHIEVED**

(A) The first performance goal was to develop the first set of integrated pest management (IPM) recommendations for WAA in both conventional and organic apple orchards using data from a diverse sampling network and multiple farm variables. The lynchpin of achieving this goal was to complete a large-scale field study examining WAA population dynamics on a network of organic and conventional apple orchards of varying pesticide intensity. In 2014, 2015, and 2016 a broad sampling of WAA populations, natural enemies, soil and plant quality, and climatic variables on nearly 20 participating apple orchards (approximately half organic and half conventional) was conducted. Statistical models were developed, evaluating the impacts of various abiotic and biotic variables on WAA populations.

The original surveys indicated that soil texture and natural enemy populations had large impacts on WAA populations. In turn, follow up experiments were conducted in 2016 evaluating how soil texture affects WAA populations. Experiments releasing earwigs and measuring impacts on WAA populations were also conducted. These experiments were not detailed in the original grant, but they provided key information on WAA populations and management options.

(B) The second performance goal was to dramatically increase the sociological understanding of the factors that affect the management decisions of conventional and organic apple producers aid in developing IPM strategies for WAA and soil quality that are easily understood and implementable by growers. To complete this goal detailed, in-depth, interviews of participating producers were conducted in 2014 and 2016-2017. In both years, growers were queried on their management practices for WAA and for information about their orchard operations more generally. From the initial interview process, some of the factors growers found important (pesticides, organic vs. conventional management) and some that growers found unimportant (earwigs) were identified. This helped focus the research objectives and identify factors that required greater exploration. In 2016, producers were re-visited and asked a series of questions again. This helped to determine if the project, and interactions with producers, changed perceptions about WAA management.

(C) The third performance goal was to determine the suite of management practices for WAA and soil quality on conventional and organic apple orchards that are expected to provide maximum economic returns for Washington producers. This was achieved by determining optimal management practices for WAA based on results of the surveys and interviews. It proved difficult to develop enterprise budgets as initially proposed, by developing recommendations based on the field surveys for both organic and conventional growers this objective was achieved. Extension materials based on the results of this objective are in the process of being developed.

The long-term goals were to reduce the number of insecticide sprays for WAA and to reduce economic damage caused by this pest. As recommendations are implemented by growers, it is expected to see long-term reductions in both insecticide sprays and economic damage from WAA. Work with growers will continue beyond the term of this project to evaluate changing strategies for management of WAA, and to continue to refine recommendations to improve WAA control.

(A) Goal 1: The first goal was to develop the first set of integrated pest management (IPM) recommendations for WAA in both conventional and organic apple orchards using data from a diverse sampling network and multiple farm variables.

Actual accomplishments: From the three-year observational dataset, relationships between management practices, natural enemy populations, soil quality, and plant nutrient levels in apple orchards were determined. While it appears that WAAs have slightly higher densities on organic farms, this was not significant. Soil quality and plant nutrient levels also did not significantly differ between organic and conventional orchards, and did not appear to influence WAA densities. The data suggest three factors are the most important for WAA management: (1) pesticide use intensity, (2) soil texture, and (3) natural enemy density. Figures and tables showing the relationship between these variables and WAA densities are shown in the Project Approach section of this report. On farms with sandier soil, WAA populations are reduced. Farmers can also incorporate mulches into their management to improve WAA management. Moreover, farms with reduced pesticide intensity had both higher natural enemy numbers and reduced WAA. The data with earwigs show that this predator is a key natural enemy of WAA. The project team is currently developing manuscripts and extension bulletins detailing these relationships, and will work to incorporate recommendations into the DAS system. Thus, the original goal set forth in the project proposal has been achieved.

(B) GOAL 2: The second goal was to dramatically increase the sociological understanding of the factors that affect the management decisions of conventional and organic apple producers aid in developing IPM strategies for WAA and soil quality that are easily understood and implementable by growers.

Actual accomplishments: In the first year of the project, interviews with all the participating growers were conducted where they were asked about their perception of which factors affect WAA populations. While growers correctly identified the role of insecticide use on WAA populations, it was clear they had less understanding of the impacts of biological control or soil conditions. Thus, the results from the first year provided a baseline showing how grower perceptions differed from the reality of WAA dynamics, and provided ideas for future study, particularly related to biological control. In the final year of the project, each producer was re-visited and asked follow-up questions about how their perceptions of WAA have changed over the course of the project. From work on this project, growers have gained a greater understanding of the role of climatic variables, particularly warm summer temperatures, and biological control, particularly the role of earwigs, on WAA control. Growers have also gained an appreciation of the role of WAA (or lack thereof) in spreading perennial canker disease in orchards. By comparing grower perceptions with the reality of WAA dynamics on the ground, both early and late in the project, the original project goal was achieved. Work with growers to refine WAA management practices to improve management of this pest over time will be ongoing.

(C) The third goal was to determine the suite of management practices for WAA and soil quality on conventional and organic apple orchards that are expected to provide maximum economic returns for Washington producers

Actual accomplishments: The project achieved this goal by determining the factors that growers can modify to improve their management of WAA. Importantly, the recommendations are similar for conventional and organic growers. First, it was found that warm summer temperatures above 95°F decimate WAA populations. Growers can use information on temperature (provided within the DAS system) to determine periods of time when WAA populations are likely to crash on their own, and during which growers can avoid costly insecticide sprays. By understanding the role of temperature on WAA populations, growers might be able to eliminate 1-2 sprays per year in the mid-summer, which could save the industry over \$10M per year. Second, the important role of earwigs as predators of WAA was identified. Growers often treat

earwigs as pests, and spray insecticides for these beneficial insects. By eliminating this practice, growers would both improve the control of WAA and save money, thereby improving the financial performance of their operations. Finally, it was found that growers might be able to use mulches to improve WAA control in orchards with heavy outbreaks. Mulches help prevent movement of WAA between the soil and the tree canopy. These recommendations can help growers improve the efficiency of their WAA control strategies while improving their financial performance.

(A) Goal 1: The first goal was to develop the first set of integrated pest management (IPM) recommendations for WAA in both conventional and organic apple orchards using data from a diverse sampling network and multiple farm variables.

As described in the Project Approach and Goals and Outcomes Achieved sections, to achieve this goal baseline data consisting of a three-year field survey of WAA in nearly 20 apple orchards of varying management type (organic and conventional) and pesticide-use intensity (high and low) was collected. From each orchard, soil and tree conditions, natural enemy densities, weather, and other management variables were surveyed. Then statistical models evaluating the effects of these explanatory variables on WAA densities were developed. Targets, and achievements, were to (i) be able to predict the density of WAA in a given orchard – while predicting pest densities is never perfect, significant progress was made on determining which factors explain outbreaks of WAA. In particular, soil texture, natural enemy densities, pesticide-use intensity, and summer temperature seem to drive population dynamics. Growers can modify some of these factors for optimal control; (ii) deliver recommendations to growers through outreach –this target was met successfully by delivering nearly 10 talks on WAA, and detailing results of the study in *Good Fruit Grower Magazine*. Currently data is being incorporated into the Tree Fruit Decision Aid System.

(B) GOAL 2: The second goal was to dramatically increase the sociological understanding of the factors that affect the management decisions of conventional and organic apple producers aid in developing IPM strategies for WAA and soil quality that are easily understood and implementable by growers.

As described in the Project Approach and Goals and Outcomes Achieved sections, the baseline data collected for this goal consisted of interviews with each participating grower detailing their orchard operations and specifically their management practices for WAA. These interviews were conducted in the first and last years of the project. The targets were (i) to develop the first sociological understanding of how growers make decisions for WAA and (ii) use interviews to determine if perceptions changed over the course of the project. Both of these targets were achieved by collecting the interview data.

(C) The third goal was to determine the suite of management practices for WAA and soil quality on conventional and organic apple orchards that are expected to provide maximum economic returns for Washington producers.

As described in the Project Approach and Goals and Outcomes Achieved sections, the baseline data collected for this goal consisted of data relating various factors to WAA population dynamics, and identifying the most effective and economical strategies for WAA control. The target was to (i) develop enterprise budgets detailing effectiveness of various strategies for WAA control. Although the detailed enterprise budgets were not developed as individual practices for managing WAA because it was difficult to identify from growers (for example, pesticide sprays affect more than just WAA), the data does show opportunities for improving WAA management. Specifically, growers should avoid spraying pesticides in weeks following warm summer temperatures greater than 95°F. Second, growers would benefit from conserving natural enemies, and earwigs in particular. And third, growers should consider their soil texture

and its' impacts on WAA dynamics. Thus, the target of this objective was met even though enterprise budgets were not developed.

### **BENEFICIARIES**

The primary direct beneficiaries of this project are the more than 1,700 growers producing apples on 150,000 acres throughout Washington, with 10% of this acreage in organic production. WAA control conservatively costs Washington growers more than \$4M annually, although actual costs are likely higher. Novel information that can aid growers in making timely and effective management decisions for WAA to maintain sustainable tree fruit production was developed.

Recommendations from this project were provided through a variety of channels with the goal of promoting adoption of economically and environmentally beneficial management practices on organic and conventional apple orchards. Results will be published in technical journals and recommendations were transmitted via industry publications (e.g., *Good Fruit Grower*), hard copy and electronic extension documentations, and numerous small and large group interactions routinely conducted throughout the state by WSU extension and fruit grower groups. Thus, the target audience will have access to both solid field research results and field-tested, immediately useful management recommendations.

If it is assumed that each pesticide spray for WAA costs \$50/acre, then eliminating a single spray per year for the entire acreage of apples in Washington would save the industry nearly \$10M per year. The project identified that growers can avoid using insecticide sprays for WAA in the warmest period of the summer when temperatures are above 95°F. Such temperatures can knock down WAA populations for 3-4 weeks. If growers avoid spraying insecticides during this time, they could eliminate sprays for WAA, which could have a large economic impact. Second, it was identified that growers often spray pesticides for earwigs, which is found to be beneficial predators of WAA. Growers would considerably increase their economic returns if they conserve, rather than kill, earwigs. Over time, quantitative data will be collected on the number of insecticide sprays for WAA, and it will determine if it decreases over time due to the findings. This will provide more conclusive economic impacts data for the project.

### **LESSONS LEARNED**

Completing this project reinforced the importance of close collaborations between research teams, producers, and members of cropping industries (i.e., the Washington Tree Fruit Research Commission). It was found that the integration of research and sociological questions provided the team with a broad, systems-level, and understanding of WAA and how growers approach management of this pest. This proved to be beneficial for the project team.

Over the course of the project, the team also gained an appreciation for the importance of inter-disciplinary research for tackling pest management in agriculture. The project would not have been successful without the close collaborations between entomologists, soil scientists, sociologists, extension agents, and growers. Working as a collaborative team allowed the group to consider this pest problem from multiple angles.

On the negative side, the team learned a bit about the difficulty of observational studies for understanding pest dynamics. Pests often have highly variable populations in the field, and even with surveys of 20+ orchards over 3 years it is often difficult to tease apart the factors that have the greatest impact on pest dynamics. The observational field surveys yielded more ambiguous results than expected. However, by combining the field surveys with experimental studies considerable insight into WAA dynamics was gained. When this project began, it was expected that the most effective natural enemy of WAA was the parasitoid *Aphelinus mali*, as this species had been discussed extensively in the literature. It was not expected to find that earwigs would be as significant as they appear to be. By following up on this finding, the contribution of earwigs to WAA biological control has been documented and the project team is working

with growers to improve conservation of this natural enemy. It is expected that this research will have considerable impact for the tree fruit industry.

The one objective not achieved during the course of the project was to develop enterprise budgets for WAA control. There were two main reasons for this. First, it was difficult to get all the information on grower management practices because interviews were not completed until March 2017. The project team will continue to work on enterprise budgets. Second, as mentioned earlier, management practices on orchards often have both direct and indirect impacts on WAA. For example, fertilization is primarily done to improve the fitness of trees, but it might also affect WAA. However, quantifying the monetary impact of fertilization on WAA is difficult due to this and the fact that data from the field are noisy. The project team learned that estimating the economic impact of pests often does not require detailed enterprise budgets, but rather requires one to value the costs saved from reduced insecticide sprays. For example, if growers could eliminate summer sprays it would save \$10+ M per year. These findings made it less important to develop detailed enterprise budgets for the system.

#### **ADDITIONAL INFORMATION**

The total amount of cash match used over the course of the project was \$196,101. These funds were used as follows:

- (A) Two weeks salary and benefits for co-PI Reganold: \$9,397 (yr1), \$9,772 (yr2)
- (B) Two weeks salary and benefits for co-PI Goldberger: \$13,707 (yr2)
- (C) 5% FTE salary and benefits for co-PI Jones: \$10,845 (yr1), \$11,279 (yr2)
- (D) 5% FTE salary and benefits for co-PI Beers: \$5,701 (yr1), \$5,929 (yr2)
- (E) Cash match from WTFRC: \$90,498
- (F) Unrecovered indirect costs: \$38,981

Items A-D above were used to support the co-PIs on the project during their time working on the project. Each of these individuals played a major role in executing the research project and in supervising the graduate student, Robert Orpet, or technicians involved in the project. Item E above was used to provide supporting funding for the project through a grant from the WTFRC, which was also on WAA. Item F was used to offset indirect costs that were not received by WSU as part of the project. WSU provided support for the project in terms of research space and facilities, PI Crowder's salary, which were essential for completion of the project.

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## **PROJECT #19**

**Project Title:** Disruption of Overwintering of Hop Powdery Mildew

**Partner Organization:** Washington Hop Commission

### **PROJECT SUMMARY**

Hop powdery mildew was introduced into the Pacific Northwestern U.S. in the mid-1990s. The disease is now endemic in the region, and management entails on average 8.3 fungicide applications annually in Washington State, with aggregate disease related costs estimated conservatively at \$15 million annually. Development of cost-effective, non-chemical, and durable approaches to disease management are a priority for the industry. This project sought to understanding aspects of disease biology and epidemiology to improve growers' management effectiveness. Specifically, this project identified and quantified factors related to the disease cycle, where and to what extent the pathogen survives from year-to-year, and means to disrupt overwintering survival of the fungus.

The hop industry is experiencing unprecedented growth and at the same time new challenges from the most important disease issue, powdery mildew. Until 2012, powdery mildew was effectively controlled on approximately half of all acres produced through planting of resistant varieties. However, two widely utilized sources of host resistance have since become susceptible due to emergence of new strains of the pathogen. Because of the combination of rapid expansion in acreage and most varieties now being susceptible to the disease at some level new approaches are urgently needed to improve management of powdery mildew and better mitigate disease risk by non-chemical means.

The current project was an extension of a previously funded SCBGP project, yet with distinct objectives. The former project identified basic aspects of the disease biology associated with how the pathogen persists overwinter and how cultural practices in spring and early summer moderate in-season disease development, crop yield, and quality. In the current project, research was focused on identifying risk factors for predicting where the pathogen actually will survive, what fields are most at risk from the disease, and how late-season disease management efforts may influence disease development in the following year. Together, these projects provided a very detailed and clear picture of when infection occurs that is most likely to lead to successful pathogen survival, risk factors for pathogen survival, and production practices that can moderate these risks.

### **PROJECT APPROACH**

This project had four primary objectives:

- (1) Identify and quantify risk factors for seasonal survival of the pathogen;
- (2) Clarify if the pathogen persists in a limited number of chronically affected fields;
- (3) Evaluate targeted and sustainable means to disrupt overwintering; and
- (4) Communicate and extend project findings to industry stakeholders and partners.

#### **Objectives 1. Identify and quantify risk factors for seasonal survival of the pathogen.**

A database was constructed that contained historical data on cultivar, severity of powdery mildew in the previous and current season, the date of the first and last fungicide application, total number of fungicide applications, field age, pruning method/intensity, date of pruning, the number of desiccation applications made mid-season, and other cultural practices relevant for powdery mildew management. The database included 169 hop yards or plots in Oregon and 244 hop yards in Washington evaluated during 2000 to 2017. Conducting studies in the contrasting environments of Oregon and Washington allowed for identification of a broader set of factors that may influence powdery mildew survival.

Historical weather data was obtained from the nearest regional Washington State University AgWeatherNet, Metar, or AgriMet weather station. Summary weather variables were calculated for each month from October to March, including mean air temperature, mean soil temperature, total precipitation, and the number of days when mean temperature was below 0, -5, and -10°C.

Preliminary analysis of potential predictor variables for “flag shoot” (bud perennation) prevalence was conducted by creating scatter plots of the continuous variables. For categorical variables, the incidence of flag shoots was expressed in box plots to compare the distribution of flag shoots amongst the potential predictor variables. The distribution of the predictor variables for data sets without and with flag shoots were compared using the nonparametric Kolmogorov-Smirnov (K-S) test. Mixed model analyses were conducted to test the association of specific factors with mean flag shoot incidence.

### **Objective 2. Clarify if the pathogen persists in a limited number of chronically affected fields**

*Intensive assessment of flag shoots.* To further understand where the powdery mildew fungus persists overwintering, during 2014 to 2017 intensive evaluations of flag shoots and powdery mildew levels were made in all hop yards in the eastern hop production regions of Marion County in Oregon. In each year, every commercial hop yard on all farms (8 to 10, year dependent) were assessed for flag shoots. This was a total of 106 yards in 2014, 122 in 2015, 125 in 2016, and 136 in 2017. The number and incidence of flag shoots was assessed using a modification of the methods described by Turechek et al. (2001) and Turechek and Mahaffee (2004). Typically, each yard was divided into strata by dividing the number of rows by 20 (rounded up to the nearest integer). One transect (row) was selected from each of one to two strata per yard, and 100 to 200 plants in each transect were inspected. In cases when a row contained fewer than the desired number of plants an additional transect was selected and sampling continued until the desired number of plants were sampled.

Sampling was conducted during late March to mid-April, just before spring pruning practices are typically conducted in hop yards (Gent et al. 2012). Each plant was inspected for the presence of flag shoots and the number of plants with flag shoots and the total number of flag shoots were recorded. A shoot was deemed a flag shoot if coalescent powdery mildew colonies were found entirely or primarily on the stem, only at each node on stipules, or mostly to entirely on a single leaf as depicted in Mahaffee et al. (2009). A similar sampling approach was followed in the same yards in May, June, and July to quantify disease progression. In these months, plants were inspected for the presence of powdery mildew and the percentage of diseased plants was recorded.

### **Objective 3. Evaluate sustainable means to disrupt overwintering**

*Late season fungicide study.* Experiments were conducted to quantify the impact of late season fungicide applications directed at basal foliage on development of powdery mildew after harvest. The experiment was conducted in a commercial yard of cultivar Cascade produced on a short trellis and located near Toppenish, Washington. Treatments consisted of two or four applications of Luna Experience (10 fl oz per acre as a banded application) rotated with Omni Supreme Oil (1% v/v). Applications were made beginning immediately after harvest (1 September) and then weekly thereafter for two weeks or four weeks depending on the treatment. These treatments were compared to non-treated plots. Applications were directed at the base of the plants in an application volume of 50 to 100 gal per acre to drench the basal foliage. Disease development on leaves was assessed by inspecting 10 basal leaves on each of 10 plants per plot (100 leaves per plot) beginning just before the first treatment was made and then every 7 days thereafter. Treatments were replicated four times in plots that were four rows wide by the length of the field (approximately 1 acre per replicate plot). Data were analyzed in a mixed effect model.

*Commercial hop yard nitrogen rate study.* Nitrogen rate studies were conducted in a commercial yard near Moxee, WA planted to cultivar Tomahawk. Three nitrogen rates were evaluated: 80, 160, and 240 pounds per acre applied during mid-May to mid-July. To measure residual soil nitrogen levels before fertilizer was

applied, soil samples were collected down to 12" from each plot and analyzed for levels of ammonium and nitrate N. The cooperating grower applied nitrogen to all plots at 50 pounds per acre banded in late winter as 21-0-0 and then 30 pounds per acre as 32-0-0 banded and incorporated in mid-May. Thereafter, 50, 130, or 210 pounds of N was injected (as CAN-17 or UN32) in equal amounts through the drip irrigation system on 3 June, 20 June, 30 June, and 12 July. Each treatment was replicated four times in large plots, with each replicate being at least 1.3 acres.

Petioles were collected from each plot every two weeks during the season and assayed for nitrogen content to relate to the fertilizer treatments. A total of 40 to 80 petioles were collected from each plot, with petioles being derived from five to six nodes from the end of the main bine (early season) or lateral branches approximately 6' from the ground.

The incidence of leaves with powdery mildew was assessed by inspecting 10 leaves on each of 10 plants per plot (100 leaves per plot) every 14 days throughout the season. From these measurements, relative area under the disease progress curve was calculated to express disease incidence over the season as a single value. During disease ratings in August, powdery mildew was noted more prominently on young, expanding leaves in certain treatments. To capture these differences, late season disease ratings were conducted that targeted the newly formed leaves on the end of branches. Ten leaves from each of 10 plants per plot were rated. The basal foliage was rated for powdery mildew as described for the late season fungicide study. The incidence of cones with powdery mildew was determined by collecting cones from lateral branches at heights of approximately 9, 12, and 15 feet from the ground on each of 10 plants per plot. The cones were bulked before selecting 15 cones arbitrarily from each plant (a total of 150 cones per plot) and each cone was evaluated for signs of powdery mildew.

At harvest, 10 to 20 plants from each plot were harvested using a picking machine to estimate cone yield. A subsample of cones from each plot was dried overnight and the percent of dry matter was used to calculate the dry weight of cones harvested. A subsample of cones were evaluated for cone color using a 1 to 10 ordinal rating scale (typical of those used by hop brokerage firms for quality assessments) in a blind manner. Cone chemical analyses and sensory assessments were conducted in the laboratory of T. Shellhammer at Oregon State University using ASBC standard methods. Petiole and cone nitrate levels were determined colorimetrically on a flow injection autoanalyzer in the laboratory of K. Trippe and C. Phillips at the USDA Forage Seed and Cereal Research Unit. Data were analyzed in mixed effects models to relate nitrogen treatment effects on powdery mildew levels, yield, and cone quality measurements.

#### **Objective 4. Communicate and extend project findings to industry stakeholders and partners**

Several levels of outreach activities were conducted to transfer information to industry partners. Results and project updates were presented to producers throughout the Pacific Northwest and nationally through a total of 23 presentations. Two university seminars were presented. Two annual reports were submitted to industry members. Timely updates and highlights also were pushed to friends of the Northwest Hop Information Facebook page and included in a revision of the Field Guide for Integrated Pest Management in Hops.

Mrs. Ann George served as the overall project lead and administrator, ensuring that project objectives, reporting, and financial management were as described in the proposal. Dr. David H. Gent oversaw technical portions of the research and extension efforts.

The project benefitted the specialty crop of hops.

### **GOALS AND OUTCOMES ACHIEVED**

#### **Objectives 1. Identify and quantify risk factors for seasonal survival of the pathogen**

Several variables related to temperature in late autumn and early winter were significantly related to the presence of flag shoots in Washington, but not in Oregon. In Washington, temperature during October to February was associated with flag shoot occurrence (K-S test  $P \leq 0.05$ ) although the strength of the association was greatest in December. There was weak evidence that December temperature was associated with flag shoot occurrence in Oregon.

Among disease related variables, in Washington there was a significant correlation between the incidence of plants with flag shoots and disease levels in the previous season (Spearman rank correlation  $S = 0.25$ ;  $P = 0.027$ ) and plants with flag shoots in the next season ( $S = 0.16$ ;  $P = 0.080$ ). In Oregon, the incidence of plants with flag shoots was correlated with disease levels in the previous year ( $S = 0.29$ ;  $P = 0.028$ ), disease levels on leaves in the current season ( $S = 0.31$ ;  $P = 0.002$ ), and also flag shoots in the next season ( $S = 0.37$ ;  $P = 0.005$ ). Therefore, in both environments there was some evidence for high disease levels in the previous year and prior occurrence of flag shoots to influence future flag shoot occurrence.

A mixed model analysis further indicated that prior season disease levels were positively associated with the occurrence of flag shoots, and also the likelihood of flag shoots occurring in the ensuing season. Under lower disease pressure situations, as found in Oregon, there was a general association between grower fungicide use patterns and the presence or absence of flag shoots. Growers made on average 1.8 more fungicide applications per season in yards where flag shoots were present versus yards where flag shoots were absent. This was associated with a 13 day delay in the timing of the first fungicide application.

The severity of powdery mildew on leaves was significantly associated with the thoroughness of pruning in Washington ( $P = 0.149$ ), but less so in Oregon ( $P = 0.363$ ). In both environments, there was a trend for the incidence of plants with flag shoots in the following season to be influenced by the thoroughness of pruning in spring.

**Objective 2. Clarify if the pathogen persists in a limited number of chronically affected fields**

*Intensive assessment of flag shoots.* Flag shoots were identified in seven yards in 2014, three in 2015, six yards in 2016, and seven yards in 2017. In all but three instances, flag shoots were detected in yards that were either not pruned or pruned by chemical desiccation. From these initial foci powdery mildew increased regionally, later being found in 35 to 68% of yards at the landscape level.

Over the four years of the assessments, where flag shoots occurred previously was associated with the likelihood of subsequent flag shoot occurrence (Table 1). The odds of a flag shoot occurring in a given yard was significantly associated with prior occurrence of a flag shoot on the same farm, in a yard adjacent to where a flag shoot occurred previously, or, most strongly, prior occurrence of a flag shoot in that yard.

**Table 1.** Association between previous occurrence of a powdery mildew flag shoot and risk of flag shoot development in the subsequent year

Risk factor	Increased odds of a flag shoot in a given yard	AUROC curve <sup>a</sup>
Flag shoot present on same farm last year	11.1	0.76
Flag shoot present in same or adjacent yard last year	7.2	0.69
Flag shoot in same yard last year	29.2	0.73

<sup>a</sup> Data is from evaluation of 490 hop yards during 2014 to 2017.

<sup>b</sup> Area under the receiver operating characteristic curve. This statistic ranges from 0 to 1 and provides a measure of overall predictive accuracy, with 1 being perfect prediction.

During 2014 and 2015, isolates of the powdery mildew fungus were collected from hop yards at the beginning and end of the season and characterized for race. In every instance, the race of the isolates at the

end of the season was identical, indicating that the population of the fungus was largely unchanged over the course of the year.

Experimental plots were established and planted to an experimental hop line with a propensity for producing powdery mildew flag shoots. Overwintering powdery mildew was found on 0.09% of plants in 2014, 5.7% of plants in 2015, and 1.8% of plants in 2016. Two plants, 10% of the total plants harboring overwintering powdery mildew in 2016, were infected in both 2015 and 2016.

### **Objective 3. Evaluate sustainable means to disrupt overwintering**

*Late season fungicide study.* Fungicide treatment reduced the incidence of leaves with powdery mildew when two to four fungicide applications were made after harvest. However, the reductions in disease from the fungicide treatments did not reduce flag shoot incidence in the following year in either 2015-2016 or 2016-2017 studies.

*Commercial hop yard nitrogen rate study.* Disease levels on leaves over the season were slightly increased on plants in plots that received the intermediate and high rates of nitrogen ( $P \geq 0.010$ ). Late in the season, there was a rapid increase in powdery mildew on newly formed, young leaves receiving the intermediate and high rate of nitrogen ( $P \leq 0.011$ ). The incidence of cones with powdery mildew also was greatest on plants that received these nitrogen rates ( $P \leq 0.025$ ). However, in neither year of the study were flag shoots found in the following year, independent of nitrogen rate treatment.

### **Objective 4. Communicate and extend project findings to industry stakeholders and partners**

Several levels of outreach activities were conducted to transfer information to industry partners. Results and project updates were presented to producers throughout the Pacific Northwest and nationally through a total of 23 presentations. Two university seminars were presented. Two annual reports were submitted to industry members. Timely updates and highlights also were pushed to friends of the Northwest Hop Information Facebook page and included in a revision of the Field Guide for Integrated Pest Management in Hops.

Impact from this project is expected to increase over time as growers experiment more on-farm with their production practices.

All proposed research, outreach, and impact documentation activities and goals were accomplished as stated.

The proposed benchmark and performance measure for this project was a “post then pre” survey of growers. This was conducted via an electronic survey sent to all hop producers in Oregon and Washington during March 2017. The target was a 10% increase in grower awareness and adoption of best management practices and efficacy of disease control. These targets were far exceeded.

- Among respondents, 82.1% indicated they were moderately to highly aware of region disease pressure; 79.3% indicated they are more aware of regional disease pressure now as compared to greater than 5 years ago.
- 86.2% of respondents indicated that they are moderately to highly aware of cultural practices that influence powdery mildew disease pressure; 86.2% indicated they are more aware now as compared to greater than 5 years ago.
- 65.6% indicated they have considerable to extensive knowledge of weather factors that favor powdery mildew; 79.3% indicated they are more knowledgeable of these factors now as compared to greater than 5 years ago.
- Respondents indicated the following changes in their disease management programs over the past 5 years:

- Increased scouting and monitoring in certain yards/varieties: 75.9%
- Prune later in spring in certain yards/varieties: 48.3%
- Try to be more thorough with spring pruning to eliminate flag shoots: 75.9%
- Remove basal growth more intensively: 55.2%
- Changed fertility program: 31.0%
- Make post-harvest fungicide applications: 6.9%
- Communicate with neighbors on disease pressure or scouting information: 41.4%
- Try to coordinate with neighbors on disease management programs: 17.2%
- (1) There were 39 respondents to the survey. Given that there are (approximately) 90 hop growing operations in Washington and Oregon, the response rate of the survey was 43.3%.

Please also note that the proposal indicated that the survey would be a "post then pre" survey, not "post and pre". A "post then pre" survey is a technical term for a form of survey questioning that elicits information retrospectively based on self-reported changes over a period of time. This enables one to measure self-reported changes by respondents in one survey step rather than two (e.g., a pre-survey and later a post-survey) and also avoids potential confounding from having different respondents in two separate surveys.

### **BENEFICIARIES**

Hop producers and downstream users of hop products were the primary beneficiaries of this project. Also reached were crop advisers, public and private sector researchers across the Pacific Northwestern U.S., brewers from across the U.S., and the 921 fans of the Northwest Hop Information Network Facebook page.

A major accomplishment of this project was clarifying when and where the powdery mildew pathogen survives overwinter. Survival of the pathogen was found associated with severe powdery mildew in the previous season, prior occurrence of overwintering, and spring pruning method. Modified nitrogen fertility and fungicide applications made after harvest reduced powdery mildew levels late in the season, but did not significantly reduce overwintering of the pathogen. Therefore, reduction or elimination of powdery mildew overwintering appears to require use of modified pruning practices in spring as additional late-season mitigation efforts are inadequate to suppress the disease in the following year. The spring pruning practices that reduce overwintering of the powdery mildew pathogen were broadly implemented by industry as a result of this research.

Based on a random survey of all hop producers in Washington and Oregon conducted during March 2017, as described above, 75.9% of survey respondents indicated that they try to be more thorough with spring pruning to eliminate flag shoots. This practice is associated with reductions in early season fungicide use of 1.5 applications per season based on research reported in Gent et al. (2012). A reduction of 1.5 fungicide applications is valued at \$75 per acre based on the Washington State University 2015 Estimated Cost of Establishing and Producing Hops in the Pacific Northwest. Other economic benefits related to reduced crop damage, reduced pesticide usage, improved crop quality, and reduced impacts on non-target organisms are not considered in this value.

(2) The beneficiaries of the project can be calculated by taking the number of growers in the region and multiplying this value by the reported changes as indicated on pages 5 to 6, question 10. There is not a single value that would represent all the beneficiaries, rather the range is from 6.9% to 86.2% depending on the practice. However, I do think it is reasonable to use the highest value reported in the survey of 86.2% of respondents indicating they are more aware of cultural

practices for disease management as compared to 5 years ago because this integrates all of the potential subcategories detailed on page 6.

*Therefore, 86.2% reported beneficiaries out of approximately 90 growers equals 78 operations impacted.*

Using the above and the information reported on page 6, question 12 the economic impact is estimated at:

*75.9% reported changes x \$75/acre in savings from the changes x 46,289 acres in Oregon and Washington in 2017 (NASS report) = \$2,635,000 annual impact in fungicide inputs alone.*

### **LESSONS LEARNED**

A lesson learned from this project is that evaluation of treatments for rare events (e.g., the influence of treatments on powdery mildew survival within a given field) is difficult. Exceptionally large plots and multiple years are needed to detect rare, but important, events. Another lesson is that communicating and motivating changes in stakeholders takes longer than the typical budget cycle for these block grants. Impact accumulates over time and the impact of work cannot be assessed fully within 2 to 3 years.

The goals and Expected Measurable Outcomes were achieved for this project.

### **ADDITIONAL INFORMATION**

Matching donations included the following:

- \$57,000 of cash contributions from Hop Research Council. Cash support was used to supplement grant funding for staff, supplies and consumables.
- \$204,750 of in-kind support from BT Loftus Ranches, Yakima. This represents 13 acres of commercial hops to support on-farm trials, including all fixed and variable production costs and additional expenses associated with application of plot-specific nitrogen applications. Value based on the 2010 Washington State University publication detailing 2010 estimated costs of producing hops in the Yakima Valley at \$7,875 per acre, equaling \$102,375 per year for two years.
- Total matching donations: \$261,750

Publications:

Gent, D. H., Probst, C., Nelson, M. E., Grove, G. G., Massie, S. T., and Twomey, M. C. Interaction of basal foliage removal and late season fungicide applications in management of hop powdery mildew. *Plant Disease* 100:1153-1160. 2016.

Probst, C., Nelson, M. E., Grove, G. G., Twomey, M. C., and Gent, D. H. Hop powdery mildew control through alteration of spring pruning practices. *Plant Disease* 100:1599-1605. 2016.

Gent, D. H., Bhattacharyya, S., Ruiz, T., Twomey, M., and Wolfenbarger, S. 2017. A network model to predict spread and mesoscale level development of hop powdery mildew. *Phytopathology* *In press*.

Iskra, A. E., Lafontaine, S., Phillips, C., Shellhammer, T., Trippe, K., Twomey, M., Woods, J., and Gent, D.<sup>3</sup> 2016. Nitrogen fertilization increases powdery mildew, arthropod pests, and nitrate accumulation in hops. APS Pacific Division Meeting, June 28-30, La Conner, WA.

Iskra, A. E., Lafontaine, S. R., Phillips, C., Shellhammer, T. H., Trippe, K., Twomey, M. C., Woods, J. L., and Gent, D. H.<sup>3/4</sup> 2016. Influence of nitrogen fertilization in hops on nitrate accumulation in cones, pest outbreaks, and crop yield and quality. Young Scientist Symposium, April 21-23, Chico, CA.

Gent, D. H., Twomey, M., Wolfenbarger, S., and Woods, J. 2015. Risk factors for perennation of *Podosphaera macularis* and landscape level development of hop powdery mildew. *Phytopathology* 105:S4.49.

Gent, D. H., Grove, G., Nelson, M. E., Probst, C., Twomey, M., and Wolfenbarger, S. 2014. Susceptibility of crown buds to *Podosphaera macularis* and its association with perennation of the hop powdery mildew fungus. *Phytopathology* 104:S3.45.

Websites:

<https://www.facebook.com/Northwest-Hop-Information-Network-147514331928522/>

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## **PROJECT #20**

**Project Title:** Proactive Approaches to Protect Western WA Potatoes against New Strains of PVY

**Partner Organization:** Washington State University – Deb Inglis, Chris Benedict, Don McMoran

### **PROJECT SUMMARY**

The potato industry in western Washington (WWA) depends on the production of high quality, specialty (red, yellow, purple, and fingerling) varieties. Since these types have strong consumer appeal and are well suited to WWA's maritime climate, they are grown as both seed tubers in Whatcom Co. (~3,300 acres; \$6.5 M value) and commercial ware potatoes in/near Skagit/Snohomish Co. (~12,000 acres; \$60 M farm gate value). Loss of potato tuber quality is a serious economic concern for both areas as well as to regions where WWA potatoes are marketed and seed tubers are exported.

Although *Potato virus Y* (PVY<sup>0</sup>) is one of the oldest known plant viruses, novel recombinant strains were reported in the 2000s causing severe foliar and tuber problems. During 2012 and 2013, two new strains of PVY became endemic in several Whatcom Co. seed potato fields that were confirmed to be PVY<sup>NTN</sup> and PVY<sup>N-wi</sup>, and there was concern about spread to other areas. The presence of these new strains was troubling because: (i) they had the ability to infect potato plants without always causing obvious foliar symptoms, making visual inspections unreliable—easy recognition has been the key component of traditional field and greenhouse seed certification programs for decades; (ii) both PVY<sup>NTN</sup> and PVY<sup>N-wi</sup> can cause severe tuber malformation and necrosis, and many growers believed the new strains also to be the cause of 'cracked' tubers—these symptoms resulted in serious quality and yield losses; and, (iii) PVY is transmitted by aphids, but non-persistently (i.e., the virus is stylet-borne so aphids are infective only for brief periods after virus acquisition)—consequently, the strategies that were being used at the time to manage aphid vectors were not sufficiently effective meaning that additional management practices were in need of investigation.

Therefore, the project was designed to: 1) investigate whether new strains of PVY can be differentially transmitted via mechanical means; 2) determine whether crops and weeds are potential alternative hosts of PVY; 3) demonstrate the use of cover crops as stylet “cleaning-sites” for aphids to deposit virus particles prior to moving into fields; 4) study whether common WWA potato cultural practices (fertility, irrigation, vine kill) affect PVY symptom expression; 5) compare various approaches for detecting PVY strains in plants and tubers during winter GH grow-out tests and in summer field settings; 6) continue monitoring for new/exotic strains of PVY, including those in organic and conventional potato fields, and assess interactions of PVY strains with selected specialty potato varieties; and, 7) develop educational programs on PVY for both seed and commercial potato growers.

PVY<sup>NTN</sup> and PVY<sup>N-wi</sup> were first reported in western Washington in 2012. These recombinant strains created challenges for WSDA inspectors and seed potato growers, in particular, because typical PVY mosaic symptoms did not always appear on potato plant foliage which impacted rogue activities by growers, plus many seed lots were inaccurately certified and unintentionally sold as being within industry virus standards. When commercial potato growers in the area harvested their potato crop, canoe-shaped cracks appeared on some lots, in some cases affecting 10 to 40% of the yield—a serious quality loss. Because tuber cracking symptoms had not been observed at such high levels before, commercial potato growers questioned whether the observed symptoms originated with the seed potato growers, and if the problem was caused by PVY. As evidence of a relationship between tuber cracking and PVY mounted, the Washington State Seed Potato Commission moved to remedy the situation and chose to mandate laboratory testing for seed potatoes submitted for certification in 2013. Unfortunately, the laboratory contracted to carry out the testing made

technical errors that contributed to false positive results. This mistake led to potential non-certification of thousands of seed potato tubers. As a result, the new regulation was removed and protocols reverted to the previous years' while alternative ways to effectively manage recombinant strains of PVY became the primary emphasis.

This project did not build on a previously funded SCBGP project.

**PROJECT APPROACH**

<b>Activities (and Dates) by Project Objective:</b>	<b>Completed By:</b>	<b>Work Accomplished and Significant Results/Conclusions/Recommendations:</b>
<p><b>Obj. 1:</b> Investigate whether PVY strains O, NTN, and N-Wi can be differentially transmitted, mechanically.</p> <ul style="list-style-type: none"> <li>- Nuclear seed tubers were inoculated with each of the three strains in 2015; then, a greenhouse grow-out experiment was carried-out in 2016 and the reactions monitored and verified by ELISA.</li> </ul>	Inglis	<p>There was no real difference in transmission ability related to PVY strain. Transmission via infected potato leaf sap to nuclear seed potatoes in a greenhouse seed cutting experiment ranged from with 4.7% (PVY<sup>O</sup>) to 9.5% (PVY<sup>NTN</sup> and PVY<sup>N-Wi</sup>). Potato growers have been advised to focus on purchasing PVY-free seed, and to practice sanitation during seed cutting operations.</p>
<p><b>Obj. 2:</b> Determine whether crops and weeds are potential alternative hosts of PVY.</p> <ul style="list-style-type: none"> <li>- Sentinel plots were established in Skagit and Whatcom Counties in 2015 and 2016; weeds were sampled in summer/fall 2015 and winter/ spring/summer/fall 2016; all samples were tested for PVY by ELISA.</li> </ul>	Beissinger Benedict Inglis	<p>Of 183 samples across 55 weed species common to WWA, no sample tested positive for PVY regardless of season or weed life cycle. Even so, project outreach materials are advising that weedy plants near fields be managed because many were found to provide abundant habitat for known PVY aphid vectors.</p>
<p><b>Obj. 3:</b> Demonstrate the use of cover crops as stylet “cleaning-sites” for aphids to deposit virus particles prior to moving between potato fields.</p> <ul style="list-style-type: none"> <li>- 2015: On-farm trials were established at five Whatcom Co. seed potato fields and monitored for PVY and aphids; then, tested for PVY by ELISA.</li> <li>- 2016: On-farm trials were established at three Whatcom Co. seed potato fields and monitored for PVY and aphids; then, tested for PVY by ELISA.</li> </ul>	Benedict	<p>No positive PVY foliar samples were identified over the two years of the study. In part, lack of detection was due to the very young age of the seed potato crop (nuclear/G1) which was more compatible with and had greater likelihood of success by employing this practice. Spring oats proved the most attractive cover crop for winged aphids though sorghum x sudangrass was the quickest to establish. In 2015, aphids were present in the barrier crop at two sampling times, but not in the adjacent seed potato crop. In 2016, no non-colonizing aphids were detected during the growing season on any barrier crop or within the potato crop itself. In 2016, yellow sticky card traps were placed at 15 foot increments, moving inward from field edges (starting at each major cardinal direction). Potato fields surrounded with barrier crops showed little migration of aphids into field interiors (as was expected). Aphid-barrier crops will continue to be</p>

		<p>promoted in seed potato producing areas, and already have been successfully adopted by growers, particularly for early generation seed fields. Identification of suitable barrier crop type and seeding rate was identified through this work.</p>
<p><b>Obj. 4:</b> Study whether common WWA potato cultural practices (fertility, irrigation, vine kill) affect PVY symptom expression, using PVY<sup>N<sup>-</sup></sup><sub>Wi</sub>-infected (G5) and PVY-free Chieftain nuclear seed tubers.</p> <ul style="list-style-type: none"> <li>- Inglis set-up screenhouse experiment in 2016 and compared effects of N fertilization with current season vs. seedborne PVY infections.</li> <li>- Inglis set-up field experiments in 2015 and compared effects of (i) high and low irrigation amounts, (ii) rapid and slow vine kill, and (iii) progressive symptom development on potato tuber yield and quality.</li> </ul>	<p>Inglis</p>	<p>Infections arising from seedborne PVY were obvious and occurred in 100% of plants. Those arising from foliage inoculations were difficult to distinguish visually, required confirmation via ELISA, and while occurring in 80% of plants without N amendment, occurred in only 20% and 10% of plants receiving 150 or 300 ppm N, respectively. N content affected PVY infection ability when leaves were directly inoculated, indicating the importance of good N management for limiting current season PVY in field production settings. Cracked tubers (% by number) was lower (7.9% vs 9.8%) at the high N rate.</p> <p>(i and ii) PVY infection and cultural practice did not statistically interact, and seed tuber infection had the greatest effect on diminishing tuber yield. Neither high or low irrigation amounts, nor slow or rapid vine kill significantly altered any tuber size or quality class. There were more cracked tubers from PVY+ plants compared to PVY- plants (<math>P = 0.0601</math>) in the irrigation trial, and significantly more from PVY+ compared to PVY- plants (<math>P = 0.0033</math>) in the vine kill trial. Seedborne PVY, rather than irrigation amount or vine kill rate, affected tuber cracking, reinforcing the importance of PVY-free seed.</p> <p>(iii) Seedborne PVY significantly reduced tuber yield beginning 77 DAP, corresponding to tuber bulking, and also gave rise to significantly higher cracked progeny tuber weights. Formation of cracked tubers at 63 DAP was unexpected, and implied that it is imposed early during tuber development.</p>

<p><b>Obj. 5:</b> Compare various approaches for detecting PVY strains in plants and tubers during winter GH grow-out tests and in summer field settings.</p> <ul style="list-style-type: none"> <li>- Two greenhouse experiments on PVY inoculation times and detection sensitivity with Agdia ImmunoStrip® vs. ELISA, set-up in greenhouse in Fall 2015.</li> <li>- Surveyed seed potato winter grow-out tests in Whatcom Co. in late winter of 2016 and compared visual results with ELISA results. A subset of samples from 43 seed lots were visually inspected and then foliar samples analyzed for PVY.</li> </ul>	<p>Beissinger Benedict Inglis</p>	<p>Chieftain plants inoculated with PVY<sup>N-Wi</sup> at emergence displayed severe and systemic symptoms of mosaic, veinal necrosis and leaf drop, while those inoculated at pre-flower, post-flower and senescence had localized veinal necrosis and only low to no incidence of mosaic and leaf drop. Low to no variability in PVY<sup>N-Wi</sup> detection occurred between the two methods for emergence-inoculated plants; but, those inoculated at pre-flower and post-flower showed the most variability by the two methods. Since PVY<sup>N-Wi</sup> symptom expression and detection can differ depending on potato growth stage at inoculation time, these variations need to be heeded when collecting field samples and selecting the testing method. Growers will be advised to test plants early in the season.</p> <p>Of the 616 samples acquired, 43 tested positive for PVY by ELISA, but only 32 of these were symptomatic—meaning that 25% of those that tested positive were asymptomatic. Of those samples testing positive by ELISA, PVY strain distribution was as follows: PVY<sup>N-Wi</sup> (56%), PVY<sup>O</sup> (23%), PVY<sup>NTN</sup> (18%), PVY<sup>N:O</sup> (3%). These results underscore that reliance on a (largely) visual system for certification can lead to false certification of a seed potato lot, and that serological testing is always needed.</p>
<p><b>Obj. 6:</b> Continue monitoring for new/exotic strains of PVY, and assess interactions of PVY strains with selected specialty potato varieties.</p> <ul style="list-style-type: none"> <li>- Visited Karasev lab at U of I for training on working with PVY in Fall 2014.</li> <li>- Set-up PVY strain x potato cultivar interaction experiments in screenhouse in Summer 2015 and greenhouse in Summer 2016 using Austrian Crescent, Banana, Cal White, Purple Majesty, and Rosefin Apple varieties.</li> <li>- Surveyed 7 (in total) commercial organic and conventional potato fields in Skagit/San Juan Co. in 2016, at full bloom and preceding vine kill; 24-50 petioles/field were obtained in a zig-zag</li> </ul>	<p>Beissinger Benedict Inglis McMoran</p>	<p>Successfully maintained PVY strains on Burly tobacco after training at U. of Idaho; inoculation and detection methods were effectively adapted by project PIs.</p> <p>PVY symptoms varied by strain x cultivar. Mosaic was frequently observed with PVY<sup>O</sup> and PVY<sup>NTN</sup> while mottle mostly occurred with PVY<sup>N-Wi</sup>. Leaf drop was infrequent except for Austrian Crescent infected with PVY<sup>O</sup>; veinal necrosis was limited with PVY<sup>N-Wi</sup>. Across strains, Cal White had highest incidence of tuber cracking, but Purple Majesty had nearly no tuber symptoms. Photos and descriptions are being included in outreach materials to help growers and inspectors with PVY recognition.</p>

<p>pattern with priority given to symptomatic plants.</p> <ul style="list-style-type: none"> <li>- Collected PVY infected seed tubers from local garden stores in Skagit and Whatcom Co. in 2016.</li> </ul>		<p>Of 750 samples from the field survey, 45 (6%) tested positive for PVY; four (0.53%) were from conventional and 41 (5.5%) were from organic fields. Percentage of O:N-Wi:recombinant strains were 50:50:0 and 48:26:22 for conventional and organic, respectively. Given the sampling scheme and ~50% prevalence of PVY<sup>o</sup> in both field types, PVY<sup>o</sup>, and PVY<sup>N-Wi</sup> to some extent, associated most consistently with obviously symptomatic plants.</p> <p>Certified, and especially non-certified organic seed potato tubers obtained at local garden outlets in Whatcom and Skagit Co. yielded 19 and 54% PVY positive plants, representing unexpected sources of O, NTN, and N-Wi in the region. An education program for home garden sales' outlets is underway.</p>
<p><b>Obj. 7:</b> Develop educational programs on PVY for both seed and commercial potato growers.</p> <ul style="list-style-type: none"> <li>- Project partners collaborated and coordinated various and diverse outreach activities over the 2 years of the project.</li> </ul>	<p>Beissinger Benedict Inglis McMoran</p>	<p><b>2015:</b> Hands-On Workshop on “Aphid Identification” featuring Dr. A. Jensen (NW Potato Research Consortium); 7 attending. Viewing of PVY experimental field plots with state seed potato inspectors; 5 attending. WWA Potato Breakfast; 12 attending. WWA Annual Potato Workshop; 90 attending. Two WSSPC bi-monthly meetings to give project updates; 22 attending.</p> <p><b>2016:</b> General information on PVY presented at field days and meetings; 114 attending. Hands-On Workshop on “PVY Detection” featuring N. Zidak (Montana State Univ.) and L. Ewing (Univ. of Idaho); 41 attending (seed and commercial potato growers, WSDA potato inspectors, area field reps, and tissue culture business owners). New research-based information on PVY presented at Annual WWA Potato Workshop; 93 attending. Potato breakfast; 15 attending. Student tours; 40 attending. Six WSSPC bi-monthly meetings to give project updates; 74 attending. Scientific information on PVY presented at three professional meetings (275+ total attendees).</p>

	<p>One trade industry magazine article published (13,000 circ.); one scientific article in press; one near submission; two extension bulletins in progress. <b>2017:</b> Hands-on demonstration on PVY detection for Myanmar Potato Delegates; 24 attending. Scientific information on PVY at two professional meetings; 100+ attending. Student tours: 36 attending. Workshop for organic potato growers; 15 attending. WWA Annual Potato Workshop: 85 attending. Two WSSPC bi-monthly meetings to give project updates; 13 attending.</p>
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Inglis – Professor and Extension Plant Pathologist at WSU Mount Vernon NWREC. Project PI. Coordinated all work on project objectives. Arranged quarterly meetings with project partners, and led reporting efforts to WSDA. Trained, mentored, and graduated M.S. graduate student (Beissinger). Carried-out numerous greenhouse and screenhouse experiments at WSU Mount Vernon with research technologist (Gundersen). Designed and participated in project outreach.

Beissinger – Graduate student in Inglis’ program at WSU Mount Vernon NWREC. Successfully completed M.S. degree, and thesis, Proactive Approaches for Managing Potato virus Y in Western Washington. Washington State University. 123 p. recently hired as Extension faculty member at Univ. of Connecticut.

Benedict – Educator, WSU Whatcom Co. Extension. Served as Project Co-PI. Collected plant from seed potato fields, tuber sample from garden suppliers, and plant material from winter grow-out tests in Whatcom Co. for PVY testing and strain identification. Coordinated barrier crop on-farm trials, including foliar sampling for PVY and aphid sampling. Met on a regular basis with WSDA personnel, attended WSSPC monthly meetings, and disseminated experimental and on-farm trial results to seed potato producers. Assisted graduate student with Whatcom Co. weed survey and served on the student’s advisory committee.

McMoran – Director, WSU Skagit Co. Extension. Coordinated two potato grower breakfasts, three Western Washington Potato Workshops, and two Potato Research Needs surveys in Skagit Co. in 2015 and 2016. Oversaw PVY organic and commercial potato field survey in Skagit Co. in 2016.

This project did not benefit commodities other than specialty crops.

**GOALS AND OUTCOMES ACHIEVED**

<b>Performance Goals and Expected Measurable Outcomes</b>	<b>Activities Completed</b>
<p><u>Goal #1:</u> Improve understanding of PVY transmission, cultural practices that impact, and options to manage novel strains of PVY in specialty potato varieties.</p> <p><u>Outcome:</u> Reduce PVY incidence in seed and commercial potato fields in Whatcom and Skagit Co., respectively, by 25% by season-end in 2016, and by 50% after 2018.</p>	<p>Beissinger comprehensively interviewed 12 potato growers on production practices and crop losses, and perceptions about PVY detection and winter grow-out testing for baseline information.</p> <p>McMoran assessed changes in grower understanding of PVY through the Annual Potato Research Needs survey in 2015 and 2016, and questionnaires at the Annual WWA Potato Workshop in 2015 and 2016.</p>

	<p>Benedict contrasted PVY incidence and strain presence in Whatcom Co. field surveys in 2015 and 2016 and compared to baseline data acquired in 2012 and 2013.</p> <p>Beissinger et al. established sentinel plots in Whatcom and Skagit Co. to determine if the area has weedy hosts of PVY.</p> <p>Inglis completed experimental field, greenhouse and screenhouse trials on PVY in 2015 and 2016.</p> <p>Benedict established on-farm trials demonstrating aphid barrier crops.</p> <p>McMoran surveyed PVY occurrences in conventional vs. organic commercial fields in Skagit Co. in 2016.</p> <p>Beissinger, Inglis and Benedict assessed seed tuber borne PVY incidence in local garden store survey.</p> <p>Benedict quantified the change in number of seed lots downgraded during winter greenhouse grow-out tests (information publically available from WSDA on seed potato certification data base).</p>
<p><u>Goal #2:</u> Improve the seed potato certification process by identifying approaches to detect novel strains of PVY in winter greenhouse grow-out tests and in summer field settings.</p> <p><u>Outcome:</u> Two new practices integrated into the seed potato certification process to improve effectiveness of PVY detection.</p>	<p>Beissinger and Inglis developed research-based information on which symptoms to expect to see when different potato cultivars are infected with different PVY strains, and identified pitfalls associated with over-reliance of only one anticipated symptom.</p> <p>Inglis et al. organized a Hand's-On Workshop and gave demonstrations on how industry members can utilize ELISA and Agdia Immunostrips® for PVY detection.</p> <p>Beissinger interviewed industry members to discern barriers and bridges to adapting winter grow-out PVY testing under tropical conditions.</p>

The long term expected outcome is a reduction in PVY incidence in seed and commercial potato fields in Whatcom and Skagit Co., respectively, by 50% following 2018. Per the PVY reductions noted in recent greenhouse winter grow-outs and field inspections, these are expected to continue to diminish and track at a steady/comparable rate. Moreover, because future outreach efforts on winter grow-out testing now will be better tailored to address industry concerns and perceptions (e.g. information provided about the logistical steps, cost, and time needed to implement a winter grow-out in Hawaii; proof of reliable potato virus testing laboratories; arranged interactions with and testimonials from seed potato growers in other states where successful adoption has already taken place, etc.), this goal is even more likely to be attained.

Finally, progress has been made in identifying outside sources of PVY; providing direction on the types of PVY symptoms to expect on different potato cultivars; offering new management practices (e.g. seed cutting sanitation, aphid barrier crops); and, in helping growers to accept and utilize testing methods. Consequently, priorities that the team can focus on for future research and dissemination of information that is relevant to PVY in this seed and ware potato production area, have been outlined. These contributions will help the industry better manage PVY and reduce its spread, and prepare for future changes in PVY strain displacement so that introductions, if/when they occur, will not be as disruptive as in years past.

<b>Established Activities and Goals</b>	<b>Actual</b>
M.S. graduate student in plant pathology hired and mentored at WSU Mount Vernon.	Accomplished Fall 2014-2016.
Work plans finalized, supplies, virus-free nuclear seed orders anticipated; visited U of I for training on PVY inoculation and detection, and PVY strain confirmation.	Accomplished Fall 2014.
PVY-infected seed potato plants/seed tubers collected from infected Whatcom Co. fields/potato storages and strain identities confirmed.	Accomplished Fall 2014, but slightly modified to more efficiently collect information.
PVY strains inoculated onto tobacco plants in growth chambers and PVY infected seed tubers increased for 2015 experiments.	Accomplished Winter 2014-2015.
Mechanical transmission experiments set-up at WSU Mount Vernon greenhouse using selected PVY strains in tubers and virus-free nuclear seed stock.	Accomplished Winter 2014-2015, but decision made to repeat in 2016.
Questionnaires for baseline data on project issued at WWA Potato Workshop.	Winter 2015
Factorial experiments on minimizing tuber symptoms through irrigation and vine kill contrasts, and on progressive tuber symptom development and yield, set-up at WSU Mount Vernon.	Accomplished Spring-Summer 2015, but in field rather than screenhouse.
PVY strain x potato cultivar experiments set-up in screenhouse.	Accomplished in Summer 2015, but decision made to repeat in greenhouse in 2016.
Sentinel plots set-up near roadways, ditches and perennial crops, to monitor and recover likely alternative PVY weedy hosts in Whatcom and Skagit Co., seasonally.	Accomplished in Spring-Winter 2015, with plot locations modified for Spring-Fall 2016.
On-farm trial in Whatcom Co. set-up to test/demonstrate replacing potato spray rows with cover crops for the purpose of aphid cleaning sites.	Accomplished Spring-Summer 2015-2016.
Early-generation seed potatoes surveyed in participating Whatcom Co. greenhouses and fields (once per week) and PVY symptoms tracked.	Accomplished Spring-Summer 2015-2016.
GH tests set-up to compare PVY detection approaches based on inoculation times.	Accomplished Fall/Winter 2015.
Year 1 research and survey data summarized for annual report. Nuclear seed tubers ordered for 2016.	Accomplished Winter 2015-2016.
Personal interviews conducted on social science study regarding winter grow-out testing.	Modified to encompass barriers and bridges, and

	accomplished Winter 2015-2016.
Project progress reported at WWA Potato Workshop. New PVY inoculum obtained and increased on tobacco. Hand's-On Workshop with invited speakers held on potato tissue culture techniques and ELISA laboratory testing.	All accomplished Winter 2016.
2016 Whatcom Co. on-farm trials set-up to evaluate aphid barrier crops. 2016 Skagit Co. PVY field survey set-up.	Slightly modified plot/survey plans, but accomplished Spring-Summer in 2015-2016.
2016 greenhouse repeat experiment on seed tuber transmission set-up.	Re-done in Summer 2016 with conclusive results.
2016 PVY strain x potato cultivar experiment repeated at WSU Mount Vernon.	Accomplished in Summer 2016.
2016 factorial experiment on nitrogen application set-up in screenhouse.	Accomplished in Summer 2016 in screenhouse instead of Summer 2015.
Year 1 project results presented at scientific meetings.	Accomplished Summer 2016.
Year 2 research experiments and surveys summarized and analyzed; graduate student thesis completed; final presentations and publications initiated.	Accomplished Fall-Winter 2016-2017.
WWA Potato Workshop again utilized for reporting project progress, gathering information, and disseminating information.	Accomplished Winter 2017.
Scientific and Extension publications reviewed and/or submitted.	Accomplished Spring-Summer 2017.

<b>Expected Outcomes</b>	<b>Measurable</b>	<b>Baseline Data Gathered and Progress Toward Achievement</b>
<u>Outcome:</u> Reduce PVY incidence in seed and commercial potato fields in Whatcom and Skagit Co., respectively, by 25% by season-end in 2016, and by 50% after 2018.		<p>Seed and commercial potato growers interviewed in Whatcom and Skagit Co. in 2015 estimated yield and tuber quality losses due to PVY in recent years, to have been between 10% and 40%.</p> <p>Questionnaires issued at Annual WWA Potato Workshop showed that confidence ratings for identifying foliar symptoms and tuber symptoms, and in using seed cutting sanitation, improved between 2016 and 2017.</p> <p>Since 2014 the number of downgraded seed potato lots has decreased 57% and the number of seed lots that have failed certification has dropped by 70%. These decreases are important because when a seed lot is downgraded, the value of the lot drops considerably. Additionally, when a seed lot fails certification it cannot be sold as certified seed or replanted for seed without significantly dropping its value. Both of these situations have large economic ramifications for seed potato growers and the industry as a whole, so improvements are a plus.</p> <p>Of 183 samples in eight sentinel plots over six sampling seasons, no weedy hosts of PVY were detected.</p>

	<p>Numerous on-farm, field, screenhouse, and greenhouse experimental trials were completed with confirmation of PVY by laboratory ELISA. Tangible results were obtained on aphid transmission mitigation by barrier crops; the relative importance of seedborne vs. current season PVY infection as related to PVY detection success and tuber cracking; impact of cultural practices on PVY occurrence; and, influence of virus strain x potato cultivar interactions on PVY symptom expression (see publication list below).</p> <p>All three PVY strains were transmissible (4.8 % for PVY<sup>O</sup>, 9.5% for PVY<sup>NTN</sup> and PVY<sup>N-Wi</sup>) via infected sap on contaminated knives to nuclear seed tubers during seed cutting as assessed on the next generation plants.</p> <p>PVY transmission via previously infected seed tubers, however, differed by virus strain and potato cultivar as well as time of detection, and ranged from 53.3% to 67% for PVY<sup>O</sup>, 60% for PVY<sup>NTN</sup> and only 8.3% for PVY<sup>N-Wi</sup> at 3 wk post planting, whereas detectability increased to 80-100%, 85%, and 91.7% for the strains, respectively, at 8 wk post planting.</p> <p>The acreage planted to aphid barrier crops in Whatcom Co. in 2014 was 0, compared to 87 acres planted in 2016.</p> <p>PVY occurrences in conventional vs. organic fields in Skagit Co. in 2016 proved to be in only 0.53% of samples acquired from conventional fields, but comprised 5.5% of samples from organic fields (a previously unknown source).</p> <p>Potato samples from local garden stores were positive for PVY; 19% (7/37) plants from certified organic seed potatoes and 54% (7/13) plants from non-certified organic seed potatoes tested positive for PVY, with all three PVY strains acquired.</p> <p>McMoran’s Annual WWA Regional Potato Research Needs survey showed that PVY fell from the No. 1 priority in 2012 to No. 6 in 2016; 73% of the participants said they are now able to identify PVY in the field, 46% reported using Agdia Immunostrips®, and 67% adapted sanitation practices during seed cutting and prefer purchasing PVY-free seed.</p> <p>Seven seed lots were generationally downgraded after 2012 post-harvest testing, whereas seven were downgraded in 2015 and only three in 2016. Lots are downgraded if they pass virus presence thresholds. In 2012, 0.152% of plants in the post-harvest test displayed mosaic symptoms. Since that time, the number reached its highest in 2015 (0.219%) but then dropped back to 0.160% in 2016. The jump was likely due to laboratory mistakes surrounding the 2014 post-harvest test. But, the drop back to 2012 levels when the new PVY strains were first detected in the region, is likely the result of outputs from this project and the outreach efforts that occurred during the project timeline.</p>
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<p><u>Outcome:</u> Integrate two new practices into the seed potato certification process to improve effectiveness of PVY detection.</p>	<p>Inglis et al., developed information on symptoms to expect to see, or not to rely on, when different potato cultivars are infected with different PVY strains.</p> <p>McMoran and Beissinger identified previously un-recognized sources (organic fields and garden stores) of PVY O, NTN, and N-Wi in the region.</p> <p>Inglis et al. held workshops and demonstrations on how industry members can best utilize ELISA and Agdia Immunostrips® for PVY detection. Of 18 who filled-out an evaluation, 11 (61 %) said they were very knowledgeable and 7 (39%) said that they were somewhat knowledgeable about managing PVY as a result of attending; also, 8 (44%) plan moderate changes to their potato farm operations regarding PVY management based on what they learned.</p> <p>Primary reasons for non-adoption of winter grow-out testing under tropical conditions were identified and suggestions for future actions, made.</p>
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## **BENEFICIARIES**

There are three main groups who have benefited from this project and its accomplishments. These include:

- (i) Whatcom Co. seed potato industry members; (ii) Skagit Co. commercial potato industry members and organic potato growers in the region; and, (iii) WSDA seed potato certification personnel, one M.S. Graduate student (graduated and now gainfully employed as an Extension faculty member at the Univ. of Connecticut), several technical staff who were hired to assist with research tasks, and the project PIs who have gained new experiences and expanded collaborations with other PVY researchers in the U.S.

The interviews conducted by the graduate student documented that Skagit Co. commercial potato growers estimated at least 10 % yield losses due to PVY. Given the \$60 M value of the industry, the economic impact could be as high as \$6 M in preventing PVY-related losses in yield and quality in the future.

## **LESSONS LEARNED**

Accurate PVY detection by Agdia Immunostrips® and ELISA are not necessarily accurate on senescing plants; these tools are more effective when used at earlier potato growth stages.

An M.S. graduate student learned about the biology and management of plant viruses, the influence of grower perspectives on agricultural management decisions, appropriate human and plant survey methods, experimental design, maintenance of field and greenhouse experiments, PVY detection methods, statistical analysis of data, appropriate ways to give presentations to stakeholder and scientific audiences, and how to write for both scientific and general audiences. The experience was key to her hire as an Extension faculty member.

Developing small stock seed potato lots that were PVY strain specific for experimental purposes proved more difficult than originally anticipated, and required more time than anticipated to obtain.

Exposing the industry to some of the benefits of conducting winter grow-outs in tropical rather than greenhouse environments, was more challenging than originally anticipated.

Ideas for improved Extension outreach were developed on how to better encourage adoption of winter grow-out testing in a tropical setting (Hawaii), based on grower's existing perceptions and concerns.

PVY field scouting methodology in organic potato fields needs to be refined in the future so that better random sampling schemes and recording of foliar symptoms by each sampled plant, occurs.

PVY strains interact with potato varieties with varying symptom expression, but times at which different symptoms are expressed may be the most informative in distinguishing among strain x cultivar combinations.

Some barrier crops (e.g. soybeans) proved ineffective in attracting aphids and for providing stylet-cleaning sites. Barrier crops are more likely to be utilized for early generation seed lots (nuclear, G1) because of size and the high value of these early generations.

Team members gained familiarity in aphid recognition at the genus level, but also were exposed to the difficulty of accurately sampling and identifying at the aphid species level. Team members learned procedures for PVY inoculum increase and strain segregation, and the management and maintenance of PVY experiments, including strict sanitation methods for aphid mitigation.

The 'Hand's-On PVY Detection Workshop' proved useful for introducing ELISA to industry members, but one-on-one training and private laboratory reputations seemed more effective for actual ELISA adoption by growers.

Weedy plants in sentinel plots proved negative for PVY; however, sampling may need to be done over several growing seasons to acquire more definitive results. Nitrogen applications may influence success/failure of current season PVY infections, but this topic needs further investigation.

Organically-grown seed potato tubers sold at local garden stores and commercial organic potato fields harbored higher than expected levels of PVY and proved to be sources of various recombinant PVY strains, thus, these stakeholder groups need to be educated about the risks of introduction and ways to manage PVY.

PVY detection by ELISA was set-up in Inglis' laboratory and made available to team members and also demonstrated to industry groups; the method is now being adapted by seed potato growers either on site or through testing services provided by out-of-state laboratories.

The symptom of tuber cracking occurred earlier in the growing season than expected in a field experiment and sometimes at a lower incidence than expected in greenhouse experiments. This observation led to a new hypothesis that tuber cracking may be related to seedborne infections in later seed potato generations, and is now being tested.

All activities, goals, and measurable outcomes were achieved.

#### **ADDITIONAL INFORMATION**

Salary matches were as per project budget proposal i.e., there was unrecovered F&A match and in addition there was 20% Inglis salary and benefits, 20% Benedict salary and benefits, 7.5% McMoran salary and benefits, and 20% Gundersen salary and benefits, plus associated F&A at 20% of the salary match. These matches were all mentioned in the original budget justification.

Publications in progress in 2017:

Inglis, D., Beissinger, A., Benedict, C., and McMoran, D. 201x. Managing *Potato virus Y* in western Washington. WSU Extension Manual: (*in progress*).

Beissinger, A., Goldberger, J.R., Benedict, C.A., and Inglis, D.A. 201x. Seed potatoes, virus management, and the non-adoption of an agricultural innovation. *Rural Sociology*: (*in press*).

Beissinger, A., Gundersen, B., and Inglis, D. 201x. Comparison of two detection methods for *Potato virus Y<sup>N-Wi</sup>* at four potato growth stages. *Plant Health Progress* (*in internal review*).

Beissinger, A., Benedict, C., and Inglis, D. 201x. Potential sources of *Potato virus Y* in western Washington. WSU Extension Technical Bulletin (*near completion*).

Inglis, D.A., Gundersen, B., Beissinger, A., and Karasev, A.V. 2017. Reactions of five fresh market potato varieties with three *Potato virus Y* strains. Ann. Mtg. Amer. Phytopath. Soc., S10, San Antonio, TX (*submitted abstract for poster presentation*).

Published articles and abstracts:

Beissinger, A. 2016. Proactive approaches for managing *Potato virus Y* in western Washington. M.S. Thesis, WSU Plant Pathology Department, Pullman, WA (136 pages).

Beissinger, A., Benedict, C.A., Goldberger, J., and Inglis, D.A. 2016. A sociological assessment of *Potato virus Y* in western Washington: Barriers and bridges to adopting new management practices. Ann. Mtg. Amer. Phytopath. Soc., S106:S4.119 Tampa, FL (*abstract and poster presentation*).

Benedict, C., McMoran, D., Inglis, D., and Karasev, A.V. 2015. Tuber symptoms associated with recombinant strains of *Potato virus Y* in specialty potatoes under northwestern Washington growing conditions. Amer. J. of Potato Res. 92: 593-602. *Note*: Fig. 1 of this paper selected for the cover of the October issue.

Inglis, D.A. May/June 2016. 'Cracked' potato tubers and *Potato virus Y*. Invited Potato Association of America Forum Article for Spudman Magazine 54(5): 22 (circulation ~13,000).

Inglis, D.A., Gundersen, B., and Beissinger, A. 2016. Evidence that tuber cracking in potato can be caused by *Potato virus Y*. Ann. Mtg. Pacific Div. Amer. Phytopathol. Soc. 106:S4.199, La Conner, WA (*abstract and poster presentation*).

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## **PROJECT #21**

**Project Title:** Expanding State Agency and Institutional Markets for Specialty Crops

**Partner Organization:** WA State Department of Agriculture

### **PROJECT SUMMARY**

With this Specialty Crop Block Grant, WSDA sought to build on previous SCBG projects to increase access to institutional markets for Washington specialty crop growers. This project aimed to provide resources and guidance to institutional buyers and support specialty crop producers in selling to state facilities, schools, preschools and childcare centers, senior care programs and other institutions, with a focus on state agency food programs. In particular, WSDA planned to examine current purchasing and food promotion policies and practices and identify opportunities to increase purchases and promotion of Washington-grown specialty crops. In addition, WSDA would research best practices for institutional local food purchasing, and develop resources for institutions and state agency food service facilities to support farm to institution efforts.

The purpose of this SCBG-funded project was to leverage current knowledge and resources to advance the successful implementation of Executive Order 13-06 and to expand markets for Washington specialty crop growers. The project allowed WSDA staff to participate in the Department of Enterprise Services-lead process of drafting policy and contracts to meet the standards of Executive Order 13-06 and to work with the Department of Health (DOH) to incorporate resources to support purchases and policies relating to Washington-grown specialty crops into their Implementation Guide for Executive Order 13-06.

The University of Washington Center for Public Health Nutrition (UW CPHN) evaluated the state's implementation of Executive Order 13-06 and this grant additionally allowed WSDA staff to work with UW CPHN to inform their research projects to ensure that included analysis of the "Washington-grown" provision to review purchasing practices, recommend improved practices, and monitor effectiveness of changes in purchasing practices relating to specialty crops.

WSDA's online Farm to School Toolkit (funded in part by a previous SCBG) provides valuable resources and publications, along with a searchable database, which includes recipes, educational information and menu plans, searchable by School, Childcare, or Senior Meal Program (nutritional guidelines). This grant was intended to fund WSDA to retool the web-based toolkit to better meet the needs of a variety of farm to institution stakeholders – including 1) new resources and user-friendly structure for specialty crop growers and processors toolkit sections; and 2) new sections for agency food programs and independently operated state agency-located food service (employee cafeteria) operators. The new toolkit sections will be linked to the DOH Implementation Guide to support the sales and promotion of Washington-grown specialty crops in state agency food service facilities.

Washington specialty crop growers and food processors also continued to report a need for technical assistance on Good Agricultural Practices (GAPs) and other buyer requirements in the rapidly changing regulatory environment, as well as networking opportunities with food processors, distributors, and institutional food buyers to their target markets. Specialty crop growers responding to WSDA's 2012 Farmer survey indicate that at the time they sold mostly into direct to consumer, small retail, and regional markets (53%, 35%, and 29% of sales, respectively), and that only 14% of their sales were in the school market. When asked which markets they were most interested in developing and expanding, growers identified schools and institutions (such as state agency-operated facilities) among their top choices. In

order to enter school and institutional markets, growers indicated they needed support with 1) developing and selling products to schools and institutions (51%); 2) Networking with other growers to share knowledge and create cooperatives (44%); 3) Good Agricultural Practices and Good Handling Practices support (42%); and 4) Food processing and co-packing (36%).

Washington state agency-run facilities (operated by the Department of Social and Health Services and the Department of Corrections) offer a newly emerging market for farm to institutional sales for Washington specialty crop growers. Starting in 2014, Washington state agencies are required to meet health standards in all of their food purchases, and to purchase and promote Washington-grown foods “whenever practical,” per Governor’s Executive Order 13-06. Implementation of the Executive Order began July 1, 2014 with a full adoption deadline of December 31, 2016.

This provided a great opportunity for Washington specialty crop growers to sell products into the food service programs at state agency facilities. However, no guidance existed to assist farms to sell directly to these types of institutions, not information for state facility food buyers, food processors, and distributors who service these institutions to support them in purchasing specialty crops from Washington growers. Most food service operators make purchases based on lowest cost, either through the State Food Contract negotiated by the Department of Enterprise Services (DES) or through broad line distributors, with no incentive to source locally or knowledge of how they can do so.

WSDA has successfully used SCBG-funded projects in the past to support development of K-12 school markets for specialty crop growers by creating an online toolkit of resources and recipes highlighting ways to purchase and serve Washington specialty crops in institutional meal programs, and by providing Good Agricultural Practices education to growers and auditors. With this project, WSDA sought to expand those resources to provide better toolkit functionality and relevance for other institutional food service settings, including state agency facilities, childcare centers, and senior meal programs.

### **PROJECT APPROACH**

WSDA planned to concentrate on the opportunities for expanded markets for specialty crops presented by government procurement via activities relating to the rebidding of the state food. However, due to shifting timeframes for those activities, WSDA adjusted that focus to explore opportunities for buyers and producers through other institutions such as child care and senior care facilities.

#### **State Food Contract and Government Procurement**

The State Food umbrella contract has six sub-contract components: Meat, Bakery, Frozen Chilled Canned & Bulk (“Bulk”), Dairy, Produce, and Food Service Equipment which were due for renewal in sequential order. WSDA focused on incorporating Washington-grown provisions in the Bulk and Produce sub-contracts, as those are the two contracts that pertain to specialty crops.

Early in the grant period, WSDA conducted outreach to state agency staff and buyers to better understand the internal agency food service policies that direct their work, and discuss their priorities, goals, and plans to buy, serve, and promote Washington-grown specialty crops within their facilities, especially within the framework of Executive Order 13-06. WSDA also underwent extensive learning about state contracting procedures, processes, and rules, and built relationships with partners at the Departments of Enterprise Services, Health, Ecology, and Social and Health Services who shared interests and goals for the State Food Contract re-bid process. WSDA used the buyer input to inform its approach to the State Food Contract re-bid process.

WSDA worked collaboratively with the Department of Enterprise Services (DES) to develop contracting language and provisions that met WSDA’s goals to prompt the new vendor(s) to make Washington-grown

specialty crops available on contract, to source-identify products on the contract, to allow for a direct-buy option if the desired Washington-grown product(s) are not available on contract, to mandate periodic reporting of Washington-grown products through the State Food Contract, and to include Washington-grown as a non-cost factor in the bid evaluation process.

The State Food Contract re-bid process was severely behind schedule due to multiple significant delays on the part of the Department of Enterprise Services. This impacted WSDA's planned project activities, requiring WSDA to constantly adapt to changing timelines, new project partners, and expectations. WSDA maintained frequent contact with DES to encourage forward movement and ensure that WSDA was available when needed at critical moments for contract review and other activities. By the end of this project in September 2017, the Bulk contract had only just announced the awarded vendor (Food Services of America or FSA) and the Produce contract has not even begun the re-bid process.

Because of the delay in the contract re-bid process, other subsequent activities originally proposed within this grant were necessarily postponed. However, WSDA continued to seek out opportunities to meet with state agency food service managers, and small business and government contracting service providers to develop relationships and refine WSDA's understanding of various aspects of participating in a government contract, from both the farmers and buyers perspectives.

Whenever possible, WSDA educated state agency buyers about the importance and benefits of buying and serving Washington-grown specialty crop items. WSDA fostered an awareness of ways in which the anticipated changes in the state food contract would allow purchasers to access Washington-grown specialty crops; their role in advocating for local food access; and introduced and familiarized them with the WSDA's available tools and resources. In sum, WSDA reached 10 DSHS facilities, and the DOC Correctional Industries' food manufacturing facility at workshops, and reached 2 facilities in follow-up meetings and technical assistance. Key outreach events and meetings include:

- Food Service of America Seattle Food Show in 2015, 2016, and 2017
- DES Vendor Training and Trade Show in 2015
- DES Business Partnership Forum in 2016 and 2017
- Meeting with DES Business Diversity Initiatives Manager whose goal is to help certified small and micro businesses, women- and minority- owned businesses, and veteran-owned businesses gain access to DES in 2017
- Meeting with the Washington State Procurement Technical Assistance Center, a non-profit dedicated to supporting small and local businesses compete for government contracts in 2017;
- Department of Health-led culinary trainings with state agency food service workers and DSB-supported public employee cafeteria operators in 2016;
- Bi-monthly Healthy Nutrition Guidelines Implementation Workgroup meetings and annual review session;
- One-on-one meetings with agency staff, including procurement staff and managers, food service directors, and others at the Departments of Corrections, Social and Health Services, Ecology, and Health in 2015, 2016, and 2017.

#### Farm to Early Care and Education (ECE)

Farm to Early Care and Education emerged as a particular institutional market of interest during this project. WSDA hosted two successful workshop series in March and August of 2017 in conjunction with the Department of Early Learning to train ECE professionals in incorporating education about healthy specialty crops into child care curricula and purchasing practices. The six workshops were located in Spokane, Yakima, Tacoma, Mount Vernon, Seattle, and Vancouver and reached over 80 Washington ECE professionals. WSDA contracted trainers from the Mount Hood Community College Head Start program in Oregon to train workshop attendees on the Harvest for Healthy Kids curriculum and activity kits. The

WSDA Project Coordinator provided training on local fruit and vegetable procurement options, local food compliance within the Child and Adult Care Food Program, and planning and promotional materials, tools, and resources. Workshop attendees received high quality printed copies of the Harvest for Healthy Kids curriculum kits, Washington Harvest posters, and regional resource packets. Seven ECE programs asked for and received follow-up support or technical assistance from WSDA.

The Project Coordinator presented on Farm to ECE at two statewide conferences: the Tribal Early Care and Education Conference in August 2016, and the Nutrition First (WIC Association of Washington) Conference in May 2017.

Under the direction of the Value Chains Development and Local Buying Mission projects (both SCBG-funded) and a SNAP-Ed project, the WSDA Regional Markets team convened a number of meetings and events with institutional buyers of many types across the state. In Yakima, Spokane and the Okanogan Valley, the Project Coordinator worked in collaboration with the other project leads to invite childcare centers into the local supply chain conversation, and educate and promote them as potential buyers to specialty crop farmers in their regions.

The WSDA Regional Markets Program serves as the Washington state lead for the National Farm to School Network's (NFSN). NFSN has a growing emphasis on Farm to ECE, so during the project period WSDA has developed staff understanding and capacity with the challenges, opportunities, programs and regulations specific to ECE settings. WSDA staff studied the Child and Adult Care Food Program, including meal patterning, procurement guidance, and reimbursement requirements; attended multiple events such as NFSN webinars, calls, and report releases; and used feedback from DEL and ECE programs to develop resources useful to ECE professionals. As a result, WSDA will be able to continue to provide some outreach and support to ECE programs going forward.

WSDA reached 81 ECE professionals at workshops, 7 ECE programs in follow-up meetings and technical assistance, and an estimated 250 ECE professionals in presentations at conferences.

#### Farm to Senior Care

To better understand the opportunities for specialty crop producers to sell to institutions serving seniors, WSDA worked with staff at the Washington State University (WSU) School of Hospitality Business Management and the WSU Center for Behavioral Business Research (CBBR) to develop and conduct a survey of all 763 assisted living facilities and nursing homes licensed in Washington State. The senior meal survey aligned with WSDA's biennial surveys of farms, school districts, and food processors, but was specifically tailored to food service providers in certain residential senior care settings. The purpose was to develop a baseline dataset of participation and interest in farm to senior care work, and conduct a needs assessment of responding facilities.

Due to the fact that senior care facilities only provide mailing addresses for contact information, the initial online survey had to be adapted to paper format, and disseminated via mail. The pre-survey announcement postcard, survey, and post-survey reminder postcard were mailed out in succession in July 2017. The response rate was very low (approximately 30 facilities) so WSU CBBR conducted additional phone outreach to senior care facilities in August 2017, which yielded mixed results. Though the response rate was not robust, WSU summarized the results and drew some conclusions from the facilities' feedback. (The full survey analysis report is attached at the end of this grant report.)

#### Healthy Nutrition Guidelines Implementation

The Healthy Nutrition Guidelines are part of the Executive Order 13-06 aimed at increasing the availability of food and beverage options available in state agencies. The guidelines include the directive for executive

agencies to purchase and promote Washington-grown foods “whenever practical.” WSDA participated in the bi-monthly Healthy Nutrition Guidelines implementation workgroup meetings and annual review session facilitated by the state’s lead agency, the Department of Health. This workgroup allowed WSDA to communicate directly with Department of Services for the Blind (DSB)-supported cafeteria operators, state agency procurement and wellness committee staff, and operators of vending machines in state facilities, as well as the University of Washington Center for Public Health Nutrition, which conducted the evaluation of the Healthy Nutrition Guidelines across state facilities.

WSDA reached 8 DSB-supported cafeterias at workshops, and reached 2 cafeterias in follow-up meetings and technical assistance.

#### Other Farm to Institution Projects

WSDA sought opportunities for collaboration in the field of Farm to Institution work. As mentioned above, the Project Coordinator worked with other WSDA Regional Markets staff focused on SNAP-Ed projects, Value Chains Development, and Local Buying Missions to bring childcare centers and other institutional buyers to the regional food systems discussions in Yakima, Spokane, King County, Okanogan County, and other areas. The Project Coordinator also participated in the King County Local Institutional Food Team (LIFT) working group (a cross-sectoral collaboration to encourage public and private institutions to purchase from local producers) and the King County Sodium Reduction Project focused on schools and emergency food systems. When possible, project staff attended events and conferences to represent WSDA and its farm to institution work, and to network and learn from others. Events of note include:

- Washington State Nutrition Association annual conference in 2015 and 2016
  - Tilth Producers conference in 2015 and 2016
  - Women In Sustainable Agriculture conference in 2016
  - WSU - Tilth Educational Farm Walks in 2015, 2016, and 2017
  - Pierce County Farm Forum in 2016
  - Closing the Hunger Gap conference in 2017
- 
- **Washington State Department of Enterprise Services (DES)** is responsible for state food contracts and state purchasing policy. DES has been an engaged partner in identifying, drafting, and incorporating language into the new contract and bid requests that encourages bidders/vendors to identify and source Washington-grown products, and allows for a direct-buy option if the desired product(s) are available on contract.
  - **Washington State Department of Health (DOH)** has been a close partner in strategizing implementation of the Washington-grown foods aspect of Executive Order 13-06 with both state agency buyers and public employee cafeteria operators. DOH continues to assist WSDA with coordinating training opportunities for state agency buyers, and providing strategic support on the State Food Contract rebid process. Meetings and connections to Department of Health have been critical to understanding the goals and expectations of the Executive Order and combine efforts to support buyers in menu-planning, and sourcing, serving, and promoting local produce.
  - **Washington State Department of Services for the Blind (DSB)** has worked with WSDA to create opportunities to engage operators of state employee cafeterias and vending machines and understanding the concerns of those business owners, provide resources and training to operators, and provide technical assistance as requested.
  - **University of Washington Center for Public Health Nutrition (UW CPHN)** has shared research findings and experience with the WSDA and DOH to guide outreach to state employee cafeteria and vending machine operators. The UW CPHN’s evaluation of state facilities provides additional information to inform WSDA’s outreach efforts with state agency facility food service managers and procurement specialists.

- **Washington State Department of Early Learning (DEL)** has worked with WSDA on developing Farm to Early Care and Education outreach efforts, including training curriculum for preschool and childcare providers centered on the Harvest for Healthy Kids activity kits, and incorporating Washington-grown foods in classroom meals and learning activities.
- **Washington State University (WSU) School of Hospitality Business Management and Center for Behavioral Business Research** are contracted partners in designing and distributing a survey of residential senior care facilities regarding their interest and participation in farm to table efforts within their meal program.

State Food Contract rebid efforts were limited to specialty crop food items, primarily in the Produce sub-contract and to some extent the Bulk sub-contract. Outreach efforts with state agencies, public employee cafeteria operators, childcare and senior care programs were exclusively focused on purchasing, preparing, and promoting Washington-grown specialty crops.

**GOALS AND OUTCOMES ACHIEVED**

A comparison of the activities and goals established for the project with the actual accomplishments are listed in the table below.

Note: The table below reflects the updated workplan per the K1510 Amendment Memorandum of Agreement signed 4/5/17, for project activities to be conducted between January 1, 2017 and September 30 2017. Preceding this timeframe, the project was largely inactive due to delays in the DES State Food Contract re-bid process and this grant’s Project Coordinator role being unfilled for an extended period.

<b>Project Activity</b>	<b>Actual activities accomplished</b>
Participate in State Food Contract rebid process for Bulk and Fresh Produce sub-contracts; see process through drafting, review, bidding, evaluation, and awarding contracts	WSDA stayed engaged with DES in the re-bid process throughout the entire grant period; encouraged forward movement on the re-bid; provided subject matter expertise and proposed draft language for source-identification requirements, definitions and reporting standards for the Bulk contract and bid request documents; and participated in several review processes as requested by both DES and WSDA. Of the two sub-contracts of interest, only one (Bulk) was successfully completed within the grant timeframe. The Produce contract is now not expected to be put up for re-bid until 2018 at the earliest. However, through developing relationships with key DES staff, as well as allied partners at DOH and ECY, staff at those agencies are prepared to advocate for the inclusion of WSDA’s draft language in the future Produce contract, should WSDA not have capacity to participate in the re-bid process when the time comes
Provide training and education to state agency buyers as State Food Contract process progresses; develop training and guidance documents as necessary	Not completed, as the State Food Contract rebid process was significantly delayed
Develop and disseminate senior meals survey to residential senior care facilities	Completed

Analyze senior meals survey results and report on findings	Completed
Conduct outreach to childcare and preschool programs in conjunction with SNAP-Ed work in 3 regions; provide education and follow-up technical assistance as needed	Farm to ECE outreach efforts largely focused on hosting Farm to ECE workshops in 6 locations across the state in March and August 2017, which reached a total of 81 ECE professionals. Additional strategic outreach in targeted regions to align with other Regional markets projects including the Spokane and Okanogan area
Seek opportunities for networking, relationship-building, and learning by attending and participating in webinars, workshops, conferences, and other events when possible	Completed Attended numerous conferences and events including: WSNA Annual Conference, Tribal Early Learning Conference, Tilth Farm Walks, FSA Food Show, Tilth Conference, Local Institutional Food Team meetings (King County), King County Sodium Reduction meetings, Healthy Nutrition Guidelines Implementation Workgroup, Women In Sustainable Agriculture Conference, Vancouver Food Summit, Pierce County Farm Forum, Nutrition First Spring Conference, DES Business Partnership Forum, Closing the Hunger Gap Conference, WSDA Bridging the GAPS and Local Buying Mission events, approximately 6 webinars, and other meetings
Provide guidance and technical assistance to institutional purchasers in the public sector, as requested and as available	Completed; had one-on-one meetings or provided technical assistance to 2 state facility foodservice operators, 2 DSB-supported cafeteria operators, and 7 ECE programs
End-of-project wrap-up and transition planning	Completed
Reporting	Completed

All Expected Measureable Outcomes were intended to be assessed within the grant period.

**Goal 1: Increase state agency purchases of Washington-grown specialty crops.**

**Updated Target 1 (per K1510 Amendment):** At least 5 state agency foodservice facilities will understand the importance of purchasing and promoting Washington grown specialty crops in their facilities; be familiar with the tools and resources WSDA offers to aid in planning, purchasing, preparing, and promoting local foods; and understand the anticipated changes to the State Food Contract that will allow them to identify and purchase Washington grown foods.

**Benchmark 1:** The UW Center for Public Health Nutrition’s (UW CPHN) surveys of state agency facilities and public employee cafeterias will be used establish baseline data in those facilities.

**Outcome 1 to date:** Eleven state agency-run facilities received training by the Project Coordinator on the topics of the importance of purchasing and promoting Washington grown specialty crops in their facilities; the array of tools and resources WSDA offers to aid in planning, purchasing, preparing, and promoting local foods; and the anticipated changes to the State Food Contract that will allow them to identify and purchase Washington grown foods.

Department of Social and Health Services	Location
Eastern State Hospital	Medical Lake (Spokane Co.)

Rainier School	Buckley (Pierce Co.)
Lakeland Village	Medical Lake (Spokane Co.)
Ridgeview Community Facility	Yakima (Yakima Co.)
Canyon View Community Facility	East Wenatchee (Douglas Co.)
Twin Rivers Community Facility	Richland (Benton Co.)
Woodinville Community Facility	Kirkland (King Co.)
Oakridge State Community Facility	Lakewood (Pierce Co.)
Naselle Youth Camp	Naselle (Pacific Co.)
Special Commitment Center	McNeil Island (Pierce Co.)

<b>Department of Corrections</b>	
Correctional Industries	Correctional Industries prepares food at two facilities (Airway Heights Correctional Center in Spokane Co. and Monroe Correctional Center in Snohomish Co.), and distributes food to all 13 DOC facilities

**Original Target 1:** At least 5 state agency foodservice facilities serving and promoting Washington-grown specialty crop

**Outcome for Original Target 1:** At least 19 state agency foodservice facilities and 4 employee cafeterias reported purchasing Washington-grown foods in 2016.

Thirteen (out of nineteen) Department of Social and Health Services (DSHS) facilities and 10 (out of thirteen) Department of Corrections (DOC) facilities in Washington responded to the UW CPHN’s survey on their implementation of the state’s Healthy Nutrition Guidelines. All data is self-reported, and not externally validated.

- Ten DSHS facilities reported purchasing Washington-grown foods through a distributor in 2016, with one additional facility indicating interest in purchasing Washington-grown products through this channel. Five DSHS facilities responded that they do not currently, but are interested in purchasing Washington-grown foods directly from farmers, or through a food hub or farmer co-op.
- Nine DOC facilities reported purchasing Washington-grown food through a distributor in 2016, six facilities reported purchasing directly from farmers, and two facilities reported purchasing from a food hub or farmer co-op.
- Four of nine employee cafeterias observed by UW CPHN offered Washington-grown products in 2016, and two cafeterias promoted or marketed these products. This number increased from the 2014 baseline observation when only one employee cafeteria offered Washington-grown products, and none marketed or promoted locally-grown foods.

**Goal 2: Increase processor purchases of Washington-grown specialty crops.**

**Target 2:** An increase of at least 2% in number of food processors reporting sourcing Washington-grown specialty crops.

**Benchmark 2:** WSDA 2012 and 2014 survey data.

**Outcome 2:** In 2016, 73% of responding Washington food processors said they purchased some amount of Washington-grown products from a wholesaler / distributor, up from 60% and 58% of respondents in 2014 and 2012, respectively. However, the percent of Washington food processors reported they sourced some amount of Washington-grown products direct from a farmer or from their own farms decreased over time (see table below). For the first time in 2016, WSDA asked if any food processors sourced Washington-grown products from a food hub or farmer co-op, and 11% of responding processors reported they did.

The WSDA food processor survey does not record the number of food processors who do/do not source Washington-grown specialty crops in a given year, but instead captures what percent of total raw product producers buy that is Washington-grown and sourced from either the processor’s own farm; direct from farmers; through a food hub; or through a wholesaler/distributor. Because survey participants varied from year-to-year, and many respondents skipped survey questions, the percentages below are not statistically sound results, and should be interpreted as illustrative.

<b>Processor source for <u>Washington-grown</u> products</b>	<b>2012</b>	<b>2014</b>	<b>2016</b>
From own farm	57%	46%	42%
Directly from growers / producers	64%	59%	55%
From food hub or grower cooperative	n/a	n/a	11%
Through wholesalers / distributors	58%	60%	73%

**Goal 3: Increase numbers of farms and food processors selling specialty crops to institutional markets.**

**Target 3:** An increase of at least 2% of growers and food processors reporting selling specialty crop products to institutions, either as new or expanded markets.

**Benchmark 3:** WSDA 2012 and 2014 survey data.

**Outcome 3:** The data is inconclusive, and it is not possible to accurately report on the outcome of this goal. WSDA edits and updates its surveys for farms, school districts, and processors before administering them each biennium. The purpose is to ensure that the survey results provide the most useful and informative data possible, and to capture information about emerging trends. While this produces more accurate and useful results in a single year, it can make it difficult to draw conclusions over multiple years due to changed questions, phrasing, or categories.

For example, in the 2012 and 2014 Processor surveys, emergency food providers (food banks) were grouped with other institutions; but understanding this as an emerging market, WSDA made emergency food providers a stand-alone category in the 2016 survey. WSDA made this same change in the Farm survey in 2014.

<b>Processors reporting direct sales to ...</b>	<b>2012</b>	<b>2014</b>	<b>2016</b>
Schools	*	9%	8%
Institutions	*	11%	11%
Emergency food providers	*	*	9%

<b>Farms reporting direct sales to ...</b>	<b>2012</b>	<b>2014</b>	<b>2016</b>
Schools	14%	16%	8%
Institutions	18%	6%	7%
Emergency food providers	*	13%	14%

**Beneficiaries**

This project tackled farm to institution purchasing in several institutional settings, with unique beneficiaries in each setting:

- State Food Contract and outreach to state agency-operated facilities: Primary beneficiaries are incarcerated individuals housed at correctional centers operated by the Washington State Department of Corrections, and patients in need of supportive and/or medical housing at facilities operated by the Washington State Department of Social and Health Services. To a lesser extent, employees and visitors to these facilities may benefit from improved local food options at the foodservice sites.
- Healthy Nutrition Guidelines work with cafeteria operators: Primary beneficiaries are Washington state employees who purchase food at employee cafeterias, micro-markets, and vending machines located in state agency buildings.
- Farm to Early Care and Education: Primary beneficiaries are young children in childcare and early education programs across Washington, with particular emphasis on programs serving low-income families (such as Head Start and Early Head Start). To a lesser extent, teachers and families connected to these programs may have increased access to fresh, healthy Washington-grown fruits and vegetables.
- Farm to Senior Care (Note: WSDA did not work directly with residential senior care facilities in this project, but rather conducted research to inform future outreach efforts by WSDA and/or WSU, so answer is long-range): Elderly adults and adults with disabilities living in assisted living facilities and nursing facilities in Washington; possible additional beneficiaries include other residential care facility settings such as adult family homes, and non-residential senior feeding programs such as congregant meal programs and delivery programs like Meals on Wheels.

In general, those fed in institutional settings tend to be more vulnerable populations with limited access to fresh, healthy, local foods. Therefore, increasing purchases of Washington-grown foods by institutions improves food equity.

There are multiple tiers of beneficiaries of this project. For example, WSDA provided information and training to approximately three dozen foodservice and administrative staff members representing 10 DSHS facilities and the DOC's Correctional Industries food manufacturing facility (which produces the majority of main courses and sundry food items served at all DOC correctional centers). These 11 facilities provide meals to over 17,000 Washingtonians each day (not counting employees and visitors who may also eat meals at the facilities' foodservice sites); at three meals and a snack per day per person, this sums to roughly 60,000 meals per day. In addition to providing direct outreach to facilities, WSDA endeavored throughout the course of this project to update the State Food Contract, making it possible for buyers to identify and purchase source-identified Washington-grown specialty crops on contract, or have a means to purchase Washington-grown foods from other sources via the direct-buy option. DSHS and DOC are the single largest purchasers on the State Food Contract, but are far from the only purchasers. Unfortunately, while it is known what entities are eligible to purchase off the State Food Contract, there is no available comprehensive list of historic or current purchasers; therefore, the full extent (by potential number of meals served/people reached) of updating the contract language is unknown. WSDA worked on updating language on two sub-contracts within the Umbrella State Food Contract: the Frozen, Chilled, Canned, and Bulk Food Items ("Bulk") and Fresh Produce ("Produce") contracts, as those are the two pertaining to specialty crops. The Bulk contract is valued at an estimated annual worth of \$18 million (as of 10/1/17) and the Produce contract is valued at an estimated annual worth of \$16.9 million (as of 3/21/13). At this time, it is not possible to calculate the percentage of either contract that could potentially be or is actually dedicated to Washington-grown specialty crops.

WSDA conducted training with the operators of 8 employee cafeterias run by operators supported by the Department of Services for the Blind through the Business Enterprise Program, and worked alongside some

of those same cafeteria operators in the Healthy Nutrition Guidelines implementation workgroup. Cafeteria operators did not share information related to the number of meals sold/customers served, or food budgets. WSDA provided hands-on training and resources to 81 Early Care and Education teachers, foodservice managers, and administrators at the Harvest for Healthy Kids workshops, and reached an additional 250 ECE professionals through presentations at conferences. WSDA did not collect information on the number of children served in the represented ECE programs, or their food expenditures. Furthermore, the first three Harvest for Healthy Kids events were advertised as train-the-trainer workshops, with the intention that attendees would then provide additional trainings to other ECE programs, but WSDA found that while attendees training other people within their own organizations, few trained people at other ECE programs.

WSDA, in partnership with WSU, mailed paper surveys to all 763 assisted living facilities and nursing facilities in Washington State, and 29 surveys were completed and returned. Follow-up phone calls yielded 10 additional, though partial, responses. The survey served a dual purpose of soliciting feedback and educating residential senior care facilities about the benefits and opportunities of purchasing and serving Washington-grown produce in their meals and the resources WSDA offers to support their efforts; therefore, while the response rate was low, a larger number of care facilities received some education about local foods. Combined, these 763 facilities provide care to over 53,000 elderly adults and adults with special needs.

The tables below detail the direct connections WSDA had with various stakeholder groups, and in the case of DSHS and DOC facilities, the number of individuals potentially impacted by WSDA’s work:

11	DSHS/DOC institutions reached at workshops
2	DSHS/DOC institutions reached via 1:1 meetings or technical assistance
8	DSB-supported cafeterias reached at workshops
2	DSB-supported cafeterias reached via 1:1 meetings or technical assistance
81	ECE professionals reached at HHK workshops
250	ECE professionals reached at conferences
7	ECE programs reached with 1:1 meetings or technical assistance

<b>Department of Social and Health Services</b>	<b>Location</b>	<b>Beds</b>
Eastern State Hospital	Medical Lake (Spokane Co.)	287
Rainier School	Buckley (Pierce Co.)	450
Lakeland Village	Medical Lake (Spokane Co.)	238
Ridgeview Community Facility	Yakima (Yakima Co.)	11
Canyon View Community Facility	East Wenatchee (Douglas Co.)	16
Twin Rivers Community Facility	Richland (Benton Co.)	16
Woodinville Community Facility	Kirkland (King Co.)	16
Oakridge State Community Facility	Lakewood (Pierce Co.)	16
Naselle Youth Camp	Naselle (Pacific Co.)	81
Special Commitment Center	McNeil Island (Pierce Co.)	345

<b>Department of Corrections</b>		
Correctional Industries	CI prepares food at two facilities (Airway Heights CC in Spokane Co. and Monroe CC in Snohomish Co.), and distributes food to all 12 DOC facilities	16,027 (All DOC facilities)

## Lessons Learned

As a result of this project, WSDA staff developed new and extensive expertise on:

- State agency food procurement policies and practices
- State contracting processes, and contracting language to encourage source-identification
- The Child and Adult Food Program, which provides meal plan recommendations and/or requirements for all child and adult feeding programs, and provides reimbursement opportunities for some qualifying programs
- Farm to Early Care and Education, which adapts Farm to School concepts for a younger audience with unique approaches to education, activities, and purchasing, preparing, and consuming local foods

This knowledge is invaluable to the WSDA Regional Markets team as it continues striving to provide useful information, tools, and resources to both Washington farmers and buyers in a variety of institutional settings.

The original workplan anticipated that the State Food Contract re-bid process would be completed by June 2015, for at least for the two sub-contracts of interest (Bulk and Produce). However, by the end of this project in September of 2017, the Bulk contract had only just announced the awarded vendor (Food Services of America or FSA) and the Produce contract has not even begun the re-bid process. (DES reported in August 2017 that the existing Produce contract “will most likely be extended” and there is currently no set timeframe for the re-bid process on this contract.) The shift in the timeline is due to multiple significant delays on the part of the Department of Enterprise Services as a result of high staff turnover, diverting contracts into pilot projects, and other causes. The grant activities planned to succeed the contract re-bid process included developing new resources, coordinating workshops and networking sessions around the state, and assisting state agencies in adoption of the Washington-grown provision of Executive Order. Due to the postponement of the re-bid process, WSDA could not engage in the subsequent activities, and WSDA had to creatively adapt to constantly changing timelines and expectations and engaging in work that furthered the overall project goal of expanding Farm to Institution networks, with a special focus on institutions partially or fully funded by public funds. WSDA developed a new workplan that focused on Farm to Institution projects outside the realm of state agency-operated foodservice facilities and employee cafeterias, instead focusing on Farm to Early Care and Education (with a special focus on ECE programs that rely on Child and Adult Food Program (CACFP) funds for school meals) and Farm to Senior Care research for facilities that may care for Medicaid clients.

This project was largely dependent on the work of others at other state agencies, and significant delays on the part of those partners prevented WSDA from completing this project as originally planned and written. One insight for future grant projects is to design projects where key aspects of the work are within the purview of WSDA staff to prevent delays and setbacks.

Finally, in becoming familiar with the State Food Contract is determining which facilities can and do purchase off of the State Food Contract. WSDA originally learned that all state agencies *must* purchase off the State Food Contract, and other public entities *can* use the State Food Contract – specifically: state boards, state commissions, higher education institutions, offices of elected officials, local government agencies (such as school districts, hospital districts, and ports), federal agencies, Washington State tribal entities, and public benefit non-profit organizations. However, a comprehensive list of which entities or individual institutions do purchase food through the State Food Contract was not available, though DES reported that DSHS (and its 19 residential facilities across the state) was the single largest buyer on the State Food Contract. However, in conversations with DSHS procurement support staff, WSDA learned that two of the largest DSHS facilities were transitioning away from purchasing food through the State Food Contract and towards purchasing food through the Premier purchasing organization (a hospital-oriented

buying group) due to lower food costs and higher rebates on bundling purchases (though it remains unclear under what guidelines state agency-run facilities can move off the State Food Contract). The other 17 DSHS facilities are eligible to switch to purchasing food through Premier as well, but have no current plans to do so. In losing two of its largest purchasing institutions, DES revised the estimated value of the Bulk contract down from \$22 million per year to \$18 million per year. This also necessarily changes WSDA's future strategy for increasing the purchasing and usage of Washington-grown products in state-agency run facilities, as now apparently not all state facilities can be reached through the State Food Contract.

The delay in the re-bid process for the State Food Contract was unexpected and caused a revision in the Expected Measurable Outcomes. The effect and outcomes are discussed in the Goals and Outcomes Achieved section of this report.

### **Additional Information**

This project proposed a total match of \$54,259 over the life of the grant. The total matching donations utilized over the life of the grant were: **\$181,400**.

In fiscal year 2017, matching donations came from the following sources:

- **Washington State Department of Health:** \$8,659 in wages and benefits for work related to the Healthy Nutrition Guidelines implementation, including outreach to and collaboration with state facility food service managers, and public employee cafeteria operators.
- **Washington State University School of Hospitality Business Management and Center for Behavioral Business Research:** \$13,000 in wages and benefits for work related to the developing, disseminating, and analyzing results of the survey of residential senior care facilities across Washington State.
- **Washington State Department of Early Learning:** \$8,880 in wages and benefits for work related to Farm to Early Care and Education outreach and trainings.
- **Washington State Department of Agriculture:** \$14,713 in indirects, representing 17% on total salaries and benefits paid in FY 2017

Matching donations utilized in FYs 2015 and 2016 totaled \$136,148.

### **Farm to ECE workshop publicity**

- WSDA Ag Brief: Farm to Kids. April 17, 2017  
Blog post: <https://wastatedeptag.blogspot.com/2017/04/FarmToKids.html>
- Washington Ag Network: WSDA Expanding Farm to School to Preschool and Child Care. May 3, 2017  
Article and podcast: <http://washingtonagnetwork.com/2017/05/03/wda-expanding-farm-school-preschool-child-care/>

### **Farm to Senior Care Survey Report**

- Report of Survey Data Collected to Examine Farm to Table Opportunities for Assisted Living Facilities and Nursing Homes – Summary report by Washington State University Center for Behavioral Business Research (August 2017)  
Report: Attached below

### **Healthy Nutrition Guidelines (Executive Order 13-06) Implementation Evaluation**

- Implementation of Washington State’s Healthy Nutrition Guidelines Under Executive Order 13-06 – Evaluation report by University of Washington Center for Public Health Nutrition (September 2016)

Report: <https://www.doh.wa.gov/Portals/1/Documents/Pubs/340-NonDOH-HealthyNutritionGuidelinesImplementationReport.pdf>

**CONTACT INFORMATION**

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**See Attachment E- 2014 SCBGP-FB**

## **PROJECT #22**

**Project Title:** Managing Little Cherry Disease

**Partner Organization:** Washington State University – Elizabeth Beers

### **PROJECT SUMMARY**

Little cherry disease (LCD) is a serious virus-caused disease of sweet cherry, which has been present at low levels in Washington (WA) State since the 1940s, but became increasingly evident as a state-wide problem during 2011-2013. The disease is incurable, and initially results in unpicked limbs, then tree or orchard removal. Trees with LCD produce cherries of small size and poor flavor, which make the fruit unmarketable. Apple mealybug is the documented vector of a causal pathogen of LCD, little cherry virus 2 (LChV2). This mealybug was recently recorded for the first time on sweet cherry in WA. In 2012, the grape mealybug, a well-established pest of sweet cherry in WA, was shown for the first time to also be a capable vector of LChV2. The absence of recommendations for controlling these virus vectors in WA sweet cherry makes management of LChV2 difficult. Mealybugs are notoriously difficult to kill because they are covered with waxy filaments, and spend most of their life cycle protected in crevices in bark or leaf axils. These life history characteristics make them extremely difficult to reach with foliar insecticides. The first instar (crawlers), the stage most vulnerable to insecticides, emerge over a prolonged time period making multiple applications necessary. This project seeks to address these issues by evaluating chemical control options for LCD vectors. Insecticide options include soil drench and foliar applied systemic insecticides (all registered on cherry) and an insect growth regulator for control of various mealybug life stages.

Correctly diagnosing LCD is challenging because symptoms may take years to appear and can vary depending on the weather. Molecular assays, currently the only tools available to reliably detect LCD in plant material, are too expensive to be cost effective for large-scale testing (\$80/tree), therefore, growers typically only test symptomatic trees or a subset of symptomatic trees. Management decisions based on the results of these assays range from the removal of only symptomatic trees to the removal of an entire orchard. The first scenario leaves potentially infected, non-symptomatic trees nearby to serve as a disease reservoir, while the second scenario may be unnecessarily removing healthy trees resulting in a replanted orchard and the associated economic loss. More information regarding the presence and movement of LCD through orchards is necessary to developing a comprehensive management plan. This project also investigated the likelihood of healthy trees becoming infected based on the proximity to previously infected trees or orchard areas and the probability of non-symptomatic trees serving as virus reservoirs.

Undetected LChV2-infected trees allowed to remain in an orchard will serve as a disease reservoir and enable spread of LCD to nearby trees or orchards over time. This disease imposes an economic penalty for the cherry grower when small, poorly colored fruit are either left unpicked or sorted out in the warehouse. Therefore, reducing the spread of LCD by controlling mealybugs, the known vectors of LChV2, and establishing sampling strategies that will optimize finding newly infected trees is important and timely.

This project was not built on a previously funded SCBGP project.

### **PROJECT APPROACH**

**1. Establish colonies of apple and grape mealybug for lab bioassays to test chemical controls.** Grape mealybug (GMB) colonies were maintained in vented plastic containers on sprouted potatoes in a growth room (83 °F, 14:10 (L:D), and 34% relative humidity). An apple mealybug (AMB) colony was initiated, but was eventually killed by a parasitoid that was brought in from the field via parasitized females. The

emerged parasitoid wasps were identified as *Anagyrus schoenherri* (Westwood, 1837). This identification is the first Nearctic find of this European species. A manuscript entitled, “Discovery of *Anagyrus schoenherri* (Westwood, 1837) (Hymenoptera: Encyrtidae) in the Nearctic region, a parasitoid of the apple mealybug *Phenacoccus aceris* (Signoret, 1875) in Washington State, with notes on the host,” is in review for publication in *Pan-Pacific Entomologist*.

**2. Complete lab bioassays using various stages of apple and grape mealybug.** A greenhouse experiment was conducted on 1-yr-old, potted ‘Bing’ trees on Mazzard rootstock to determine the effects of foliar and soil-applied systemic insecticides on GMB. Mealybugs from colonies were transferred to greenhouse trees and given 7 days to become established, and then treated with Admire Pro and Aza-Direct as soil drenches. Ultor, a foliar-systemic compound and Centaur, an insect growth regular, were both applied to the point of drip with a backpack sprayer, using an equivalent insecticide concentration of 100 gpa. Counts of GMB crawlers (0.1-0.5 mm in length), nymphs (0.6-2 mm in length), and adults (>2 mm in length) were made 1 day pre-treatment, and 18, 27, 35, and 56 days after treatments were applied. The average number of crawlers, nymphs, adults, and total GMB was calculated for each treatment for each sampling date. Statistical analysis was done by using the difference between the pre- and the post-treatment means for a given date. Data were analyzed using the Statistical Analysis System (SAS 2016). PROC MIXED was used to conduct an analysis of variance, and treatment means were separated using a pairwise comparison of the least-squares means. Average crawler and total mealybug differences were similar for all treatments and all dates (data not shown). Nymph numbers were reduced to zero on Centaur-treated plants at 18 days post-treatment (Figure 1) and close to zero on trees treated with Admire Pro and Aza-Direct at 27 days. Admire Pro, Aza-Direct, and Centaur reduced adult numbers to zero 18 days after application. Ultor did not significantly reduce GMB numbers for any life stage; however the addition of an adjuvant (recommended on the label), might have increased the effectiveness of this product. These results are published in *Arthropod Management Tests*.

**3. Locate 8 (4/year) sweet cherry orchards containing variable levels of LCD infected trees.** Four sweet cherry orchards with a history of LChV2 infection were located for use in 2015 field studies. Orchard A and C were ‘Bing’, Orchard B was ‘Rainier’, and Orchard D was a ‘Lapin’ orchard. In 2016, four additional sweet cherry orchards, with a history of LChV2 infection were located for field studies. Orchard E and G were ‘Rainier’ cherries, Orchard F was ‘Skeena’, and Orchard H was a half ‘Chelan’ and half ‘Bing’. Growers/orchard owners consented to the use of trees ( $\pm 250$ /orchard) for leaf and fruit samples, access for fieldmen (for diagnosing visual symptoms), and researcher visits.

**4. Collect plant material for molecular assays from 250 trees in 8 (4/year) LCD orchards.** Plant material was collected from Orchards A, B, C, and D during 2015 and E, F, G, H in 2016. Different tissues were collected depending on time of season. Sampling periods were spread out over the year to manage the PCR workflow, given the 3-month maximum storage period for samples. Dormant season sampling (January and February) required 8 inches of dormant bud wood collected from each of the tree’s leaders (minimum of five bud wood samples per tree). Harvest/post-harvest season sampling (June to September) required 2 leaves from each of 5 leaders, or a total of 10 leaves per tree. Because of the large size of the orchards, it was not possible to sample every tree; therefore 2 categories of trees were sampled: 1) adjacent trees – trees that were directly adjacent to or 15 trees (within or across rows) away from trees that were removed due to previous LChV2 infection and 2) suspect trees – trees showing visual disease symptoms, but outside of the “adjacent tree” area. In 2015, “random” trees were sampled as well; however, no LChV2-positive trees were identified using this method, and it was dropped from the 2016 sampling procedure. Samples (wood or leaf tissue) were then analyzed using PCR.

**5. Perform molecular analysis (RNA extraction and PCR) on plant material samples (1,000/year) from LCD orchards to determine virus infection (Jan-May 2015 and 2016).** Reverse transcription

polymerase chain reaction (RT-PCR) was used to determine LChV2 infection in collected plant material. RNeasy Plant Mini Kits were used to extract and purify RNA from plant material. Molecular analysis of dormant bud wood required extracting phloem from samples using a sterile razor blade, while leaf tissue was processed without alteration. ‘SuperScript III One-step RT-PCR System with Platinum Taq DNA Polymerase’ was used in combination with known primers specific to LChV2 (developed by Ken Eastwell’s lab, WSU, Prosser, WA), for the reverse transcription. PCR products were identified using gel electrophoresis, with known positive and negative controls in each gel.

Molecular analysis for LChV2 identification was completed for all samples for both years. Surprisingly, many trees showing symptoms of LCD had negative PCR results for LChV2; those symptomatic trees were resampled for Western X (WX) phytoplasma, another causal pathogen of LCD.

**6. Walk through LCD orchards and categorize trees as symptomatic or non-symptomatic based upon visual symptoms (1-2 weeks before harvest, June-August 2015 and 2016).** Trees were individually labeled in a 500-700 tree block, in and around the LCD sample area in each orchard. During the week before harvest, when LCD symptoms are most obvious, a group of fieldmen (experienced in identifying LCD) walked through the block. Based on visual symptoms, fieldmen identified the trees as symptomatic or non-symptomatic. Depending on availability, 3-8 fieldmen walked through individual orchards. All participants walked through an orchard on the same day to avoid differences in symptom appearance that can occur over time. Walkthroughs were performed on two separate dates in orchard H for the two cultivars which ripened at different times. Many of the trees determined by fieldmen to have visual symptoms of LCD were negative for LChV2 via PCR. Up to 10 symptomatic trees infection in Orchard B, F, E, and H that tested negative for LChV2 were resampled and tested for WX.

**7. Collect a 2-lb clamshell of cherries from each tree in a subset of 20 trees (10 symptomatic and 10 non-symptomatic) in each LCD orchard (1-3 days before harvest, June-August 2015 and 2016).** A 2-lb clamshell of cherries was collected from a subset of trees including, up to 10 positive and 10 negative trees (depending on availability). In most cases, the trees were chosen and the fruit was picked before knowing the LChV2-infection status, thus only visual symptoms could be used as a clue to infection. Therefore, some fruit presumed to be collected from a positive tree was actually from a negative tree, and sample sizes were unequal for positive and negative. Of the four orchards sampled in 2015, collections were made from 6 to 10 positive trees. In 2016, very few trees were LChV2-positive in the chosen orchards, and therefore, collections from positive trees were made in only 2 of the 4 orchards.

**8. Perform fruit quality assessments on cherry samples (cherry size, color, and firmness) directly after they are collected (June-August 2015 and 2016).** Fruit size and quality (size, color, brix, firmness, and acidity) were measured 1-3 days before the start of commercial harvest to determine if LChV2 infection caused changes in fruit quality. These measurements were completed by Stemilt Growers R&D labs. Firmness was measured non-destructively using a fruit firmness tester (FirmTech 2, BioWorks, Wamego, KS). In addition to firmness, this device also calculated fruit diameter and row size (defined as the number of cherries that will fit in a 10.5 inch (276 mm) container (Webster and Looney, 1996)). Brix (% soluble solids) was measured with a refractometer (Atago PAL-1, Kirkland, WA). Titratable acidity (expressed as % malic acid) and pH was measured with an autotitrator (888 Titrand, Metrohm USA LLC, Riverview, FL). Fruit color was measured in 2016. Hue angle was measured with a color meter (Minolta Chroma Meter CR 300), and visual rating of cherry redness (red cultivars only) was conducted with the CTIFL color chart on a scale of 0 (light) to 6 (dark).

Firmness was significantly lower in LCD-positive cherries in 2 orchards, higher in 2 orchards, and not significantly different in 2 orchards (Table 1). Fruit size, however, was consistently smaller and soluble solids consistently lower in LCD-positive fruit from all 6 orchards. In 3 of 5 orchards, pH was higher in LCD-positive fruit, but % malic acid was unchanged. In the 2016 ‘Bing’ sample, the CTIFL color rating

was lower in LCD-positive fruit; hue angle was significantly different in both 2016 orchards (Bings were less red, Rainiers were more green) in LCD-positive fruit.

**9. Sample a 50-tree subset in LCD orchards for mealybug species, presence, and abundance (Post-harvest, July-September 2015 and 2016).** Mealybug sampling was conducted in the study orchards on LCD-positive and LCD-negative trees using a ladder. No mealybugs were found during the course of the sampling.

**10. Walk through LCD orchards and categorize trees as symptomatic or non-symptomatic based on reddish leaf coloration (late summer-early fall 2015 and 2016).** Based on 2015's observations that there were no obvious color differences between known positive and negative trees, this assessment was discontinued in 2016.

**11. Statistical analysis and modeling of data collected in LCD orchards (September-December 2015 and 2016).** Using data collected during 2015 and 2016, Dr. Marc Evans (WSU, Program in Statistics) performed a directional spatial analysis to determine evidence of a spatial relationship between infected trees within the same row and across rows. All data were analyzed using the Statistical Analysis System (SAS 2016). To determine if there was a spatial pattern among the PCR tested LChV2-positive or -negative trees, a spatial analysis of disease infection using PROC GLIMMIX was performed. The orchard trees were coded by position in the orchard with X = row position and Y = column position and coded for LChV2 infection as positive (1) or negative (0). These X and Y positions were used to develop the correlation structure among trees that were LChV2-positive or -negative.

Two of the three 2015 orchards showed a significant spread pattern within rows, but not between rows. The third orchard did not display a significant spread pattern in either direction; however, statistics showed that it was more likely to spread within than between. For 2015 orchards, new LChV2 infections were located on trees within a 1- to 3-tree radius of trees previously removed from the orchard, due to historic LChV2 infections. In one orchard three LChV2-positive trees were identified in a completely different location of the orchard, where LChV2 had not been previously detected. The trees were detected based on visual symptoms and were later confirmed LChV2 positive with PCR.

Of the 2016 orchards, only 2 could be analyzed for spatial patterns due to lack of sufficient LChV2-infected trees. In one orchard, where 4 additional LChV2 trees were located within a 1-tree radius of previous infections, statistics showed that the disease was more likely to spread within rows than between. In another orchard 13 of the 14 additional LChV2 infected trees were all located within a 1- to 3-tree radius of previous infection. Analysis revealed the disease was likely to spread within and between rows in this orchard.

In order to determine if visual symptoms are good indicators of LCD infection, an analysis comparing visual symptoms identified by fieldmen to actual LCD infection, as determined by PCR, was also completed. PROC FREQ was used to produce a one-way frequency table to determine the percent of LChV2 infected trees, verified by PCR, determined to be positive by at least one fieldman, the percent of LChV2-positive trees correctly classified by fieldmen (true positive), and percent of LChV2-negative trees classified as positive by fieldmen (false positive); 1 = determined positive (PCR and/or fieldman) and 0 = determined negative (PCR and/or fieldman). The proportion of fieldmen who indicated trees were positive for LChV2-positive trees (correct decision) and LChV2-negative trees (incorrect decision or false positive) was determined by using PROC MEANS. A Chi-square test was used to determine if the percentage of positive guesses for positive trees (true positive) and negative guessed for negative trees (true negative), differs from random chance (significantly exceeds 50%).

In all but two orchards, all LChV2-positive trees were identified by at least one fieldman. Trees in those two orchards (total of 3) did not show the typical visual symptoms of LChV2 infection, and were therefore overlooked by all participants. Fieldmen (at least one) incorrectly identifying negative trees as positive (false positive) ranged from 9 to 96% of trees in orchards.

When looking at the frequency of fieldman guesses, the number of correct guesses for positive trees (true positive) compared to the number incorrect guesses (false negative) significantly exceeded 50% or differed from random chance in all but two orchards. One of those orchards contained a number of trees that appeared to show symptoms, but were LChV2-negative. In this case the number of positive guesses on LChV2-positive trees didn't differ much from the number of positive guesses on LChV2-negative trees. The other orchard had only one LChV2-positive tree, and was only identified by one participant, while other LChV2-negative trees in the orchard were identified as positive by most or all participants as being positive.

The number of true negative guesses compared to false positive guesses differed from random chance in all orchards. This indicates that fieldmen were overall good and unified at determining LChV2-negative trees.

**12. Provide research updates to producers and consultants during winter meetings (November-February, 2015-16 and 2016-17).** Completed outreach activities during October 2015-February 2017:

- 1) Washington State Tree Fruit Association Annual Meeting; Yakima, WA; December 8, 2015
- 2) G.S. Long Grower Meeting; Chelan, WA; December 16, 2015
- 3) Orchard Pest & Disease Management Conference; Portland, OR; January 14, 2016
- 4) Cherry Institute, Yakima, WA; January 15, 2016
- 5) Stone Fruit Day, Wenatchee, WA; January 19, 2016
- 6) Northwest Wholesale Grower Meeting; Oroville, WA; January 26, 2016
- 7) Developing a management strategy for little cherry disease, WA State Annual Tree Fruit Association Meeting. Wenatchee, WA, December 2016
- 8) Managing the vectors of little cherry disease. Orchard Pest and Disease Management Conference, Portland, OR, January 2017
- 9) Detecting and managing little cherry disease, Wenatchee Stone Fruit Day. Wenatchee, WA, January 2017
- 10) Developing a management strategy for little cherry disease, Bluebird Annual Meeting. Wenatchee, WA, January 2017
- 11) Viruses: Little Cherry/Western X & More, Organic Pest and Disease Management Fruit School, Wenatchee, WA, February 2017

**13. Prepare reports.** Reports were prepared as requested for the granting agency, as well as for the agency providing matching funds (Washington Tree Fruit Research Commission).

The primary project partners were the Washington State Tree Fruit Research Commission and Stemilt Growers LLC. Stemilt Growers LLC contributed by performing field work and completing fruit quality assessments. The Washington State Tree Fruit Research Commission provided the matching funds from a 3-year grant (2014-2016).

This project only benefitted specialty crops.

**Goals and Outcomes Achieved**

One goal of this project was to provide educational and informative extension presentations to cherry industry groups that incorporate the newest findings associated with LCD management. In January of 2016, a survey of 60 attendees at an outreach talk indicated high levels of concern with LChV2. Before the talk,

68% could identify the best time to assess visual symptoms, and after the talk this improved to 90%. Before the talk, 88% knew the correct sampling strategy, which improved to 97% after the talk. After hearing the information provided, 78% plan to change their current management strategy for LChV2.

Another outreach presentation in January 2017 focused on correct identification of LCD via visual symptoms versus PCR test and LCD management strategies. The audience (124 participants) consisted of over 90% cherry growers or managers, who were mostly all aware of LCD and its effects, and at least 25% were actively managing it in an orchard they owned or managed. At the end of the presentation the group was asked to look at a series of 10 images of fruit and based on visual symptoms, determine the LCD status (positive or negative) of the tree containing these cherries. Infection status (4 negative, 6 positive) of the trees was determined via PCR prior to this presentation. When the infection status was negative, 60% to 82% of the participants guessed correctly. When the infection status was positive, 53% to 100% of the participants guessed correctly. These results emphasized to the participants that while visual symptoms are important, they can be easily mistaken, and a PCR test done by a certified laboratory is essential. Additionally, an informative web-page developed in conjunction with Washington State University Extension <http://treefruit.wsu.edu/crop-protection/disease-management/little-cherry-disease/>. The web-page provides current and updated information on LCD identification and management.

Recommendations for mealybug control on sweet cherry will be incorporated in the next version of the WSU Crop Protection Guide.

Information regarding the spatial distribution of LCD and the economic thresholds for orchard/tree removal is being summarized, and will be published in scientific journals and made available on the WSU website. A manuscript on the economic thresholds for orchard removal is in advanced stages of preparation.

*Goal #1: As a result of this project, cherry growers and/or their IPM consultants will have the necessary IPM information to protect their sweet cherry crop from mealybugs/LCD vectors.* A bioassay comparing two drench systemic insecticides (Admire Pro and Aza-Direct), one foliar systemic insecticide (Ultor), and one insect growth regulator (Centaur) was completed on GMB-infested greenhouse trees. Admire Pro, Aza-Direct, and Centaur reduced nymph and adult numbers to almost zero between 18 and 27 days post-treatment application (Figure 1). Since LCD has become a state-wide problem, many growers and managers have used Centaur as a mealybug control method. Previously, very little empirical evidence of the Centaur's efficacy existed. A field experiment, as part of a sister project, showed a reduction in AMB crawler numbers when Centaur was applied at the delayed dormant timing. The active ingredient in Admire Pro (imidacloprid) and in Aza-Direct (azadirachtin) can reduce mealybug numbers in grape vines via soil drench application (Lo and Walker 2011, Balikai 1999). Based on these results and previous evidence, all three of these compounds show promise as mealybug controls in sweet cherry orchards. Due to problems with parasitism in AMB colonies, greenhouse bioassays with this species could not be performed.

*Goal #2: Sample data from trees in LCD orchards will be used to develop measurable indicators to predict the probability of non-symptomatic trees serving as reservoirs of LCD, and to guide in making management decisions to remove whole orchards or just a subset of infected trees.* In 2015 measurable indicators such as small fruit, reduced sugar content (determined by tasting fruit), and lighter color proved to be good indicators of LChV2 infection. Fruit quality analysis on LCD-positive and -negative cherries in 2015 and 2016 showed consistently smaller fruit size and lower and soluble solids in LCD-positive fruit from all orchards. In the 2016 'Bing' sample, the CTIFL color rating was lower in LCD-positive fruit and hue angle was significantly different in both 2016 orchards (Bings were less red, Rainiers were more green) in LCD-positive fruit.

Based on 2015 data, it appears that many ‘newly’ infected trees are located within a 3-tree radius of prior infections, and that monitoring and sampling efforts to locate LChV2 infected trees should be prioritized in this zone. An additional search (using visual symptoms) will be necessary to locate other patches of infected trees. The results from 2016 orchards seem to stray from 2015 conclusions, with less contiguous LChV2 infections. A large number of trees showed visual symptoms of LCD, but molecular analysis results were negative for LChV2. Many symptomatic trees were tested for WX (an unexpected addition to the project), however, only a small number were positive. There are a number of additional viral infections or the combination of one or more viruses (cherry rasp leaf, cherry decline, cherry mottle leaf, etc.) that were not tested for in these orchards, and may have been the cause of visual symptoms resembling LCD.

The vector management recommendations are ready for incorporation into the Crop Protection Guide, and have been widely presented at grower meetings. The use of sample requests as an indicator of LCD spread within the state is likely a poor indicator. An increase in sample requests is more likely a result of increased awareness of LCD, which will lead to containment of the disease through vector control and tree removal.

### **BENEFICIARIES**

The sweet cherry growers of Washington State have benefited from the information gathered by this project. Sweet cherry growers in other parts of the United States and the world, which may contend with LChV2 infection, can apply what has been learned in Washington to their own region.

The economic analysis from the matching project from the Washington Tree Fruit Research Commission indicated that the break-even point for profitability of a cherry orchard is a 10% loss in production either through tree removal or unpicked/culled fruit. This can be a guide for growers for orchard removal/replant due to LCD.

This project has impacted 78% (29,857 acres) of the sweet cherry acreage in Washington state, represented by the five counties in which LChV2 has been detected (Chelan, Douglas, Grant, Okanogan, Yakima). The growers in these counties have benefited directly from the information gathered by this project in having concrete information on LCD symptoms and economic decision-making. Sweet cherry growers in other parts of the United States and the world, which may contend with LChV2 infection in the future, can apply what has been learned in Washington to their own region.

### **LESSONS LEARNED**

When considering measurable indicators of LChV2, it is clear based on the eight orchards examined, mealybug presence is not as important as was initially thought. All orchards had a history of mealybug infection; however, during the examination time, no mealybugs were found in any orchard, but LChV2 was found in all but one orchard. Mealybugs can be an indicator of infection, but they don’t have to be in the orchard for an active infection to be present. Leaf color in autumn has also been associated with LChV2 infection; however, no clear connection was found between fall color and positive infection.

The pattern of newly infected trees tended to mostly be related to the proximity of previous infections, about a 3-tree radius. In some cases new infections were not close to previous infections, but were discovered based on visual symptoms. To slow the spread of this disease, or to eliminate it from the orchard requires careful scouting close to previous infection, but also throughout the orchard. It is also possible that symptomless infections remain undetected in areas of the orchard that were not tested, however this is impossible to determine without prohibitively expensive PCR sampling.

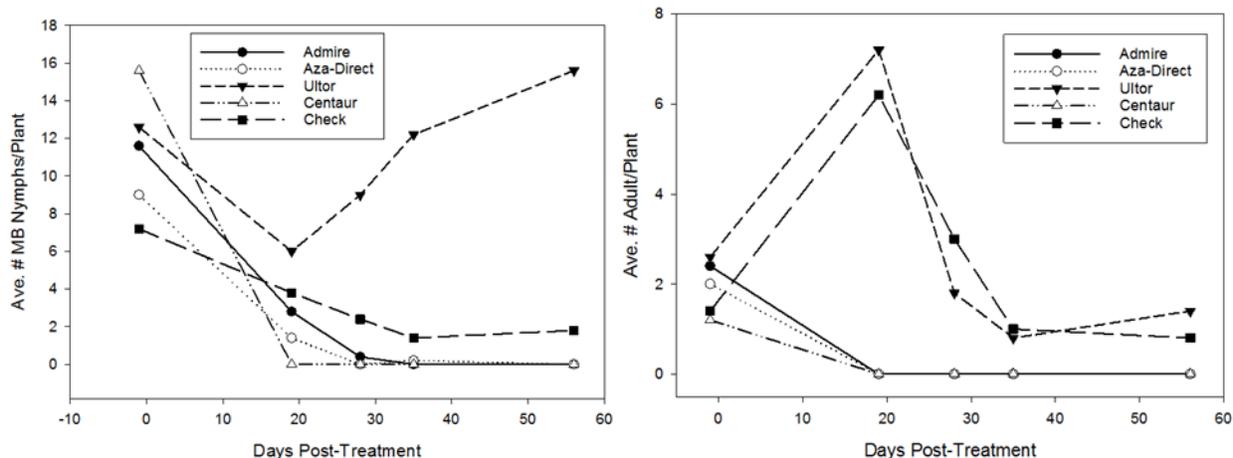
The most unexpected outcome was the sole orchard that had trees with visual fruit symptoms throughout, but was negative for LChV2. In the remaining orchards, visual symptoms were fairly reliable indicators of infection. This underscores the need for testing to verify the status of symptomatic trees.

Activities #1 and #2 were only partially completed, in that a GMB colony was established and tested, but the AMB colony failed due to parasitism. However, several years of field tests on AMB in the matching WTFRC project provided adequate information for making control recommendations.

**ADDITIONAL INFORMATION**

This project was matched (cash) with a three-year grant from the Washington Tree Fruit Research Commission in the amount of \$151,242 (see attached letter of matching pledge). This was used primarily for salaries. Stemilt Growers LLC provided in-kind donations of ca. \$80,000 in field work and fruit quality analysis for Activities #7 and #8.

**Potted tree bioassay of insecticides for control of grape mealybug**



Year	Cultivar	LCD infection	n	Firmness	Row size	Soluble solids (%)	pH	% Malic acid	CTIFL color	Hue angle
2015	Bing	01.Positive	14	325.02 b	12.17 a	13.51 b	.	.	.	.
		02.Negative	4	349.97 a	10.22 b	19.83 a	.	.	.	.
2015	Rainier	01.Positive	5	325.39 a	10.45 a	18.22 b	3.95 a	0.804 a	.	.
		02.Negative	14	304.44 a	9.44 b	21.82 a	4.00 a	0.825 a	.	.
2015	Bing	01.Positive	9	298.95 a	11.87 a	18.44 b	4.85 a	1.178 a	.	.
		02.Negative	10	280.47 b	9.91 b	21.92 a	4.30 b	1.323 a	.	.
2015	Lapins	01.Positive	10	378.62 a	12.11 a	12.82 b	4.10 a	0.919 a	.	.
		02.Negative	10	310.48 b	9.28 b	17.11 a	3.94 b	0.886 a	.	.
2016	Rainier	01.Positive	3	304.00 a	11.27 a	11.53 b	3.75 a	0.800 a	.	93.59 a
		02.Negative	10	281.12 a	9.15 b	19.80 a	3.81 a	0.806 a	.	39.35 b

2016	Bing	01.Positive	10	366.31 b	11.67 a	14.42 b	3.77 a	1.033 b	8	2.56 b	24.07 a
		02.Negative	10	432.96 a	9.58 b	22.24 a	3.67 b	1.139 a	9	4.35 a	15.77 b

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## **PROJECT #23**

**Project Title:** Apple Maggot Host Reduction

**Partner Organization:** North Yakima Conversation District

### **PROJECT SUMMARY**

Apple Maggot a quarantine pest in Washington, has encroached on commercial apple orchards in the fruit growing regions of the state. The current trapping, detection, and notification of horticultural pest and disease boards is a recognized treatment program. The detection of apple maggot within ½ mile of commercial orchards causes the orchards within this radius to be inspected for the presence of apple maggot in commercial apples.

The annual cost of monitoring for apple maggot in Washington is approximately \$500,000. This combined with treatments and labor costs approaches \$750,000. These costs continue to rise annually. New markets for the increasing apple production of Washington are necessary, and these anticipated markets have stringent requirements on pest detections in and near orchards.

This project did not build on a previously funded SCBG but was modeled after previous work performed by the WSDA plant protection division. The previous project did not collect data or intend scientific proof of efficacy. This projects goal is to prove that by eliminating apple maggot host plants, apple maggot populations in that area can be reduced to near zero.

### **PROJECT APPROACH**

In the first season (2014-15), apple maggot hosts were eliminated in three of six replicate treatment areas of “west valley,” an area of Yakima County comprising approximately 7 square miles. After all host were eliminated, “sentinel trees” with traps and lures were placed from late May through October of 2015. Traps were monitored for adult apple maggot in the treated three replicates, and the three untreated (control) replicates. It was expected that apple maggot adults would be detected through trapping in both the control and treated replicates in 2015 due to apple maggot life cycle of pupating in the soil beneath the host plants. Apple maggot adults were found in low numbers in the 2015 season in both treated and control replicates.

In the 2016 season the sentinel trees and traps were placed out from late May through October in the same locations as the previous field season from GPS coordinates. Traps were monitored for adult apple maggot with the expectation that adult flies would be reduced to near zero in the treated three replicates. A single adult fly was detected on the edge of a treated replicate near a host plant just outside of the treatment area. The other two treated replicates had no adult flies detected. The untreated control replicates did have detections of adult apple maggot in low numbers.

The 2017 field season was from late May through mid-September. The sentinel trees and traps were placed in the same locations throughout the three treatment replicates and three untreated replicates. Apple maggot adults were detected in the three untreated controls, and no adults were detected in the treated replicates where all apple maggot hosts were removed.

North Yakima Conversation District provided labor for host removal, purchased, grew, and maintained the sentinel trees, transported the sentinel trees to and from the field, provided project oversight, and performed data collection.

USDA-ARS provided project guidance, experimental design, interpreted data, and verification of apple maggot specimens.

WSU Extension project guidance, project oversight, and publication of handouts.

WSDA Plant Protection provided GIS mapping of project sites, project guidance and oversight, collaborated with trap data within the project area.

Yakima County Horticultural Pest & Disease Board provided project labor, data collection, project reporting, grower outreach, and project field maintenance.

Chelan and Douglas County Horticultural Pest and Disease Boards provided data collection, collaboration, and control plots for non-treated areas.

This project did not benefit non-specialty crops.

### **GOALS AND OUTCOMES ACHIEVED**

The goal of reducing apple maggot populations in areas where apple maggot host plants (hawthorn) were removed was demonstrated in the three treatment plots. This is in comparison to the three control plots where hawthorn was not removed, and apple maggot adults were detected.

An educational booklet explaining the benefit of host removal in proximity to commercial orchards has been produced and will be available through Conservation Districts and WSU Extension Offices. Through cooperation with WSDA and future trapping data, the intent is to reduce the quarantine in local areas surrounding commercial orchards. The North American Plant Protection Organization and the European Plant Protection Organization set the standards for “Areas of Low Pest Prevalence” and “Pest Free Areas.” Through host plant eradication and therefore pest reduction, it can be inferred that eradication and suppression measures can reduce apple maggot populations to near zero.

An educational webpage explaining apple maggot and its life cycle has been produced. A description of the grant project is included and will be expanded once the scientific paper is published. The website will be promoted at the annual Washington State Horticultural Association meeting, along with a poster in the poster session.

Apple maggot hosts and detections of apple maggot were mapped through GIS to determine the effectiveness of the project and for visual representation of the project.

The project has the long-term goal to ease the burden of apple orchardists in their efforts to produce apples and more easily export them. Through partnering with Conservation Districts in the apple growing areas orchardists can reduce apple maggot populations by host elimination near their orchards. A benefit of this project, four orchards collaborated and demonstrated the benefit of host elimination. Many orchards are located within apple maggot quarantine areas and outreach from this project will occur within these areas through regional grower meetings. An informational document has been produced for distribution through Conservation Districts and WSU Extension offices. Here is the link: <https://extension.wsu.edu/yakima/apple-maggot-host-reduction-project/>

#### Activities and Goals:

- The goal of obtaining data to show that hawthorn tree removal reduces apple maggot populations around commercial orchards was accomplished through host removal and was fully successful in the three treatment plots. Apple maggot detections in the 2017 season were reduced to near zero.
- Developing a document to assist growers with methods to reduce apple maggot populations around their orchards has been produced. This document and its methods will assist growers in achieving classification as an area of “low pest prevalence,” or “pest free area.”

- A webpage targeting commercial apple growers on methods of controlling apple maggot has been produced. The information on apple maggot life cycle, hosts, and description of the project will be updated after the scientific paper is published.
- The goal of monitoring/trapping for adult apple maggot within the three treated and three control plots was accomplished and established data indicating that host removal is an effective treatment strategy.
- Mapping to measure success of apple maggot host removal has been accomplished. Project trapping of apple maggot adults within the three treatment areas demonstrates that prevalence of host hawthorn trees indicates apple maggot populations. Through this mapping, populations of apple maggot can be inferred from hawthorn prevalence.

The data collected over three field seasons demonstrates that apple maggot host reduction is a viable method of controlling apple maggot populations in areas of apple production. During the span of the project one apple maggot adult was captured within a treatment plot, while in the non-treated control plots, apple maggot adults were captured in small numbers typical of Yakima County.

The North American Plant Protection Organization (NAPPO), has established “Regional Standards for Phytosanitary Measures,” that this project directly addresses. Reducing apple maggot populations to near zero within the treatment areas has been achieved. Currently the orchardists that participated are under apple maggot quarantine. By removing the host black hawthorn within ½ mile of these participating orchards, a “buffer zone” area has been achieved. This project has the potential to reduce trade barriers to commercial apples grown in Washington.

### **BENEFICIARIES**

The commercial orchardists of Washington will benefit from this project. Through outreach and guidance provided by Conservation Districts and WSU Extension growers and exporters will benefit from reduced trade barriers. Growers within apple maggot quarantine areas will have the opportunity to reduce apple maggot populations that impact their orchards to near zero.

The current costs of apple maggot monitoring and control efforts in Washington are estimated at \$750,000 annually. Monitoring for apple maggot is a necessity in quarantine areas of commercial apple production at this time, however this project demonstrates that it is possible through proper application of integrated pest management to remove quarantine from areas where it is demonstrated that apple maggot populations are not present according to European and North American plant protection organizations. By reducing apple maggot populations to near zero, the costs of monitoring, inspection, and treatment can be lowered for the apple industry in the future.

### **LESSONS LEARNED**

This project demonstrated to staff that certain aspects were overestimated as to budget and that funds were not needed in the amounts estimated. Performing a large-scale field experiment over several seasons with multiple agencies is possible and rewarding as the combined agencies work together to benefit a larger group. The negatives of the project were small in comparison, and were related to timing of project duties and tasks.

This project demonstrated an outcome of agencies working towards a common goal. Previously, the parties involved had not worked together and were unaware of the abilities of the individual and different agencies. Cooperative projects in the future are planned between the agencies.

This project is unique in that it includes both implementation and scientific aspects. Through this project, the removal of apple maggot hosts within a large area were removed and populations of apple maggot were reduced to near zero, thus benefitting apple orchardists within the project area. The scientific aspect of the

project involves the proof through scientific method that removal of apple maggot host is a feasible method of control of the pest. Collaborators had this understanding, and that it will involve efforts after the project is completed involving outreach and education to growers and the orchard industry as well as with regulatory agencies and trade partners.

#### **ADDITIONAL INFORMATION**

North Yakima Conservation District:

- Provided labor and oversight in the amount of \$52,631.00. These funds were sourced from the North Yakima Conservation Districts annual budget elements.

USDA-ARS:

- Provided scientific oversight, scientific method, labor, and expertise totaling \$8,054. These funds were derived from regular annual budget.

Yakima County:

- Provided labor, maintenance, salary, expertise, and transportation over the project totaling \$37,260. These funds were sourced from the department's regular annual budget.

WSU Extension:

- Provided scientific oversight, expertise, outreach, website creation/maintenance, and document publication totaling \$9,600. Funding was sourced from WSU's annual budget.

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## **PROJECT #24**

**Project Title:** Fresh Market Strawberry Pre-Breeding

**Partner Organization:** Washington State University

### **PROJECT SUMMARY**

The value of fresh-market strawberries in Washington and Oregon increased 144% between the years 2000 and 2012 (USDA National Agriculture Statistics Service, 2001 and 2013); producers, commodity groups, and buyers indicate that shifts in the fresh market strawberry sector may be occurring. Day-neutral strawberries with repeat flowering (RF) have long production seasons highly suitable to fresh market sales, but Washington producers lack adapted day-neutral cultivars to support the growing industry. Work in day-neutral cultivar development began at WSU in 2011, where initial efforts have concentrated on developing protocols to grow and evaluate day-neutral materials. This project was undertaken as a foundational and targeted pre-breeding project to assess available parental material for RF and powdery mildew susceptibility. Thorough evaluation of foundational germplasm is a prerequisite to launching a dedicated day-neutral strawberry breeding program with a high likelihood of success.

RF in strawberry is significantly affected by day length and temperature, most potential parent material has not been evaluated for RF in Washington, a region with the longest and most seasonally fluctuating day lengths as well as some of the coolest summer temperatures of any US production area (Stewart and Folta, 2010; Bradford et al., 2010). Many day-neutral genotypes that flower repeatedly in California, where most cultivars have been developed, have lower rates of flowering when grown in areas with longer day lengths (Durner et al., 1984). Day-neutral cultivars commonly grown in this area also experience a “gap” in production of about 2 weeks (Hoashi-Erhardt and Walters, 2014). The current project was undertaken to gather information about yield and flowering pattern in Washington growing conditions, with the goal of identifying highly repeat-flowering genotypes for breeding activities.

Additionally, powdery mildew is an important disease of day-neutral strawberries, more likely to affect yield and fruit quality than in June-bearing strawberries (Carisse et al., 2013; Kennedy et al., 2013). The long production season of day-neutrals overlaps with conditions favorable to the disease. Although powdery mildew has been studied to some extent with a limited number of genotypes, information is lacking for proposed parental day-neutral genotypes in Washington (Carisse et al., 2013; Kennedy et al., 2013). Results generated from this study are directly inform breeding efforts to increase the stability of remontancy and powdery mildew resistance in adapted day-neutral cultivars.

The US strawberry crop was worth \$2.4 billion in 2012 (USDA National Agricultural Statistics Service, 2013), which translates to an annual per capita spending of almost \$7.60. With the state’s 6.9 million residents, producers have an opportunity to greatly expand from fresh markets sales of \$4.2 million in 2012, into local fresh markets worth about \$50 million (USDA National Agricultural Statistics Service, 2013). Such growth is favored by strong consumer interest in local foods and health benefits conferred by consumption of berry fruits. Washington strawberry growers face favorable consumer demand for fresh local strawberries, but also deal with challenges. One challenge is the lack of a regionally adapted, disease resistant day-neutral cultivar with consistent size, balanced firmness, and excellent color, shape, and flavor. Washington strawberry producers only have access to day-neutral cultivars transferred directly from California, developed under conditions of climate, pest pressure, soil, and market demands dissimilar to those faced by WA producers. A recent study of these cultivars found that these California cultivars are not adequately meeting production needs for yield, durability, disease resistance, and excellent flavor,

especially for organic producers (Hoashi-Erhardt et al., 2013). The motivation to complete this pre-breeding project was to make progress toward developing an excellent regional cultivar in the next 5-10 years, and thereby would contribute to a thriving fresh-market strawberry industry.

This project will generate the crucial germplasm knowledge that will form the basis of a thriving day-neutral breeding program, which directly supports the 2014 funding priority of developing New Seeds and Cultivars. Available parental genotypes were evaluated for repeat flowering and powdery mildew resistance, as a prerequisite to dedicated day-neutral cultivar development. This is crucial pre-breeding work that thoroughly evaluated available parental material, to prevent time and field work from being wasted on progeny of unsuitable parent plants. Cultivar development is necessarily a long-term endeavor and outside the scope of this grant. However, the project will greatly advance the current efforts at day-neutral breeding at WSU and at public breeding programs in the region. Washington State's approximately 326 fresh market strawberry farmers (USDA, 2009) will be the main beneficiaries of improved cultivars with powdery mildew resistance and day-neutral traits, as they will realize greater production of higher quality fruit than is possible with current cultivars. New cultivars developed specifically for the Washington industry could make day-neutral strawberries a profitable crop for hundreds more specialty crop farmers, organic and conventional, who are seeking to diversify further or supply the current unmet demand for fresh local strawberries.

This project doesn't build on a previous SCBGP project.

### **PROJECT APPROACH**

A planting of one hundred repeat-flowering strawberry genotypes was established in 2014 at the WSU Puyallup Research and Extension Center. They were planted in four reps when possible. Many of the genotypes originated as propagules from the National Clonal Germplasm Repository (NCGR) in Corvallis, Oregon. Beginning in April 2015 and continuing through Sept 2015 and then April-Sept 2016, the plants were evaluated for the presence of open flowers weekly and for powdery mildew symptoms monthly. Yield and number of fruit was also assessed during the 2015 and 2016 harvest season. Additionally, a cross plan devised in 2015 and 2016 targeted highly repeat flowering genotypes identified from the evaluation to be used in the following season's breeding activities.

Eleven of the genotypes flowered at least 33 weeks out of 47, or 70% of the time over two harvest seasons, indicating strong repeat flowering tendencies. At the other end, another 22 genotypes flowered less than 50% of the time, often with very long periods without blooming. These had very weak repeat flowering patterns and were similar to June-bearers (short-day types). The rest of the genotypes had intermediate repeat flowering patterns between 50 and 70% weeks of bloom, indicating repeat flowering tendencies, but not strong patterns under the growing conditions of Western Washington. The yield of the genotypes evaluated ranged from 0 to 1733 g/plant in over two years (Table 1), which is in the typical range for repeat flowering cultivars during the second fruiting season in Western Washington. Several of the highly repeat-flowering genotypes also had some of the higher yields, especially 'Superbe Remontante Delbard', 'CA 70.3-121', 'WSU 13.3-3', 'WSU 12.216-1'. Genotypes that had very low yields were highly vegetative and did not initiate many flowers. There were some genotypes with high yields, such as 'WSU 12.216-4', but performed as a June-bearing type, fruiting in a concentrated period in mid-May to June, with very little production during the extended season. While such genotypes are productive, their use in day-neutral breeding is limited.

The "gaps" or periods without flowering, were also calculated. Two genotypes were continually blooming during the evaluation period: 'Superbe Remontante Delbard' and 'CA 70.3-121', indicating high value as parent material for the repeat flowering trait in this region (Tables 2 and 3). The rest of the genotypes had at least one gap in flowering that ranged from 1 or 2 weeks to 21 weeks, or 84% of the evaluation period.

In general, the genotypes with the greatest number of flowering weeks also had the shortest gap, but some genotypes had repeated gaps of short duration as well, which are less valuable as potential parents.

Powdery mildew symptoms were assessed on a monthly basis (Tables 2 and 3). Powdery mildew symptoms were variable by year, and the majority of genotypes did not appear to be greatly affected by the disease. This is good news for breeding, that the available parent material is not particularly affected by powdery mildew during average growing conditions.

Cross plans were devised every year based on current flowering results for total flowering weeks, gaps and duration of gaps, yield, and powdery mildew. Several planned crosses had to be postponed because of the poor flower quality of 'Brighton', 'Rabunda' and 'September Sweet' during pollinations. An overview of performed and planned crosses is included in Table 5. The aim was to cross genotypes with the highest rate of flowering, the shortest gaps in bloom, and adequate yields over two years, as well as to incorporate other advanced selections from the WSU breeding program. It was also important to avoid crossing genotypes that are too closely related, because genetic diversity is required to produce variability within populations that is the whole basis for traditional plant breeding. The updated cross plan for the first year after completion of the project includes these considerations of consistent repeat flowering, short gaps, high yield, while trying to avoid crosses between highly related individuals.

Extension of project. As communicated in the project agreement, an extension of this project was planned and executed between Sept 2016 and Sept 2017. Twenty-nine genotypes that failed to establish in the first planting or that became available after the start of the project were included in a second-phase extended study. These genotypes were planted in four replicates in September 2016, and were maintained over the winter prior to evaluation of bloom, yield, gaps in flowering, and powdery mildew symptoms starting in April 2017 and continuing through September 2017.

Five of the genotypes flowered between 70% and 80% of the time, indicating strong repeat flowering tendencies (Table 4). At the other end, 13 genotypes flowered less than 50% of the time, showing weak repeat flowering patterns and greater similarity to June-bearers than to day-neutrals. The rest of the genotypes had intermediate repeat flowering patterns between 50 and 70% weeks of bloom, indicating repeat flowering tendencies, but not strong patterns under the growing conditions of Western Washington. 'Fort Laramie' (WY), 'Hecker' (CA), WSU 13.1-1(WA), and WSU 13.1-11(WA) were the highest yielding selections included in this extension (Table 4). Each of these also demonstrated high RF, indicating that each of these is a good candidate as a parent for future day-neutral breeding work for the region. All except WSU 13.1-11 have small fruit size, so they will need to be crossed with genotypes with large average fruit size.

Powdery mildew affected more of the genotypes in 2017 than in previous years (Table 4). Particularly notable was the significant susceptibility of 'Fort Laramie' to the foliar disease.

This project is a pre-breeding project that relies on other breeders and the NCGR to provide germplasm for inclusion in the study. These partners did provide germplasm and their roles are fulfilled. Further partners are the breeders of Michigan State University, who supplied repeat-flowering genotypes included in the second phase extended study.

The overall scope of the project benefits only the strawberry industry.

#### **GOALS AND OUTCOMES ACHIEVED**

Plants were inventoried, acquired, propagated and maintained as greenhouse plugs prior to establishment. The genotypes were planted in replicate in field plots and maintained with adequate irrigation, fertilizer, and weeding. Plants were evaluated weekly for open blooms, ripe fruit weight, and fruit number. Plants were evaluated monthly for symptoms of powdery mildew. A total of 86 genotypes were evaluated, 64

genotypes that established in the first stage, and 29 genotypes in the extension, with 7 overlapping genotypes that appeared in both. Data was compiled and analyzed for seasonal means. Genotypes with high RF, high yields, short yielding gaps, and low powdery mildew were identified and included in cross plans. Pollen was collected and flowers were emasculated, and pollinations were performed for planned crosses. Seeds were germinated in vitro from these controlled pollinations, and planted as greenhouse plugs, then in field plots for the next rounds of selection.

Plant breeding is necessarily a long-term endeavor. The activities proposed and completed fell within the timeframe of a 3-year project. However, the impact of the activities stretch beyond the timeframe of the funded project. Seedlings generated from the crosses completed during the project and new crosses informed by the results of the project will be planted and evaluated in the next one or two years. Additionally, valuable flowering and yield information about potential parent genotypes, including both WSU advanced selections and outside cultivars/selections will continue to direct how they are used in breeding. This knowledge base about available parent material increases the likelihood that a regionally adapted cultivar with excellent fruit quality and horticultural traits can be released from the WSU breeding program to benefit the larger strawberry industry.

The goals established for the project were to 1) evaluate the flowering patterns of 100-120 repeat-flowering strawberry genotypes, 2) evaluate the symptoms of powdery mildew of those genotypes during the production season, and 3) draft a plan for germplasm and cultivar development with a set of parent strawberry plants identified with high RF, high yield, and powdery mildew resistance. Plants were inventoried, acquired, and propagated to meet the planting requirements for multiple replicates. Weekly flowering patterns, yield, fruit size, and incidence of powdery mildew were evaluated for a total of 86 genotypes as set forth in the proposal, 64 genotypes that established in the first stage, and 29 genotypes in the extension, with 7 overlapping genotypes that appeared in both. Controlled pollinations (crosses) were performed and planned using parent material identified in the three years of evaluation as having high RF, good yields, and low powdery mildew susceptibility. Seeds germinated from these pollinations have been planted for the next round of selection to identify genotype possessing excellent traits for fresh market strawberry operations

One expected measurable outcome is to have a body of information on repeat-flowering patterns for a core collection of repeat flowering strawberry genotypes that are potential parents for repeat-flowering cultivar development for the state of Washington. Repeat flowering has been studied in warmer areas with shorter summer day lengths, but WA has the longest and most seasonally fluctuating day lengths of any US production area, where repeat flowering data is not available for parental genotypes proposed for WA breeding efforts. At the commencement of this project, such information was available for fewer than 5 genotypes included in the study. Two to three years of flowering, yield, and bloom gaps data have now been collected for 86 genotypes.

Another expected measurable outcome is to have information on powdery mildew for the same core collection of repeat flowering strawberry genotypes. At the commencement of this project, such information was available for fewer than 5 genotypes included in the study. Two to three years of powdery mildew symptoms have been evaluated, indicating overall that powdery mildew doesn't appear to greatly affect the genotypes included in this study, except for a select few. That information is helpful in that no special consideration of powdery mildew susceptibility needs to occur when planning crosses, unless when using highly susceptible parents like 'Fort Laramie'.

The third expected measurable outcome is a draft of a cross plan outlining the hybridization of high yielding, consistent flowering genotypes with low incidence of powdery mildew. Two to three years of data have allowed the identification of highly repeat flowering and high yielding genotypes that have previously

not been used for breeding in this region. A cross plan is now in place that will cross these valuable parents to produce seedling populations from which further selections can be made, that represent advances in yield and consistent fruiting patterns.

### **BENEFICIARIES**

The National Agricultural Statistics Service indicates that in 2012, the most recent census data available, 477 operations in Washington harvested strawberries, including both conventional and organic producers. The number of beneficiaries is likely to be similar to this number, and there is potential for new producers of fresh market strawberries to also benefit if adapted cultivars and marketing opportunities expand as a result of this project. Additionally, nurseries serving this region may also benefit if the completed project leads to a release of a new cultivar in the next 5 to 10 years.

It is always difficult to estimate the economic impact of a project, but it is clear that the demand for fresh strawberries continues to grow: between 1980 and 2014, per capita consumption of strawberries increased from 2.0 lbs. to over 7 lbs., with nearly all that growth in the fresh sector. Wholesale and retail buyers participating in a Pacific Northwest workshops conducted by the NW Berry Foundation indicated that demand for fresh local strawberries in the region is unmet by current supply, indicating that large growth in the fresh market strawberry sector is supported by markets. The 477 operations in Washington that harvest strawberries may be able to tap into the unmet demand for fresh strawberries, thus capturing purchasing dollars that otherwise go to strawberry industries that ship into Washington.

### **LESSONS LEARNED**

The main lesson learned about implementing a project including a large number of genotypes is to allow a very large margin for variable plant quality. The plants obtained in this project were from a variety of sources, collaborators, the NCGR, and commercial nurseries. These all have highly variable propagation quality, leading to irregular establishment in field plots. Controlling this aspect more closely is advisable, by obtaining plant material a few years in advance and conducting runnering or tissue culture propagation.

The outcomes of the project were largely expected.

The poor establishment of several genotypes led to a lower number of evaluations than were planned: 86 compared with 100 planned. Again, this was due to the variable propagule quality from the sources used to obtain plants.

### **ADDITIONAL INFORMATION**

Washington State University provided \$4,807.95 as in-kind matching donations in the form of overhead and administrative funding. These donations were used to administer the grant, hire and process temporary employee wages, and other overhead functions.

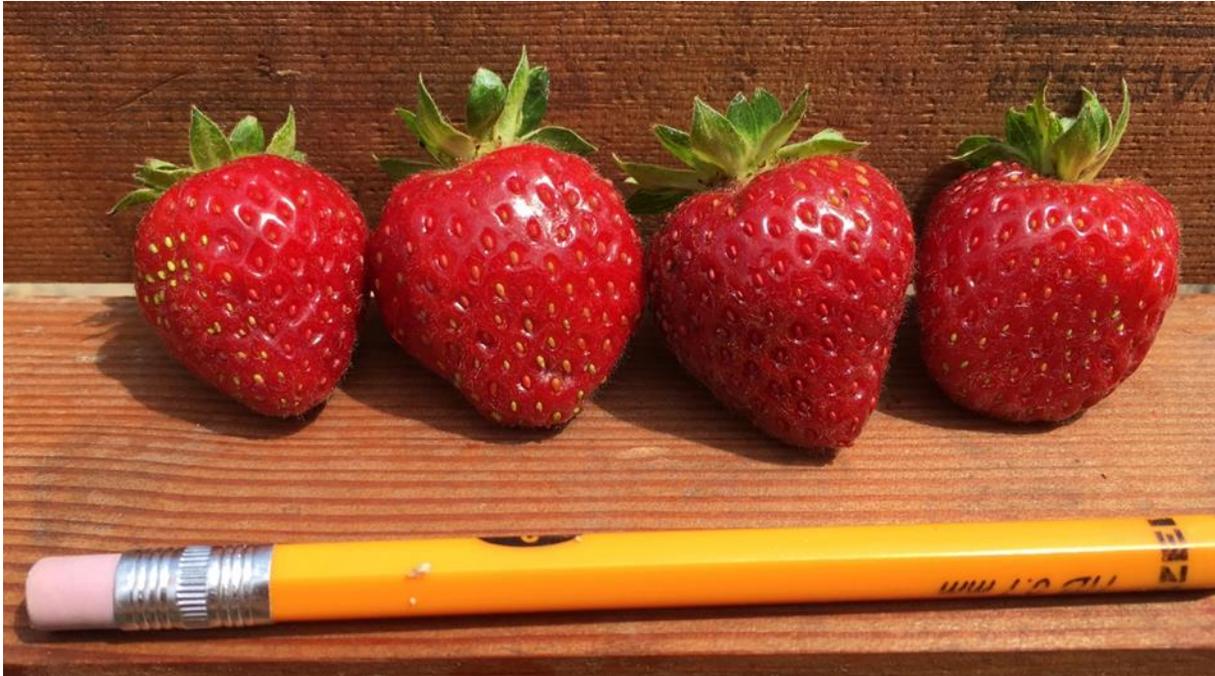


Fig. 1. WSU 12.216-3, a good yielding selection with high RF identified as promising selection and valuable parent in further breeding as a result of this project.

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**See Attachment E- 2014 SCBGP-FB**

## **PROJECT #25**

**Project Title:** Increasing Sales for Specialty Crop Farmers at Seattle Farmers Markets

**Partner Organization:** Neighborhood Farmers Market Alliance

### **PROJECT SUMMARY**

There are limited venues for Washington specialty crop farmers to direct-market their products in Seattle. Thriving urban Farmers Markets are essential for small farms to hone their direct sales strategy and maximize their profits, and for mid-sized farms to reach wholesale accounts.

The Neighborhood Farmers Markets are a system of seven highly regarded farm and food-only markets in diverse Seattle neighborhoods, serving over 400,000 shoppers per year, with gross sales to farmers and food artisans totaling \$8,105,256 in 2013. The Seattle food economy is worth about \$4.5 billion, and these Farmers Markets represent less than 1% of that market. By capturing a larger proportion of those food dollars through a number of innovative outreach methods, this investment will increase sales to specialty crop farmers by at least \$750,000 over two years. That growth will be sustained and compounded into the future.

This project initially took a 3-tiered approach to increasing shoppers and specialty crop sales at seven Seattle Farmers Markets:

1. Increased low income shopper sales through specialty crop-focused SNAP incentives. (This work eventually became part of a state-wide USDA FINI grant.)
2. New marketing strategies utilizing digital and multi-media approaches.
3. Strategic partnerships with the University of Washington to support the NFM's flagship market.

In 2014, the economy was rebounding from the Great Recession and the time was right to engage a new, younger, health-conscious consumer base to grow Farmers Markets and Washington specialty crop sales into the future.

The year the grant was submitted, Seattle population growth was at 2.4%, in the years since, it topped 3%, adding 21,000 residents in 2016, making it the fifth fastest growing city in America. These new residents are ripe for teaching about seasonality, Washington state agriculture and for buying direct from the farmer at Farmers Markets.

Previous SCBGP grants supported marketing and outreach in the more traditional sense: printed newsletters and market-based events. These were successful in their time, but focusing on digital media and institutional (rather than individual) relationships had a greater impact.

At the outset of the grant, low-income food access was part of the scope. However, once the FINI grant began, the SCBG funds were only used for non-FINI related expenses. In my report, I listed:

Fresh Bucks: Incentives and at-market staff time are now covered in Food Insecurity Nutrition Incentive (FINI) grant; the following list is additional activities necessary to support the SNAP program and Fresh Bucks outreach, for which SCBG funds were used:

- TSYS system upgrade and equipment replacement
- Trained new market staff on EBT transaction procedures
- Token inventory and reordering

- Created new EBT System to streamline EBT display, transaction procedures, and increase security and ease of use of technology and SNAP tokens at all markets
- Oversee VISTA volunteer in creating digital content related to seasonal, low cost recipes for students and SNAP shoppers, and simple "Tasty" videos

### **PROJECT APPROACH**

Fresh Bucks: Incentives and at-market staff time are now covered in a Food Insecurity Nutrition Incentive (FINI) grant; the following list is additional activities necessary to support the SNAP program and Fresh Bucks outreach:

- TSYS system upgrade and equipment replacement.
- Trained new market staff on EBT transaction procedures.
- Token inventory and reordering.
- Created new EBT System to streamline EBT display, transaction procedures, and increase security and ease of use of technology and SNAP tokens at all markets.
- Oversee VISTA volunteer in creating digital content related to seasonal, low cost recipes for students and SNAP shoppers, and simple "Tasty" videos.

The University District is the flagship and largest market in the NFMA market system and the nearby University of Washington has 44,000 students and 25,000 employees. Market outreach and engagement with the University of Washington community over the past years includes:

- Meetings with Buerk Center for Entrepreneurship to support student small business incubation (exploring offering a student vendor booth) and driving students to the market.
- Meeting with former Seattle City Council Chair, Sally Clark, now employed at the University of Washington as Director of Regional and Community Relations, to explore Husky card use at the market and other outreach opportunities.
- Meetings with the student group "Eco Reps" regarding their on campus Green Market; participation in and consultation for their quarterly markets.
- Early April annual cooking demos and outreach for UW Parent's Weekend.
- Continuing the 1st Saturday Husky Bucks incentives for students and staff: the market redeemed over \$22,000 in Husky Bucks during the period of the grant (counted as a match, not reimbursed).
- Fall ad campaign in The Daily (UW newspaper) coinciding with Husky football home games.
- Late Summer/Fall ad campaign in The Stranger featuring specialty crops; cooperative advertising campaign with all Seattle Farmers Markets.
- Ads in the spring, summer and fall "Survival Guides" for UW students.
- New student outreach during the Up Your Ave events plus Appleloozza Heirloom apple tasting.

Digital Media: The Outreach and Development Coordinator continues in a staff position to bring expertise in digital media to the organization. They also hired a contract photographer, software developer, and Digital Media Consultant. Together they accomplished:

- Continuing focus on building Instagram presence as well as developing coordinated social media protocols for all of the markets.
- 5 short Tasty videos created and shared in conjunction with Husky Days (University of Washington outreach and incentives).
- Professional photo shoots completed at West Seattle, Columbia City, Phinney and U District between June and September 2016, capturing high season crops, bountiful tables of produce, farmer portraits, and crowds of shoppers.
- Staff content creation for digital media (photographs, graphic design, social media posts, etc.)
- Consultants took over social media channels for 8 weeks in high harvest season in 2017, developed best practices (content buckets, when to post, what to post, how to track success), did A/B testing for social media advertising content, ran a number of ad campaigns, provided general social media

training for staff and in depth back-end training (Facebook Business Manager) for Outreach Coordinator.

- Farmers Market blog created.
- Farm Profile project: creates standardized signage and content for social media and blog profiling every market farmer.
- Software updates to on-line application process including better integration between product list and permit calendar so website is more up to date regarding product availability and farmer presence.

The farmers are always the most important project partner for the NFMA, especially the vendor-elected farmer board members who provide oversight to their programs.

The University of Washington is a project partner, though as a large institution, it is often difficult to find the right champions.

The Washington State Farmers Market Association is always an excellent partner, especially in helping to disseminate NFM programs to smaller markets, which helps even more farmers.

This project has the potential to benefit non-specialty crops. 60% of all market sales are to specialty crop farmers and over 80% of all farm sales are specialty crop sales. All activities were focused on farmers. The NFMA provided match in the following areas to compensate for any non-specialty crop farmer benefiting: 50% match for all staff time and a match for supplies and contracts (all of which are primarily focused on specialty crops) depending on the output, at least 10-20% of costs for farm-related supplies and contracts (when 80% of the sales are specialty crops) in case a non-specialty crop farmer benefits.

**GOALS AND OUTCOMES ACHIEVED**

Activities were completed as described above in the Project Approach section of this report. The only performance measure that proved difficult to track was the impact of engagement with the University of Washington. Anecdotally, there seem to be more students at the market, but the demand for Husky Bucks incentives hasn't grown significantly. However, since students graduate and leave the area a stable program could show that they are at least continuing to reach new students.

Increasing sales to farmers is always a long term objective. This project included some staff training and organizational investments that should continue to yield results into the future.

The general goal is an increase in specialty crop sales of 5 % annually and increase shopper counts by 10%. Specific goals were benchmarked and tracked in the areas of: SNAP and incentive program sales, increase in vendor sales (as reported by vendors), shopper counts (counted every 30 minutes of every market day), and social media followers and likes.

Fresh Bucks incentives were not funded by this grant, but the program did expand through a vegetable prescription program launched in 2016. Interestingly, SNAP transactions are down over the period of time of the grant, since the incentive program incentivize smaller EBT transaction because the match is \$10. Fresh Bucks are restricted to specialty crops only, while EBT is allowed for other products. The estimate of specialty crop sales through EBT is 60%.

	October 2014-Sept 2015	October 2015- September 2016	October 2016- September 2017	% Chance 2014- 2017	Specialty Crop Sales
<b>Fresh Bucks &amp; EBT</b>	\$ 89,428	\$ 93,679	\$ 120,959	35%	\$ 120,959

EBT	\$ 127,231	\$ 120,848	\$ 109,791	-14%	\$ 65,875
					\$ 186,834

The total increase in vendor sales during the period of the grant is 15% or \$1,384,210. Over \$830,000 of those dollar are sales to specialty crop farmers. 2015 was a difficult year for farmers in Washington state with fires and droughts, 2016 was an excellent season, and 2017 sales growth was slow because of an extremely wet and cold winter and spring. Vendor sales growth still far surpassing the goal of 5% per year on average.

15%	Increase from 2014 to 2017
\$ 1,384,210	Total Increase
\$ 830,526	Specialty Crop Increase

Shopper Counts are another measure of the success of marketing and outreach. Shoppers are counted on the half hour at each of the markets. Shopper counts increased in 2016 by 13%. Overall shopper counts are up 21% since the beginning of the grant period, from just under 500,000 shoppers annually to over 600,000 shoppers.

Social Media goals were not explicitly set, but growth is as follows, since bringing social media expertise to an existing staff position and also having an 8 week consultation:

<b>Social Media</b>	<b>late 2014</b>	<b>9/30/16</b>	<b>YtY Increase</b>	<b>9/30/2017</b>	<b>YtY Increase</b>	<b>Increase (Total)</b>
Twitter Followers	10,000	15,200	6%	16,712	10%	67%
Facebook Followers	9,500	17,510	14%	24,657	41%	160%
Instagram Followers	900	8,286	434%	18,091	118%	1910%

Baseline data is set as the data from the beginning of the grant, fall 2014.

### **BENEFICIARIES**

Specialty crop farmers benefited from an increase in sales, and will continue to benefit from the marketing knowledge that the NFM has gained as an organization. The NFM will also be distributing some of the best practices they've learned to farmers via their annual meeting and to market managers via conferences, so farmers beyond the NFM market system will benefit.

The impact is measured in increase in sales for specialty crop farmers, and increased foot traffic at the markets.

The sales increase is 15% from the start until the end of the project, or \$830,526 dollars.

15%	Increase from 2014 to 2017
\$ 1,384,210	Total Increase
\$ 830,526	Specialty Crop Increase

Overall shopper counts are up 21% since the beginning of the grant period, from just under 500,000 shoppers annually to over 600,000 shoppers.

### **LESSONS LEARNED**

While it took some time to find the right consultants, it was worthwhile to bring in outside experts as photographers and marketing consultants, especially with the understanding that some training would be

involved. The staff is now better equipped to produce more professional results, and to utilize paid advertising on social media platforms.

Although the SNAP incentive project was trimmed from this grant, an unexpected outcome of introducing an incentive program was a reduction in SNAP sales. The food access dollars sales to farmers increases overall, but SNAP sales did not rise because people were incentivized to take only \$10 off their cards instead of the higher amount that they had spent previously.

The Expected Measurable Outcome of this project was achieved.

**ADDITIONAL INFORMATION**

\$22,301 Husky Bucks (\$2 vouchers) to current UW students and staff.

\$27,070 Wages and Salaries: 50% match to ensure specialty crop focus

\$ 4,331 Benefits: 50% match to ensure specialty crop focus

\$ 4,522 Contracts: 70%-90% match to ensure specialty crop focus

\$13,034 Indirect overhead and administrative costs

**\$71,258 Total**

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## **PROJECT #26**

**Project Title:** Evaluation of an Alternative Irrigation Water Quality Indicator

**Partner Organization:** The Center for Produce Safety

### **PROJECT SUMMARY**

Foodborne illness is a preventable public health risk caused by consumption of contaminated food containing harmful microbial agents. In recent years, agricultural water has been associated with an increasing number of foodborne illnesses, especially in fresh produce. Much has been debated and written about the inadequacy of current methods for routine monitoring and assessment of the microbiological quality of agricultural water used for irrigation, crop protection applications, and other pre-harvest inputs for fresh, edible, and perishable horticultural foods such as the diverse category of leafy greens. The lack of consistent correlation between chemical or biological indicators of fecal contamination at the local, regional, national, and global level is well documented in the scientific and public health literature. A generic fecal indicator organism, *Escherichia coli*, is currently used for monitoring microbiological agricultural water quality. *E. coli* is a non-pathogenic bacteria present in all warm-blooded animals. The presence of *E. coli* in agricultural waters indicates the possible presence of a pathogen; however, this traditional fecal indicator cannot quantify and identify different sources of fecal contamination. An alternative and well-established biological indicator of fecal contamination of water sources is the gram-negative obligate anaerobic bacterium *Bacteroides*. Tracking and differentiating animal sources of bacteria in the genus *Bacteroides* has long been a tool for evaluating fecal contamination of surface water used as drinking water sources and for recreational purposes.

Current microbial source tracking techniques are used to identify and quantify dominant sources of fecal contamination by using *Bacteroides* 16S ribosomal RNA (rRNA) gene sequences that are a very prominent component of gut microflora. The current project sought to determine whether *Bacteroides* markers could be an alternative and more predictive fecal indicator in different irrigation water sources. The overall objective of the project was to establish a baseline of preliminary data to support collective expert evaluations to replace quantitative generic *E. coli*-based irrigation water standards with a qualitative presence-absence standard based on *Bacteroides* as an improved indicator of fecal contamination and, more specifically, the presence of pathogens. (This qualitative presence-absence standard would actually be a semi-quantitative threshold based on a designed risk-assumption limit of detection.)

The publication of the Food and Drug Administration Food Safety Modernization Act (FSMA) “Standards for the growing, harvesting, packing, and holding of produce for human consumption - Final rule” (Produce rule [PR]) on November 27, 2015, was anticipated during the proposal period and overlapped the research implementation period for this project. The regulatory provisions for agricultural water, as defined within the PR, established the compliance criteria for the standards, metrics, and corrective measures related to the required Microbial Water Quality Profile for produce covered by the rule. These requirements identified generic *E. coli* as the recognized fecal indicator bacteria (FIB), but the PR allows for scientifically valid alternatives. The produce industry has long recognized the limitations of *E. coli* as a FIB in common irrigation and produce production water sources in California and many of the Western states. However, multiple studies have shown low correlation of *E. coli* levels with actual pathogen presence or significance in water sources. Despite being a routine and relative low-cost FIB test, there are a number of limitations, including instability during sample transport and variability of test results, even within recognized standard methods. Validation of an alternative FIB with greater predictive

relevance to pathogen potential in water sources, particularly surface water, is of high interest and benefit to the industry.

This project was initiated as a new project and did not build on a previously funded SCGBP project.

### **PROJECT APPROACH**

During the project, 691 surface water samples were collected, processed, and analyzed from multiple farm locations in California, Washington, Oregon, and Arizona. Sample collection was approximately evenly split between 2015 and 2016 and, as much as practical, the samples were collected from the same source-locations to allow for trending of results. As laid out in the approved Work Plan, all CA samples were collected and processed at the University of California, Davis (UCD). All WA samples were collected by collaborators and placed in insulated containers with gel refrigerant and then shipped to UCD for processing. Though limited in number due to lack of resolving a collaborative arrangement, the UCD lab collected and processed samples from southern OR. The majority of water samples from AZ were collected and processed by the Co-PI at the University of Arizona (UA), following standardized methods, with the exception of 102 stabilized samples shipped to UCD for pathogen detection with the ROKA Biosciences Atlas system. Following the objectives of the Work Plan, analysis of replicate homogenized surface water samples was conducted to contrast the primary *E. coli* quantitative method used by the produce industry (i.e., most-probable-number method) and the enumeration method specified by the PR (i.e., membrane filtration: colony forming units): a total of 1,382 *E. coli* analyses were conducted over the project period.

As membrane-filtered water samples for Total Bacteroides analysis can be stabilized by freezing, all 348 samples collected in 2015 were stockpiled awaiting finalization of standard curves and internal controls between UCD and UA, as described in the Work Plan. Implementing the Work Plan for testing Total Bacteroides levels in these water samples with two different genomic-based methods and conducting pathogen screening for Shiga toxin-producing *E. coli* (STEC), enterohemorrhagic *E. coli* (EHEC) and *Salmonella* in the samples brought the total number of analyses to 2,764. This moderately exceeded the planned number of tests from the projected baseline of at least 600 samples in the original Work Plan.

A great deal of effort was directed at making scientifically sound assessments of the two FIB in relation to qualitative detectable pathogen presence in representative surface water sources used for fresh produce production across the multi-state locations. Overall, the key significance of the project team's collective results is that *E. coli* levels were overwhelmingly in full compliance with both industry standards and the FSMA compliance standards in the Produce Rule. All test results were subjected to calculation of Geometric Mean and Statistical Threshold Value (STV), as required under the PR, using an FDA-vetted auto-calculator spreadsheet. Across all collected samples, only two date/location events resulted in an STV exceedance, which would require a 1-day pre-harvest interval to allow for the PR-specified 0.5-log CFU die-off corrective measure. This is a highly significant substantiation, by current testing requirements, of the general adequacy of surface water sources used for produce irrigation in the Western states.

The project provides further evidence of the limited insights that can be obtained by this FIB criterion, based on qualitative pathogen detection in the water sources from at least 6 liters of collected water (per sample), as described in the Work Plan. Seventy-two of the 348 samples (21%) in 2015, and 90 of the 343 samples (26%) in 2016, were positive for either STEC/EHEC or *Salmonella* or both detected in the same sample. Of these positives, the levels of FIB *E. coli* would have been compliant, which further reinforces the limited correlation from a food safety perspective.

The general outcome for Total Bacteroides assessments was the same. In these surface water sources, there was significant variability in semi-quantitative levels detected by the DNA-based methods relative to *E. coli* and pathogen detection. In general, the team demonstrated a better fit of the AllBac genetic marker

assays than the commercial assay kit (Genesig) in relation to E. coli, but neither provided strong predictive fidelity to pathogen detection.

The conclusion from these studies is that either FIB may provide good indication of a recent and high level of fecal contamination of a water source, but neither FIB is likely to provide a strong indication of bacterial pathogens in that water source. Regardless, the industry must implement one of the FSMA PR corrective measures for agricultural water sources, and further development of a standard method for AllBac testing in accredited labs is worth pursuing for the greater flexibility in overcoming sample-to-submission-compliance time barriers encountered by many farms.

It should be noted that the team had fewer than anticipated opportunities to follow the persistence of water-borne pathogens to the irrigated crop in Year 2 of the project because cooperating growers either switched to drip irrigation or to well water or antimicrobial-treated water.

### **GOALS AND OUTCOMES ACHIEVED**

Analysis of more than the original goal of at least 600 surface water samples from diverse fresh produce production districts was completed; this analysis was essential to develop validation data and performance criteria for alternative irrigation water quality standards to the current system based on indicator E. coli. Irrigation, foliar contact, and other agricultural water samples were tested for indicators and bacterial pathogens. The measurable outcome of qualitative and quantitative assessment of these water sources for levels of FIB using four techniques and the associated three pathogen targets (human pathogenic E. coli [STEC and EHEC] and Salmonella) was fulfilled.

Outcome measures were planned for a two-season baseline assessment, and this assessment has been completed.

During the project period a total of 691 water samples were processed, which was an additional 91 samples compared with the original goal of ~600 water samples to be collected for analysis. Interest in the project has been high among specialty crop industry commodity boards and regional produce and horticultural associations. The results showed that the water testing, while required, indicated compliance but did not provide a strong indication of bacterial pathogens in that water source. The adoption of a real-time Total Bacteroides protocol will be partly dependent on the dissemination of the project results; the completion of the project was delayed by many months primarily due to various sampling issues in the spring of 2016. A white paper outlining the project results will be prepared for peer review by the United Fresh Produce Association's Food Safety & Technology Council to assess the support for pursuing the Bacteroides assay as an alternative water quality indicator, with expanded regional studies and interaction with potential test kit developers.

Extensive spreadsheet compilations of all 691 samples have been compiled and verified to provide the individual and comparative data across years and multi-state locations. Data have been analyzed by the FDA-vetted FIB auto-calculator, and multiple data presentations have been prepared for dissemination.

This project resulted in a substantial body of new, detailed data with standardized assays on 691 surface water sources over diverse and numerous locations and times, which greatly increases the knowledge of microbial water quality in key specialty crop regions.

### **BENEFICIARIES**

Multiple stakeholders will benefit from the data developed by this project, including the specialty crop industry and supply-marketing chain, public health agencies, risk modelers, extension educators, and industry associations involved in training and guidance development.

The tens of thousands of growers of fresh consumed specialty crops, both covered by FSMA regulations and those subject to industry-based audit standards will benefit from this project. The potential for changes in the economic impact of agricultural water testing compliance is uncertain as it revolves around rule making and future guidance documents from FDA.

Dr. Suslow (PI), University of California, Davis, presented final research results in June 2016 at the seventh annual CPS Produce Research Symposium in Seattle, WA, to 315 symposium attendees. Interim results were presented previously at the 2015 CPS Produce Research Symposium in Atlanta, GA, to approximately 245 attendees. The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results are available online as follows:

Final reports submitted to CPS (after the June 2016 symposium) are posted on the CPS website: [http://www.centerforproducesafety.org/grant\\_opportunities\\_awards.php](http://www.centerforproducesafety.org/grant_opportunities_awards.php).

CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.

The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the “CPS 2016 Research Symposium Key Learnings” on the CPS website at the following link:

<http://www.centerforproducesafety.org/amass/documents/document/365/CPS%202016%20Key%20Learnings.pdf>.

The following websites provide additional resources on the final reports and symposium proceedings: Center for Produce Safety: <http://www.centerforproducesafety.org/resources.php>

Produce Marketing Association: <http://pma.com/> (e.g., <http://www.pma.com/content/articles/2016/09/2016-cps-research-key-learning>)

Western Growers Association: <http://www.wga.com/> (e.g., <http://www.wga.com/magazine/2012/03/08/2016-cps-symposium-highlights>)

### **LESSONS LEARNED**

The team conducted hypothesis-driven research to determine whether the Total Bacteroides testing would substantially improve the value of water quality testing for growers. While the team believes the assay holds much promise as an improved system, the previously known and further verified low correlation with pathogens in typical surface water sources, within the limits of any survey, has not altered this perspective.

No unexpected outcomes or results were obtained from this project. Outcome measures for this project were achieved.

### **ADDITIONAL INFORMATION**

There is a minor balance remaining: ~\$580 (CDFA) and ~\$10 (WSDA).

Extension and peer-reviewed publications are planned for 2017.

**CONTACT INFORMATION**

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## **PROJECT #27**

**Project Title:** Improving Soil Health for Whatcom County Raspberry Growers

**Partner Organization:** WA State Department of Agriculture

### **PROJECT SUMMARY**

Washington State is the number one producer of red raspberries in the nation, and Whatcom County is the location of the vast majority of Washington's red raspberry farms. In 2017, 75 growers out of a total of 90 growers in Washington State produced nearly 70 million pounds of red raspberries (WRRC, 2017). In addition, Whatcom County is home to 27% of Washington's dairy farms. Dairy manure contains beneficial nutrients essential for crop growth, as well as organic material that improves soil quality by increasing water holding capacity, soil structure, soil fertility, and soil organic matter content. During recent years, acreage previously used for dairy support crops like corn, alfalfa, and grass hay has become available as dairy operations have closed or moved to central Washington. This acreage has a long history of manure applications and high soil organic content. As berry (red raspberry and blueberry) plantings have been established on this acreage growers have benefited from this good soil quality. However, there are food safety concerns surrounding manure applications during flower and fruit development which, combined with weather related limitations on manure application, means that growers have little opportunity to make manure applications when plants are in the field. Generally growers' only opportunity to improve soil quality through manure application is during years when plants are removed and soil is prepared for the next year's plantings. These intermittent applications have limited ability to maintain soil quality, and with no plants in the ground to take up applied nutrients, may result in nutrient leaching to groundwater or runoff to surface water. Over time, red raspberry growers in Whatcom County have experienced decreased planting lifetimes that result in more frequent expenses for field renovation. Contamination of groundwater and surface water with nutrients or pathogens and indicator organisms may eventually result in increased regulation of off-dairy manure applications, which could adversely affect the raspberry industry. If growers were able to make manure applications while plants were in the field, they would have the flexibility to make smaller applications when weather conditions are optimal, with less chance of nutrients or pathogens moving off-farm.

In order to address the problem of declining soil quality and limited resources for growers, WSDA has partnered with WSU to investigate the risk of pathogen transfer to red raspberry leaves and harvested fruit from different soil amendments. The project (which was funded by this award and was extended to include a third year of research, funded by an additional Specialty Crop Block Grant) consists of a field trial involving applications of manure-derived nutrient products. WSU funded treatments of several nutrient sources produced from anaerobic digester effluent through a USDA Conservation Innovation Grant. With this Specialty Crop Block Grant Program award, WSDA and WSU were able to add a treatment of composted dairy manure solids, a product that could be produced in large quantities in the region. All treatments were compared to both conventional fertilization practices (commercial fertilizer only, no manure application) and raw manure applications. The trial is being conducted on a red raspberry farm in Whatcom County by the WSU Whatcom County Extension and microbial analysis is being conducted by Food Science faculty at WSU in Pullman, WA. In addition to the microbial analysis, plant and soil health benefits are being documented by monitoring soil characteristics, the presence of plant pathogens, and any changes in yield.

This project is timely because growers are currently experiencing decreases in red raspberry planting lifetimes. While previously plantings sustained good yields for 7-10 years of production after establishment,

now planting lifetimes are more typically 5-7 years, resulting in increased cost for growers due to increased frequency of field renovation. Demonstrating the safety of composted dairy manure solids in this cropping system would give growers another tool to increase soil health, and potentially reduce the pressure for them to make large, infrequent manure applications with the associated risks to water quality.

This project does not build on previously funded SCBGP project.

## **PROJECT APPROACH**

### **Workplan Activities 1-5**

- Collate and review information that WSDA collects. Plan for information gathering as needed.
- Develop mapping and data analysis tool.
- Ongoing review of academic research on soil quality improvement through use of manure, potential barriers to use, environmental concerns of use, and other relevant technical information.
- Meet with raspberry growers and other stakeholders to gather input on barriers preventing manure use for soil quality improvement.
- Complete initial identification of barriers.

WSDA's Natural Resources Assessment Section already maps all crop fields throughout the state of Washington, including red raspberry fields in Whatcom County. WSDA's Dairy Nutrient Management Program conducts regular inspections of all operating dairies, which includes documenting numbers of milking and dry cows, heifers, and calves present. Manure management practices are also included, such as the presence and degree of solids separation and whether the producer composts. This information can be used to estimate manure and nutrient availability on farm and the proximity of these resources to red raspberry fields. This information is updated on a regular schedule by WSDA and has been compiled into a GIS map containing dairy and red raspberry information that is updated as new information is collected by involved programs.

As part of the ongoing review of academic research WSDA staff attended a number of scientific conferences and industry meetings in order to watch presentations, talk with university and government researchers, and gather industry information. Staff attended the Washington Small Fruit Conference (Lynden, WA) in December 2014, December 2015, and November/December 2016, the Pacific Agriculture Show's Horticulture Day (Abbotsford, B.C., Canada) in January 2015, the Cooperative Extension System's biennial Waste to Worth Conference (Seattle, WA) in March/April 2015, the International Association for Food Protection's annual meeting (Tampa, FL) in July 2017, and the American Society of Agricultural and Biological Engineers annual meeting (Spokane, WA) in July 2017. In addition, WSDA staff has engaged in ongoing review of peer-reviewed literature and state and federal government reports.

WSDA has participated in regular meetings with individual raspberry growers, the Washington Red Raspberry Commission, and WSU and conservation district researchers. Meetings were conducted in October 2014, December 2014, January 2015, March 2015, May 2015, June 2015, October 2015, December 2015, March 2016, April 2016, June 2016, July 2016, December 2016, June 2017, July 2017, August 2017, and September 2017.

WSDA's initial research and meetings with the red raspberry industry indicated that food safety concerns (the potential for pathogen transfer from manure to raspberry fruits) overwhelmingly lead the initial list of barriers identified. Without significant work to address this obstacle, raspberry growers will not have the ability to use any dairy manure or manure-derived products (compost or recovered nutrients). As a result of this initial identification, the project workplan was revised and the collaboration with WSU was developed to conduct the manure application field trials.

### **Workplan Activities 6-12:**

- Raspberry field trial – Year 1.
  - Conduct soil and plant nutrient analysis.
  - Conduct food safety and pathogen testing.
  - Year 1 data analysis.
- Outreach, fact sheet, and planning future work.
- Raspberry field trial – Year 2.
  - Year 2 data analysis – qualitative.

Year 1 field trials, soil and plant nutrient analyses, food safety and pathogen testing, and Year 1 data analysis are complete. Results are summarized here. In addition, WSU's report of Year 1 results to WSDA is attached to this document (Attachment 1).

Surface applications of compost (as conducted in the red raspberry field trials) do not result in measurable soil quality improvements until several years of applications have been conducted. As a result, differences between the compost and conventional fertilizer treatments were not expected after just one year of compost applications. Cane diameter, primocane height, fruit yield, soil pH, bulk density, infiltration rate, soil compaction, plant pathogen populations, and soil chemical analysis (other than nitrate and phosphate) did not show statistically significant differences between compost and conventional fertilizer treatments. Nitrate and phosphate were higher in the conventional fertilizer treatment than the compost treatment on 7/7/16 and 6/20/16, respectively.

Total coliforms, *E. coli* O157:H7, *Listeria* spp., *Listeria monocytogenes*, and *Salmonella* spp were enumerated in soil samples, foliar samples, and harvested fruit samples. Total coliforms were stable in soil samples at 2.5 log<sub>10</sub> CFU from February through the summer, with an increase to 3.5 log<sub>10</sub> CFU in August, which was attributed to soil disruption during harvesting or seasonal variation. Total coliforms were below detection levels on foliage and harvested fruit. There were no detections of *E. coli* O157:H7, *Listeria monocytogenes*, or *Salmonella* spp. in soil, foliar samples, or harvested fruit. There were, however, detections of *Listeria* spp. in soil samples from February through August and on some June foliar samples. Although foodborne pathogens were not detected, that is not a guarantee that they were not present. Pathogens are not uniformly distributed in the environment, and sampling may have missed pathogens that were present.

During the second year of field research, WSU had the opportunity to extend the field research of the project for a third year (originally planned to consist of monitoring only). As a result, WSDA applied for SCBGP funding during the 2017 application cycle in order to extend the compost treatments for a third year as well, which was successful. Because the field trials have been extended, most of the outreach that was planned during this project has been deferred. The majority of the outreach will take place after the conclusion of the third year of field work, when full project results will be available. Outreach activities during this project consisted of the publication of year 1 and 2 results in the Whatcom Ag Monthly, an e-newsletter circulated by the WSU Whatcom County Extension to the agricultural community in Whatcom County. The article is attached to this report (Attachment 2).

Because of the recent completion of the second year of field trials in September, year 2 data analysis is still primarily qualitative in nature. Similar to Year 1, plant characteristics (floricane diameter, primocane height, and yield) were similar between the compost and conventional fertilizer treatments. Soil health indicators were also similar between compost and conventional fertilizer treatments. Pathogen analysis is ongoing.

#### **Workplan Activities 13-15:**

- Irrigation/surface water pathogen monitoring: Planning analysis, sampling schedule, site selection, lab selection and contracting.
- Irrigation/surface water pathogen monitoring: Method development.

- Irrigation/surface water pathogen monitoring: Sampling and analysis.

During the final year of the project additional project activities were planned with surplus funds. A pilot project consisting of irrigation and surface water sampling for indicator organisms, pathogens, and viruses was planned during the spring and summer of 2017. A bid was prepared, a microbiology lab was selected, red raspberry growers willing to allow irrigation water sampling onsite were identified, and a sampling schedule was developed. A sampling trip was conducted during late July of 2017 to identify sampling techniques and required sample volumes, and to confirm that lab performance would meet the project needs.

During September of 2017, samples were collected from irrigation water sources on 6 red raspberry farms and 2 streams. Irrigation water was sampled from 12 wells and 5 ponds. The interior of 2 dripline sections and 2 pipes was swabbed, and 1 dripline section was removed for lab analysis. Water and sediment were sampled at 3 locations on Bertrand Creek and 1 location on Fishtrap Creek. Samples were analyzed for *E. coli* by 2 methods, EPA method 1603 and Quanti-Tray. Pathogen analysis for *E. coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* spp. was conducted by culturing and PCR. Whole genome sequencing was conducted on all samples, as well as conversion to RNA to identify the presence of Hepatitis A and norovirus.

Initial analysis is available for this project, although data analysis of DNA samples is still taking place.

Five irrigation ponds were tested for *E. coli* by method EPA 1603 and Quanti-Tray. Although only 5 ponds were tested, they were sampled in a variety of ways (for example, the surface layer and the bottom) which accounts for the larger number of total samples. In irrigation pond samples (Figure 1) although there were *E. coli* detections, all detections were below the proposed regulatory guideline in the Food Safety Modernization Act (126 CFU/100 mL). The 2 methods tested were similar, although the range of the *E. coli* results by the Quanti-Tray method was larger.

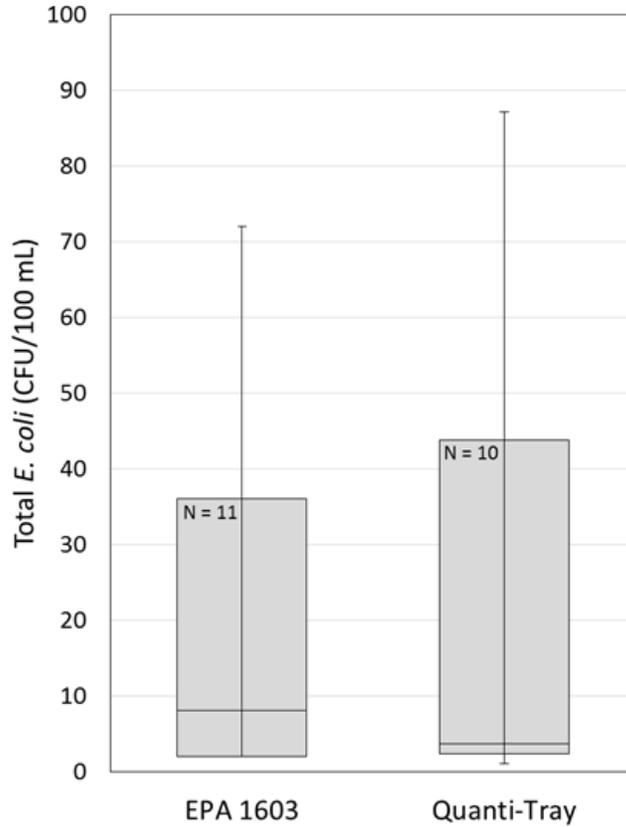


Figure 7. Results from *E. coli* analysis of irrigation pond samples by method EPA 1603 and Quanti-Tray

Bertrand Creek was sampled in 3 locations. One site was near the Canadian border, with a second and third site about 2.5 and 5.5 miles downstream, respectively. Fishtrap Creek was sampled in 1 location, in downtown Lynden, near the bottom of the Fishtrap Creek watershed. The watersheds of both streams contain a large amount of agricultural acreage in both the U.S. and Canada, and both are used for irrigation water withdrawals. Although there were only 4 sampling locations, several locations were sampled multiple times. An analysis of time variability of *E. coli* results has not yet been conducted. *E. coli* detections in streams were much higher than *E. coli* detections in ponds, although again, the 2 methods used were similar, with the spread of the Quanti-Tray results larger than the spread of the EPA 1603 results (Figure 2).

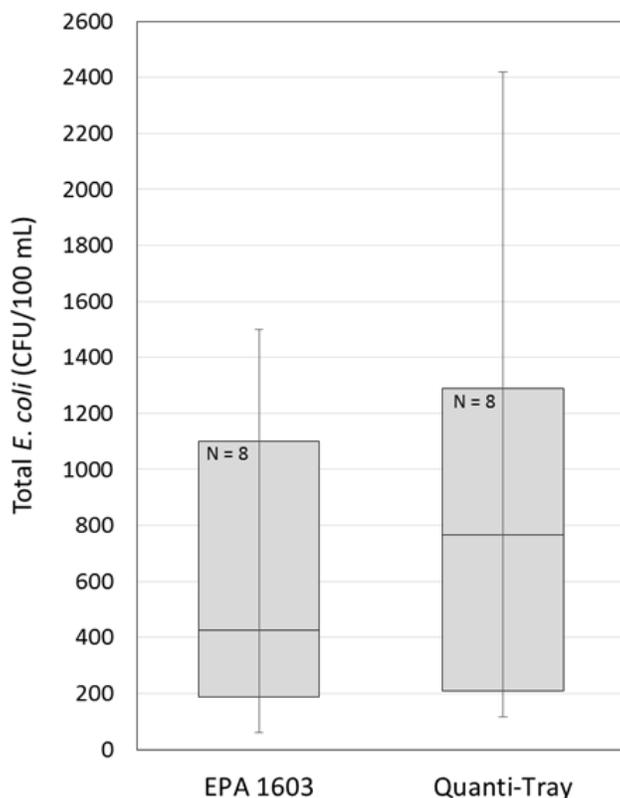


Figure 8. Results from *E. coli* analysis of stream samples by method EPA 1603 and Quanti-Tray

In 13 groundwater samples from 12 wells all *E. coli* results were below the detection limit of the method. Samples from groundwater, streams, and ponds were also tested for the presence of pathogens (*E. coli* O157:H7, *Salmonella* spp., and *Listeria monocytogenes*). There were no pathogen detections in groundwater or pond samples, although there was a detection of *Listeria* spp. in 1 pond sample (not *Listeria monocytogenes*). There were a number of pathogen detections in stream samples; *Listeria monocytogenes* was detected at the lower Bertrand Creek site and both *E. coli* O157:H7 and *Listeria monocytogenes* were detected at the Fishtrap Creek site. In addition to water samples, sediment was collected from all 4 stream sites for pathogen analysis (*E. coli* O157:H7, *Salmonella* spp., and *Listeria monocytogenes*). There were detections of pathogens or related organisms at all sites. *Listeria monocytogenes* was detected in sediment from the middle Bertrand Creek site, while *Listeria* spp. was detected in sediment from the upper and lower sites. Both *Listeria monocytogenes* and *Salmonella* spp. were detected at the Fishtrap Creek site.

No viruses were detected in any water samples, and DNA population analysis is still in progress.

Although sample analysis is still in progress, some initial conclusions can be made based on these results. Based on this limited round of testing, irrigation water currently used in the red raspberry industry would meet the proposed regulatory guidelines of the Food Safety Modernization Act. In addition, the red raspberry industry is already working to manage food safety concerns. Of the 6 growers participating in this study, 3 were using exclusively groundwater. Of the 3 relying on either surface water or a combination of surface water and groundwater, all growers disinfected water before application to crops when fruit was present.

For this project, 20% of samples sent to the lab were collected for quality assurance (QA) purposes. Blank samples (filled in the field with reverse osmosis water) were used to assess the risk of sample contamination

in the field. There were no detections of *E. coli*, pathogens, or viruses in blank samples. Replicate samples (samples collected simultaneously and analyzed by the same method) were collected to assess how consistent sampling methods were. Quantitative analysis of replicates has not yet been conducted, but based on initial qualitative analysis, replicates were in good agreement. Based on this initial review, field and laboratory methods used for this project were sufficient to identify the presence of indicator organisms and pathogens, and samples were not contaminated during collection and transport.

**Workplan Activity 16:** Specialty Crop Block Grant Program reporting: quarterly reports, annual reports, and final report.

All reporting for this project was completed on time, or with deadline extensions approved by WSDA SCBPG staff.

This project could not have been completed without the work of Washington State University researchers who conducted all of the field work and laboratory analysis for the composted dairy manure applications to red raspberries. Chris Benedict (WSU Whatcom County Extension) supervised and conducted the field work, soil analysis, and plant health analysis. Dr. Meijun Zhu (WSU Department of Food Science) conducted the laboratory analysis for pathogens. Chad Kruger (Director, Center for Sustaining Agriculture and Natural Resources) supervised and coordinated the research.

In addition, the irrigation water analysis was conducted with the support of a microbiology lab (Exact Scientific Services, Ferndale WA) where sample analysis was conducted. Kent Oostra, the lab owner, was essential for planning the project and developing sampling procedures.

This project did not benefit commodities other than specialty crops.

### **GOALS AND OUTCOMES ACHIEVED**

In order to achieve the performance goals and Expected Measurable Outcomes of this project, field trials are being conducted by WSU where composted dairy manure solids are applied to mature red raspberry plantings with amounts and timing that would be used for soil quality improvement. Composted dairy manure solids applications are being compared to conventional synthetic fertilizer applications and raw manure applications. Any changes in plant health are tracked through analysis of cane diameter, primocane height, florican quantity, and fruit yield. Improvements in soil quality are expected due to the compost applications, and are being tracked through testing of soil pH, bulk density, infiltration rate, soil compaction, plant pathogen populations, and soil chemical analysis. Differences in the presence of zoonotic pathogens between treatments are being tracked through analysis of soil, foliar, and fruit samples for *E. coli* O157:H7, *Salmonella* spp., and *Listeria monocytogenes*. These applications and analysis have been tracked for 2 field seasons (summer 2016 and summer 2017) and will be continued with separate funding for a third field season (summer 2018). This work is being conducted to achieve Goal 1: “Determine whether moderate applications of composted dairy manure solids elevate pathogen levels on harvested fruit above background levels”. In addition, a separate project was begun to assess whether irrigation was used by the red raspberry industry represents a risk of pathogen contamination. Initial results of that research indicate that it does not. The second goal of this project was “Share research results with growers, processors, and regulators so they can make informed decisions about the safety of manure applications.” This goal is in progress. Additional funding has been secured to extend the compost application trials for a third field season (summer 2018). As a result, only preliminary results are currently available. Much of the outreach is being deferred until the third year of research is complete and full research results can be analyzed and shared. However, these preliminary research results have been discussed with growers in informal meetings and the WSU Whatcom County Extension has published an overview article in the Whatcom Ag Monthly, an e-newsletter that is

circulated to the grower community and posted on their website. This article summarizes the first 2 years of results and is included as Attachment 2 to this report.

The final goal “Identify whether irrigation water represents an additional pathway for contamination of plant tissue or fruit with pathogens” is complete. In order to answer this question, a qualitative study of irrigation and surface water was conducted among red raspberry growers in Whatcom County. Irrigation water sources were sampled at 6 red raspberry farms, in addition to 2 streams in the region that are sometimes used for irrigation. Water samples were tested for *E. coli*, *E. coli* O157:H7, *Salmonella* spp., and *Listeria monocytogenes*. This initial qualitative survey of irrigation water sources did not detect pathogens in irrigation water used by red raspberry growers.

It was initially anticipated that the main Expected Measurable Outcomes for this project would be completed during the project term, but new opportunities allowed the extension of the project for an additional year. This makes it more likely that soil health improvements and related plant health improvements will be observed but does make the accomplishment of the outcome longer term. The first 2 years of the field trial are complete, and funding has been secured for a third field season of research (summer 2018). The outreach and education component of this project has begun with informal communication and e-newsletter publications, and after the completion of the field research in fall 2018, the full dataset will be analyzed and the full results will be publicized to red raspberry growers.

All activities and goals of this project are either completed or in progress. The goal of identifying whether applications of composted dairy manure solids to red raspberries elevates the risk of pathogen detections on harvested fruit is in progress. It was expected that there would be 2 field seasons of research and the research would be completed at this point, but it became possible for WSU to extend their field research for a third season. As a result, WSDA applied for additional funding to conduct a third year of composted dairy manure applications as well. This funding was secured and the third year will take place in summer 2018. The third year of field research makes it more likely that changes in soil and plant health (which take time to develop) will be observed during the project term. In addition, the third year of data collection will allow more opportunity to collect information about pathogen transfer.

The majority of the outreach efforts associated with this project have been deferred to after the summer of 2018, when all of the data is available. However, outreach to publicize preliminary results is taking place with the publication of a WSU Extension article covering the first 2 years of research (Attachment 2). A goal was added while this project was in progress, of determining whether irrigation water sources represent a risk of pathogen contamination on red raspberries. A preliminary study to answer this question has been completed.

The benchmark for achievement of the Expected Measurable Outcomes was providing data where little data is available. Even the preliminary data that has been collected so far is much more than what was currently available and provides growers with information they can use in decision making. When the full dataset and analysis are complete, growers will have reliable information about the risks of composted dairy manure applications in red raspberry cropping systems.

### **BENEFICIARIES**

Red raspberry growers will benefit from the completion of this project. The field trials are still in progress, but, the preliminary results are that the applications of composted dairy manure solids have not elevated pathogen detections on the harvested fruit. If the third field season confirms this result, growers may be able to make moderate applications of this beneficial material on a regular basis, and will experience resultant improvements in soil quality with direct benefits on plant health. Grower’s ability to benefit from this research will depend on their freedom to adopt the practice of regular dairy manure compost

applications, which will depend largely on the willingness of processors to accept fruit from growers making compost applications. The outreach and education component of this project will be essential to inform growers and processors about the results of the study and expand the suite of options growers have to make soil quality improvements.

The irrigation water monitoring study was a preliminary scoping study, but again, red raspberry and other specialty crop growers in the Whatcom County region are the group who will most directly benefit from this information. Although many growers have begun testing irrigation water for pathogen indicators like fecal coliforms and E. coli, little to no testing of irrigation water for pathogens has taken place. This first round of sampling only tested irrigation water at 6 red raspberry farms, but even those results may be useful to growers making decisions about irrigation water source and capital projects (like developing new groundwater sources). Growers who are interested in analysis of their own water sources can use WSDA's sampling methods and procedures as a reference. Other specialty crop growers in the region may also benefit from this data; all groundwater withdrawals in the region are made from the same aquifer and these initial samples have relatively wide geographic distribution throughout the aquifer.

In 2017, there were 75 red raspberry growers in Whatcom County and 90 in Washington State (WRRC, 2017). They harvested crops on more than 9,500 acres in Whatcom County and just over 12,000 acres statewide. The information about dairy manure compost applications in red raspberry cropping systems could benefit all of them. The information from the irrigation water analysis could also benefit additional specialty crop growers, especially blueberry growers, who produce crops on 5,900 acres in Whatcom County. Irrigation withdrawals in the region draw on the same surface and groundwater sources, so information about the microbial water quality in these sources could benefit all specialty crops growers in the region.

### **LESSONS LEARNED**

Scientific results and conclusions of this project are still preliminary. During the first year of dairy manure compost applications no pathogens were detected on harvested fruit in either compost or conventional fertilization treatments. Pathogen analysis of harvested fruit from the second year of field trials is not yet complete. Soil quality and plant health improvements from the dairy manure compost applications have not yet been demonstrated. This result was expected; improvements in soil quality and resultant plant health improvement from surface applications of compost take time to develop. Continuing the field trials for a third year increases the likelihood that these changes will be observed. This work represents a successful research collaboration between WSDA and WSU; the funding provided by WSDA enabled WSU researchers to include the dairy manure compost treatment that would not otherwise have been part of the trial, and WSU's research expertise allowed WSDA to participate in research that it could not have conducted otherwise.

A number of lessons were learned by WSDA staff during this project period. Required WSDA staff time commitment was overestimated. WSDA originally estimated 0.4 FTE of staff time would be required to meet project goals. Because of the partnership with WSU, where field trials and microbiological analysis was conducted by experienced WSU and WSU Extension researchers this time commitment was not needed. The additional funds made available by this time savings were used for the irrigation water sampling. In addition, the time needed for sample analysis and data analysis after each field season was underestimated. Pathogen analysis of samples from the second field season is still pending. The workplan and timeline for the third field season has been planned accordingly, with extended timelines for sample and data analysis after the third field season.

During irrigation and surface water monitoring for indicators and pathogens, groundwater irrigation sources tested for E. coli were all beneath method detection limits (either 1 or 4 CFU/100 mL, depending on method). Irrigation pond samples had E. coli detections, but all pond samples were beneath the proposed

Food Safety Modernization Act guideline of 126 CFU/100 mL. No pathogens were detected in any irrigation water samples, although *Listeria* spp. (not pathogenic *Listeria monocytogenes*) was detected in 1 sample from 1 pond. Pathogens were detected in stream water and stream sediment in both streams sampled and across all samples all 3 pathogens (*E. coli* O157:H7, *Salmonella* spp., and *Listeria monocytogenes* were detected). Analysis of DNA results is ongoing, but neither virus (Hepatitis A or norovirus) was detected in any water or sediment samples. These results don't represent a statistically significant sample, but preliminary qualitative results suggest that irrigation ponds and groundwater are not likely to contain pathogens. The field methods WSDA developed for this sampling project have been demonstrated; there were no detections in field blank samples.

The collaboration between WSDA and the red raspberry industry to conduct the irrigation water sampling follows previous work by WSDA with the red raspberry and blueberry industry on pesticide research. WSDA conducts an ongoing ambient surface water monitoring program in the region for pesticides, and has conducted edge-of-field studies of pesticide drift on blueberry farms with grower cooperation. This project has included growers WSDA had not previously worked with and will help WSDA to identify industry needs for future research and during FSMA implementation.

The only unexpected outcome as an effect of implementing this project was the availability of additional funds and the opportunity to conduct the irrigation water sampling project. WSDA was able to begin exploring another potential pathway for pathogen introduction to red raspberries.

Only 1 project activity identified in the workplan has not been completed. Workplan Activity 15: Irrigation/surface water pathogen monitoring: Sampling and analysis is still in progress. All sample collection and laboratory analysis is complete, but WSDA is still engaged in analysis of microbiological results and information sharing with the individual growers involved and the red raspberry industry as a whole. The irrigation water microbiological sampling was planned to take advantage of additional funds available in the project budget, but project planning and execution was challenging because of WSDA staff limitations and low availability of grower participants during the growing and harvest season. As a result, the sampling was conducted in September 2017, just before the end of the grant term, and the microbiology lab conducting the analysis received a large number of samples simultaneously, which resulted in an unexpected wait for results. Future work will take these limitations into consideration. In addition, the microbiology lab (Exact Scientific Services) has streamlined their sample receiving and processing systems to meet the needs of this and similar projects.

Some Expected Measurable Outcomes were modified during the project term or are still pending. Goal 1 (Determine whether moderate applications of composted dairy manure solids elevate pathogen levels on harvested fruit above background levels) is still in progress. Initial results are available (from the first year of field trials). The time required for pathogen analysis was longer than expected, so results from the second year of field trials are not yet available. An opportunity arose to extend the field trials for a third year, with separate funding, which will provide valuable additional data. Final results will not be available until after those trials are complete (in summer 2018). Because of the time needed for sample analysis, the project plan for the third year of field trials includes an entire year after the conclusion of the field trials for completion of sample and data analysis. Goal 2 (Share research results with growers, processors, and regulators so they can make informed decisions about the safety of manure applications) has been partially deferred until the conclusion of all 3 years of field trials. However, results from the first 2 years of trials have been shared informally with growers and through a WSU Whatcom County Extension article published on the Extension website and in an e-newsletter circulated to growers. Goal 3 (Identify whether irrigation water represents an additional pathway for contamination of plant tissue or fruit with pathogens) is complete. An initial qualitative survey of irrigation water sources did not detect pathogens in irrigation water used by red raspberry growers.

**ADDITIONAL INFORMATION**

WSDA provided matching funds of \$21,585 for indirect costs for staff working on this project.

Two publications are attached to provide additional information:

Attachment 1: WSU report to WSDA, Year 1 results

Attachment 2: WSU Extension publication, [Using Compost as a Soil Amendment in Red Raspberries](#)

References

[WRRC] Washington Red Raspberry Commission. Statistics: PNW Red Raspberry Production. <https://www.red-raspberry.org/statistics>. Accessed December 6, 2017.

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**See Attachment F- 2014 SCBGP-FB**