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PART ONE

PROJECT #1

Project Title: Cherry Powder Placebo Development

Partner Organization: Washington State Fruit Commission (WSFC)

PROJECT SUMMARY

The purpose of this project was for the Washington State Fruit Commission (WSFC) to utilize funds from the Washington State Department of Agriculture (WSDA) Specialty Crop Block Grant (SCBG) program to develop a freeze-dried placebo cherry powder. This placebo powder would then be used for testing in human trials against actual Bing cherry powder. The lack of a placebo powder, as well as a standardized cherry powder, has constrained the Washington State cherry industry's ability to conduct health and nutrition research on sweet cherries. The intention of this project was to create a placebo that would match a standardized cherry powder product that WSFC was, at that time, in the process of developing. The placebo powder would match the standardized cherry powder in terms of taste, smell, consistency, and caloric content, but would be absent of any whole cherry or cherry components. This placebo would then be available to utilize in trials along with the WSFC cherry powder, and serve to demonstrate the health and nutrition benefits of consuming sweet cherries.

The Washington State cherry industry has been investing in health and nutrition research since 2005. However, each study that has been conducted since then has cited the lack of a standardized product as a limiting factor. Furthermore, this impacts the timing of when research studies can be conducted, given that Washington fresh sweet cherries are unavailable year-round. Prior to the funding of this SCBG, WSFC funded a study on the effects of cherry consumption on prostate health in men. However, the research timeline was delayed due to a lack of available product, and variances in anthocyanin content contributed to gaps in study findings. Researchers agreed that a standardized product and a placebo were necessary if WSFC were to have success in its health research efforts. Furthermore, with growing production, the Washington State cherry industry is concerned about building lasting demand for fresh sweet cherries in the U.S. and abroad. Communicating the health benefits of consuming cherries is seen as a key market development strategy, and WSFC would like to make investments in this area to solidify cherries' position as a healthy option for consumers.

At the time this project was proposed, WSFC was in the process of developing a standardized cherry powder using industry funds. WSFC then sought assistance from the WSDA Specialty Crop Block Grant program to fund the development and production of a placebo powder, a critical step towards the successful execution of research studies. Because additional research studies could not take place without the development of a placebo, this project was of great importance to the industry and its health and nutrition research efforts.

This project was new and did not have links to previously-funded SCBGP projects.

PROJECT APPROACH

In October 2013, upon approval of the project, WSFC contracted with the United States Department of Agriculture's Agricultural Research Service (USDA/ARS) to begin formulation of the cherry placebo. The standardized cherry powder, which was developed independently by WSFC, was sent to USDA/ARS for analysis. From October 1, 2013 through October 31, 2014, WSFC worked with the USDA/ARS Western Human Nutrition Research Center (WHNRC) to develop the formula for the placebo powder. Dr. Tara McHugh at the USDA/ARS consulted with Don Olson, a food technologist, to develop a powder that matched the standardized cherry powder product in terms of taste, smell, consistency, and caloric content when dissolved in water. As a result of their work, a formula for the placebo powder in addition to a standardized freeze drying process was completed in August 2014.

In November 2014, WHNRC assessed how the placebo reacted in the planned water soluble delivery method when compared to the cherry powder, completing the first phase of the approved Project Plan. The results of this test are crucial for researchers preparing samples for participants in advance of consumption. Several experiments were conducted, and the placebo tested positive for the presence of soluble phenolics. Follow up experiments resulted in the identification of maltodextrin as the cause of the false positive. In addition, the USDA/ARS conducted a side-by-side comparison of the anti-oxidant content and total soluble phenolic content of the cherry powder and placebo. The placebo was found to contain no anti-oxidant content.

Following the favorable outcomes of both tests, WSFC selected Columbia Phyto Technology (PowderPure) as the powder manufacturer. Columbia Phyto Technology (PowderPure) was the producer of the standardized cherry powder and this allowed for consistency in product development for the placebo. However, the processes of obtaining a quote

for production of the placebo powder proved to be an arduous and time consuming process. Under WSFC's original timeline, the placebo was to be produced by October 2014 with RFPs issued to potential researchers starting in November 2014. However, because of the change in how the final product will be administered (in a water soluble form rather than in powder form), additional formulation was required. This delayed the timeline and ultimately the placebo was not produced until May 2016. The formulation was tweaked to ensure that all differences between the cherry powder and placebo were minimized. Furthermore, additional reformulation was required to ensure that the powders did not clump, and the final processing was completed in August 2016. The placebo and cherry powders are now ready for packaging and WSFC is working to identify a packer that can work in a temperature-controlled environment and insert the powder into 25-gram metal film bags. Once packaged, these powders will be available for future research studies.

Despite the delays in the manufacturing of the placebo powder, the WSFC and the California Cherry Marketing & Research Board (CCMRB) convened a one-day Health & Nutrition Committee (HNC) meeting and a gathering of the sweet cherry industry's Scientific Advisory Board (SAB) on January 8, 2015 at the UC Davis Western Human Nutrition Research Center. The meeting was organized to gain consensus from the SAB and industry to identify top health research objectives and receive feedback on the development of a Request for Proposal that will be utilized for research that will be conducted using the powders. The objectives and feedback laid out will be instrumental in advancing the sweet cherry industry's research agenda once the powder is packaged in the 25-gram bags. While it finalizes arrangements related to packaging, WSFC is already overseeing an initial study with the bulk powder.

Through a separate WSDA SCBG, in the 2015 funding year, WSFC entered into a contract with Texas Agricultural & Mechanical University to begin conducting research as soon as the powders were available for use. Research is currently ongoing, and progress will be reported in the Annual Performance Report for that grant.

Researchers at USDA/ARS played the primary role in development of the placebo powder formula. The USDA/ARS team has experience developing similar placebos for other fresh fruit products. USDA/ARS's work on this project was completed on March 31, 2015.

Another partner that has an interest in WSFC's health and research efforts is CCMRB. Together, WSFC and CCMRB representatives participate in joint meetings to discuss research priorities that affect the entire cherry industry. When available, results of research studies will be communicated to these groups at future SAB and HNC meetings.

After formulation of the powder, WSFC selected Columbia Phyto Technology (PowderPure) as the manufacturer of the placebo powder formula. The WSFC's primary contact at this company changed abruptly, delaying the negotiation of the contract. Nevertheless, in September 2015, through constant communication initiated by WSFC, a plan was put into place to move forward with the development of the powder. The powder was produced in May 2016 and Columbia Phyto Technology (PowderPure) worked to tweak the formulation to prevent clumping, as well as match the placebo to the cherry powder. Columbia Phyto Technology (PowderPure) is now working with WSFC to determine an acceptable packaging solution for both powders. Once packaged, these powders will be available for future research studies.

Because of the nature of this project, it has only benefitted the fresh sweet cherry industry.

GOALS AND OUTCOMES ACHIEVED

As outlined in the project proposal, this project had three goals:

1. To generate interest among the scientific research community to conduct research on the health benefits of eating fresh sweet cherries
2. To increase media publicity about the health benefits of eating fresh sweet cherries
3. To increase sales of Washington State fresh sweet cherries

In order to achieve performance goals and Expected Measurable Outcomes, WSFC focused on completing project activities within designated timeframes. Unfortunately, these objectives were not met due to delays in manufacturing the powder. That being said, the most fundamental component of this project was the development of the cherry placebo powder. As a direct result of this grant, WSFC was able to formulate and produce the placebo powder to be used in research trials. Ultimately, WSFC now has the foundation in place to meet the above objectives, and plans to do so, albeit after the grant period has concluded.

While no measures have been met at this time, significant progress has been made to enable WSFC to conduct future research trials on fresh sweet cherries. The development and manufacturing of a placebo powder is a critical step towards conducting successful research projects. WSFC has already applied and received funding for another WSDA SCBG project to conduct research on the effects of cherry consumption on modulation of intestinal bacterial populations,

inflammation, and obesity markers. WSFC plans to meet the Expected Measurable Outcomes and will report progress through the Annual Performance Report for that grant project.

Project Activity	**Responsible Party**	**Timeframe Completed (*month and year*)**
Contract with USDA/ARS initiated	WSFC	October, 2013
Standardized cherry powder samples sent to USDA/ARS for analysis	BCI and USDA/ARS	October, 2013
Analysis, sensory testing, and product formulation	USDA/ARS	November 2013 – March 2015
Placebo manufacturing partner identified	BCI	December 2014
Placebo produced	PowderPure	January 2016
Final sensory tests conducted and placebo available for use	USDA/ARS	May 2016
Proposals selected and placebo distributed	BCI and WSFC	March 2016
Interim report prepared with results for Goal 1 provided	BCI	November 2015
Project completed and final report written which includes Goal 2 and Goal 3, along with any update on Goal 1.	BCI	November 2016

Much of the project plan has been completed, as outlined above. Additional steps that remain, as noted, have encountered unexpected delays. Remaining work plan activities include: packaging the powders, issuing a Request for Proposal to qualified research institutions, selecting researchers and distributing the placebo, conducting research, and publishing research results. WSFC plans to complete all project activities within the work plan and achieve project goals, though not within the grant period.

The Expected Measurable Outcomes for this project were designed to take place after the placebo is produced and packaged. At the end of the grant period, the cherry powder and placebo had not yet been packaged, and therefore research utilizing these powders was unable to begin under this grant. Because of this, there are no key results to report at this time. However, achievement of the targets set in the proposal will still come after the conclusion of this grant period. Despite the delays (discussed above) which prevented multiple research projects to be completed and reported on during the grant period, WSFC has already initiated research into the effects of sweet cherry consumption on gut health (with the support of a SCBG in FY15). The placebo powder is a critical component for this project. Although it has not been packaged yet, WSFC was able to send a portion of the powder to the researcher at Texas A&M University so that studies may begin on the impact of sweet cherry consumption on obesity-related disorders. Furthermore, more studies will be conducted after the powder has been individually packaged. Ultimately, this will form the basis for scholarly findings that WSFC anticipates will generate media interest and increased sales of fresh, sweet cherries.

Upon the completion of the ongoing research, WSFC expects to garner approximately $500,000 in media discussion about cherry health benefits. Given that the timeline for research has been extended, this will take some time to achieve. Successful research studies will contribute to market development efforts, and ultimately increase the sales value of Washington State fresh sweet cherries. WSFC expects that this will begin providing significant impact to cherry sales during the 2018 season (once initial studies are completed and results are publicized).

BENEFICIARIES

While no research studies have been completed yet, this project was an important step towards that goal. This project directly affects 1,480 sweet cherry growers in Washington State who produce around $600 million worth of cherries each year. Development of a cherry placebo, a critical component for cherry research and nutrition trials, will allow WSFC to conduct studies that aim to prove health benefits of consuming fresh cherries. Positive study results will be an important marketing tool and will affect the entire Washington cherry industry.

As previously indicated, this project benefits sweet cherry growers who produce around $600 million worth of cherries each year. Successful research and nutrition studies will contribute to an increase in consumer awareness and demand for Washington sweet cherries. Furthermore, WSFC expects that positive health benefits evidenced by research studies could drive a 10% increase in crop value.

LESSONS LEARNED

Even with appropriate planning, projects can nevertheless encounter interruptions or delays. For example, this project encountered delays in the beginning phase with the formulation of the cherry powder. Additional interruptions included negotiating a contract with a manufacturer and additional powder reformulation before the manufacturing could begin. Furthermore, unexpectedly, finding a packer for the placebo and cherry powders has been quite challenging. While a crucial part of the project, it is not something that was anticipated to be a difficult task. To keep the integrity of the

powders intact, a specialized packaging process is required. Many packers have been unwilling to take on such a small project and therefore the powder remains packed into 15 kg boxes at this time. Ultimately, WSFC needs to have the powders packaged into 25 gram packets for easy use in research trials. WSFC is exploring alternative packaging options, and remains optimistic that this part of the project can be completed, albeit not within the grant period. Most importantly, WSFC now has key components needed to conduct future research on cherry nutrition benefits. This project has laid the foundation for success in cherry health research efforts.

No unexpected outcomes or results were observed in the implementation of this project.

While the goals and outcomes have not yet been achieved, WSFC has taken important steps to further the soundness of cherry research efforts through the formulation and development of a cherry placebo powder. The goals outlined in the project proposal have not been met during this particular grant timeline, but will certainly be met in the foreseeable future. WSFC has already taken steps to ensure that the placebo powder and standardized cherry powders are being used in research efforts funded with the support of a separate WSDA SCBG project. In terms of "lessons learned", this project is a great example of why it is important to remain adaptable as timelines shift. Furthermore, delving further into miniscule details of a project before implementing it may help predicting challenges before they arise. Finally, having a backup plan to fund and advance project efforts after the conclusion of the grant period, if needed, is critical to ensuring that the overall impact remains positive and significant.

ADDITIONAL INFORMATION

WSFC has utilized $38,982.80 in SCBG funds towards this project. WSFC has contributed $26,000 in industry funds and another $10,000 in in-kind contributions towards the completion of this project. Funds were utilized to develop and manufacture the cherry placebo powder. It is expected that WSFC will spend additional funds to complete the packaging of the placebo and cherry powders following the submission of this report. Because a packer has not yet been identified, the amount of additional industry expenditures is not known at this time; however, contribution already exceeds the match that was indicated in the project proposal.

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PROJECT #2

Project Title: Reverse Trade Mission – Canada and China

Partner Organization: Washington State Wine Commission (WSWC)

PROJECT SUMMARY

This project primarily sought to address the issue of too few Washington State wines available in high potential export markets, as well as the need for a more robust, coordinated effort to capitalize on the opportunities for wine tourism with foreign visitors. Washington's state wine industry has an $8.5 billion economic impact on Washington State's economy and supports more than 14,000 jobs in the State, but exports only total approximately 2% of annual wine production. By contract, California wineries export approximately 16% of their wines. The WSWC targeted improved sales and tourism from Canada and China for this project, because those two markets have the highest potential for Washington wine.

The project was important and timely because, in spite of the accolades that Washington wines receive, awareness among trade, media, and consumers overseas is limited. As a result, sales, distribution, and wine tourism are limited too. Thus, at the time of application, only 20 Washington State wineries (out of 750) had distribution in Canada, and only 13 had distribution in China. These numbers are low, but actually represent a significant increase compared with prior years. Interest in Washington wines in both markets is growing, thanks to targeted marketing outreach. But a more comprehensive program was important to generate more significant attention for the Washington producers. Moreover, it was timely because the Washington State wine industry is not the only wine industry seeking to expand sales in Canada and China. Wine associations from around the world, including both those representing Old World European producers and New World producers are focusing their attention on these high-potential markets. Without a robust program to bring influential trade and media to an event like Taste Washington, the WSWC risked missing an opportunity to increase its market share through more sales, distribution, and wine tourism.

This project did not build upon a previous SCBGP-funded initiative.

PROJECT APPROACH

Below is a summary of tasks by target market.

Canada

The WSWC hosted six major wine journalists from the provinces of British Columbia, Ontario, and Quebec. Combined, these three provinces represent approximately 80% of the Canadian wine industry. One of these journalists arrived in advance of the Taste Washington wine tasting event and visited several wineries in Eastern Washington. The others arrived for Taste Washington and focused their attention on learning about Washington wines at the event itself. Their visit included not only significant tasting opportunities with 200 wineries pouring, but also educational opportunities through seminars and two wine-and-food pairing dinners with WSWC staff and representatives.

China

The WSWC hosted 11 members of the Chinese trade and media, primarily from Shanghai but also from other cities where Washington wine has distribution. In contrast to the Canadian delegation, there was a greater focus on trade because Washington wine has less of a presence in the Chinese market. Participants arrived for the Taste Washington wine tasting event, and as with the Canadian group, also gained the opportunity for education through seminars and wine-and-food pairing lessons through meals with WSWC staff and representatives. After Taste Washington, the majority of attendees visited four wineries in Washington State to gain a greater understanding of the wine production process and the unique nature of the Washington State wine industry.

The visit yielded gains in both trade and distribution. Export growth is discussed in the sections below. Regarding media, the following articles were prepared as a direct result of the project:

(1)Kurtis Kolt in Westender Vancouver (53,671 circulation, valued at $10,000)
(2)Bill Zacharkiw in Montreal Gazette (116,446 circulation, valued at $10,000)
(3)Ruby Gao in Shanghai Daily (100,000 circulation, valued at $20,926.58)
(4)Beijing TV News Live Beijing Segment (estimated 50,000 viewership, valued at $2,575.58)
(5)Monica Zhu in Modern Weekly (estimated 50,000 circulation, valued at $10,000)
(6)Monica Zhu in Restaurant Review (estimated 50,000 circulation, valued at $10,000)
(7)Monica Zhu in Horizon (estimated 50,000 circulation, valued at $10,000)
(8)Monica Zhu in Urban Space (estimated 50,000 circulation, valued at $10,000)

The WSWC had several key contributors to this project, including the United States Department of Agriculture (USDA)'s overseas staff, Visit Seattle, Nantel & Associates (the WSWC's retainer-based contractor), and several Washington State wineries. In order to select the most influential trade and media for the reverse mission, the WSWC took nominations from the USDA Agricultural Trade Offices (ATO) in Shanghai and Hong Kong, as well as Nantel & Associates and Washington wineries. Because of the quality of the nominees, the WSWC decided to expand the size of its mission and fund 17 guests (6 from Canada and 11 from China) through SCBG funds. ATO Shanghai assisted with travel logistics for some of the guests, which ensured they could participate. Visit Seattle provided interpretation for the three non-English speaking guests from China. Nantel & Associates helped host the visitors from Canada, and four Washington wineries (Columbia Crest, Hedges Family Estate, Milbrandt Vineyards, and Chateau Ste. Michelle) hosted guests from China following Taste Washington, to give the trade and media visitors an opportunity to see Washington wine country firsthand.

The project did not benefit commodities other than wine grapes.

GOALS AND OUTCOMES ACHIEVED

The activities that were completed as part of this project were all described in the previous section. They included participation in Taste Washington, seminars, wine dinners, and a tour of Washington wine country. The trade and media visitors were selected thanks to their influence in the Canadian and Chinese wine markets, and their ability to position Washington wine brands for exposure and new business. Ultimately the goals for the project were to support new distribution and attention for Washington wines in both countries.

The Expected Measurable Outcome goals for the project were (1) Washington wineries with distribution in Canada and China will expand significantly, (2) Washington wineries will report increased sales as a result of new distribution agreements that greatly exceed cost of activity, (3) Online and print articles secured through activity will expose consumers to Washington State wine industry, (4) Online and print article advertising value equivalent secured through activity will greatly exceed cost of activity, (5) over half of tasting room managers will report an increase in Canadian and/or Chinese visitors over a two year period.

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

A comparison of the activities and goals established for the project and the actual accomplishments are listed below:

Expected Measurable Outcome	Goal	Baseline	Actual
Washington wineries with distribution in Canada and China will expand significantly	70	33	55
Washington wineries will report increased sales as a result of new distribution agreements that greatly exceed cost of activity	$300,000	0	$5,468,055
Online and print articles secured through activity will expose consumers to Washington State wine industry	1 million consumers reached	0	520,117
Online and print article advertising value equivalent secured through activity will greatly exceed cost of activity	$200,000	NA	$83,502.16
Over half of tasting room managers will report an increase in Canadian and/or Chinese visitors over a two year period	55%	NA	~100%

WSWC's project expanded distribution, generated media, and increased wine tourism in Washington State. With respect to distribution, the number of wineries exporting to Canada and China increased by 67% during the lifetime of the project. While this expansion did not quite reach the goal set at the beginning of the project, it is still a significant success for the Washington wine industry. At the same time, the value of exports more than exceeded the goal thanks to new, high-value distribution in Canada and China.

Meanwhile, the goals set for media were estimates that turned out to be overly ambitious. WSWC's generated eight quality media placements, reaching an estimated 520,117 people with a value of $83,502.16. The placements were primarily in leading trade and lifestyle magazines that are critical for expanding awareness of the Washington State wine industry. Thus, WSWC's remains satisfied with the media results. Finally, the WSWC has learned from its

wineries that international tourist visits are increasing with China in particular having a large increase. While this information is anecdotal, it demonstrates that Canadian and Chinese wine tourism has increased following from the project.

The Washington State wine industry in general benefited from the project. Hundreds of wineries had the opportunity to share their wines with the visiting trade and media at Taste Washington. Meanwhile, the visitors also had the opportunity to obtain more in-depth knowledge about Washington State wine via educational seminars, winery visits, and wine and food pairing dinners.

The project helped ensure that (1) wineries that exported before saw demand increase in Canada and China, (2) wineries that were looking to export had new distribution opportunities and began exporting to the target markets, and (3) non-exporting wineries benefited from media exposure and the expansion of wine tourism.

As discussed in the Expected Measurable Outcomes section above, the project generated eight high-quality media placements that reached an estimated 520,117 people. The value of these placements is estimated at $83,502.16. Meanwhile, during the time period of the project, the number of Washington State wineries exporting to Canada and China increased from 33 to 55. Many of exporters developed strong relationships with their importers, which led to the value of wine exported rising more than $5 million.

LESSONS LEARNED

A key lesson learned was the importance of effective planning and a strong nomination process for the reverse trade mission. WSWC began preparing for the visit months in advance, which allowed it to develop a robust agenda and select the most influential candidates in each target market. As a result, the visit was a success at advancing the interest of the Washington State wine industry.

Managing the logistics of the visit could have been streamlined in certain areas. Specifically, the WSWC allowed attendees to RSVP after its initial deadline. This led to a higher-than-expected number of participants on the reverse trade mission. In addition, the WSWC did not build in winery visits until late in the process. Winery visits are important for reverse trade missions and should have been included in the project proposal. Instead, those visits were not covered by SCBG funding.

There were no significant unexpected outcomes or results from the project. The WSWC successfully implemented the reverse trade and media missions in both markets and there was solid interest among participants. As expected, the project generated interest, distribution, and media exposure for Washington wineries in Canada and China. This is not only evident from the data that has been reported to date, but should also result in gains in the coming years as some of the reverse trade mission participants essentially become ambassadors for Washington State wine.

As discussed above, three of the expected measurable outcomes were not attained. Despite this, all three results for these outcomes were successes for the Washington State wine industry. Distribution increased 67%, while eight significant media hits were generated. Thus, the key lesson learned for WSWC is to set goals that are not only aggressive but also attainable.

ADDITIONAL INFORMATION

The WSWC, along with its partner Visit Seattle, met the matching commitment to this project. Contributions totaled $26,398.86.

For its cash match, the WSWC contributed $9,398.86 in wine, dinner, and hotel charges that were not paid for with grant funds. For its in-kind match, WSWC staff and contractors devoted $12,000.00 in time (approximately 120 hours in salary/benefits) to activity planning, coordination, and implementation. Visit Seattle staff devoted $2,000.00 in time (approximately 20 hours in salary/benefits) to activity planning, coordination, and implementation, and also covered 20 hours of interpretation services valued at $3,000.00 for Chinese guests.

Bill Zacharkiw: Washington needn’t stand in California’s shadow

BILL ZACHARKIW, GAZETTE WINE CRITIC 04.10.2014 |

About as green as it gets. Washington State's southeastern grape growing regions, like Red Mountain, are technically deserts. B I L L Z A C H A R K I W / T H E G A Z E T T E

For up and coming wine regions, creating an identity can be a tough slog. Choosing the appropriate grapes for a particular climate and soil can take a long time. Vines take years to establish themselves, so any change of course is a time-consuming, and costly, endeavour.

Washington State is well into this process and for the most part has done a pretty solid job. I first visited this northwestern state, which is second to California in terms of wine production in the U.S., in 2008, and left feeling pretty bullish. After spending a week there recently, I'm even more so.

I tasted Bordeaux styled blends that were worthy of the reference to the fabled French region. The Rhône grape varieties — syrah, grenache, mourvèdre, counoise, cinsault — were arguably even better, as well as being unique and interesting. The same could be said for many of the whites. I tasted some very good viognier, grenache blanc and riesling. All good, and at times, really good.

The one greyish cloud was the reliance on the state's most planted red grape, cabernet sauvignon. I did taste some great examples. But in many instances the results were excessively tannic wines that left me staring bleakly into my glass, wondering why there wasn't more of that delicious syrah, or some other Rhône styled blend.

I was reminded by a few winemakers that "nobody" in the U.S. drinks
syrah: If you can't sell it, then why grow it? I would argue that it's a long-term investment, because people will eventually figure out that syrah really isn't all that different from cabernet sauvignon. Then, Washington State will be leading the way. But I don't pay the bills.

I also got a sense that there exists a bit of a complex with respect to California winemakers, who have made their name with cabernet. Despite the fact that there is little to compare the two states when talking grape growing conditions — latitude and soils in particular — I heard California comparisons uttered way too many times during my visit.

Winemakers seemed almost apologetic when talking about cooler vintages like 2011, when in fact the wines were in many cases absolutely stellar, unless of course you were looking to make a California-style wine. All too often, I felt as though many winemakers were trying to squeeze too much out of the grapes, rather than making the more elegant and finessed wines of a cool growing season.

Ultimately, it's a case of moving beyond what kind of wine you "want" to make, and accepting what kind of wine most authentically represents the land, soil and vintage. But that is coming. So while the fine tuning continues, here's what Washington State has going for it.

The vast majority of grape growing happens in the Columbia Valley, which covers 4.4 million hectares of land (about nine times the size of Montreal). Due to two coastal mountain ranges, which keep Seattle and other coastal areas drenched, the interior is starved of rain. Some sub-regions are technically deserts with less than 30 centimetres of rain per year. So irrigation is necessary nearly everywhere. But because of the lack of humidity, there is very little disease pressure.

One thing I didn't realize was that Washington State has little or no phylloxera, the sap-sucking insect that wiped out vineyards across the wine world.

This is due to the soils, which tend to be predominately silt and sand on top of basalt (hardened lava), which the little pests hate. So much of the state's vines are planted on their own roots, which puts Washington State in a very small group of wine growing regions. Is it better? When I tasted at Cayuse, one of my favourite wineries in Washington, I much preferred the wine made from the original rootstock grapes.

Washington State also has a unique mix of latitude, altitude and heat. Like many of the world's top growing regions, the higher latitude means long summer days filled with sunlight to ripen grapes. The altitude means cool nights that allow grapes to keep their acidity. Summer temperatures, however, can reach over 37C, which can make vines shut down and stop ripening.

This might be one of the reasons cabernet and merlot, which aren't heat-loving grapes, aren't always the best choice. Conversely, syrah, mourvèdre, counoise and other Rhône grapes can flourish in this climate.

One of the particularities of the wineries in Washington State is that they tend to source grapes for their wines from a number of different sub-regions. Most of the wines I tasted used the broad Columbia Valley AVA (American Viticultural Area) on the label. An AVA is much like a European appellation, though it only defines the geography of a region. European appellations rules about which grapes you can grow and deal with such qualitative issues as yields.

The most memorable wines I tasted during my trip were sourced from grapes grown solely from the smaller AVAs that make up the larger Columbia Valley AVA. The Hedges syrah from Red Mountain and Cayuse single vineyard Bionic Frog syrah from "The Rocks," are two examples of great syrah. The Ancient Lakes region is the source of some exceptional riesling, and Sleight of Hand made one of my favourites.

My favourite AVA was Yakima Valley. Located on the western side of the Columbia Valley, its cooler temperatures and higher altitudes made for some pretty elegant wines.

The Bordeaux styled blends from Fall Line Winery, Eight Bells and Côte Bonneville were phenomenal. The grenache blanc from Two Vintners was a model of finesse.

So maybe the next step is really dialing down and making more wines from the smaller AVAs to really show the character of these sub- regions. However, many already are. Here's hoping that even more will embrace what they have, because in many ways, it's pretty special.

The writer was a guest of the Washington Wine Commission. The organization did not review or approve this article.

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You can hear Bill Zacharkiw talk about wine on CHOM-FM (97.7) every Friday at 7:45 a.m.

A few choice growths from the Evergreen State Riesling 2013, Kung Fu Girl, Charles Smith Wines, Washington State white, $19.65, SAQ #11629787. Nice balance between riper fruit, with tropical notes of pineapple and peach. Minerality is there, subtly pumping and driving the wine. A hint of lime rind bitterness on the finish balances out the sweet fruit. Great job. Serve at 6-8C. Drink now-2016. Food pairing idea: apéritif, spicy seafood stir-fries.

Hedges C.M.S. 2012, Sauvignon Blanc/Chardonnay/Marsanne, Washington State white, $20.20, SAQ #11035655. Sauvignon blanc dominates the blend with its blend of citrus and herbal notes. But then the chardonnay and marsanne add some richness to the finish. Easy drinking and totally dry. Serve at 8-10C. Drink now-2015. Food pairing idea: apéritif, mussels.

Riesling 2011, Eroica, Chateau Ste-Michelle, Washington State white, $28.50, SAQ #10749681. Nice to see this wine evolve over the years. Lemony pineapple, just a hint of residual sweetness, mineral, juicy. I tasted a 2008 recently and these wines evolve nicely. Serve at 8C. Drink now-2017. Food pairing: apéritif, Thai curries with coconut milk.

Syrah 2012, Boom Boom, Columbia Valley, Charles Smith Wines, Washington State red, $24.65, SAQ #11208561. Well named. No lack of power, but not overblown, and the fruit stays pretty fresh. Reminds me of a Crozes-Hermitage, though with darker fruit. The peppery spice, bacon, add to the depth. Oak is nicely integrated with none of that excessive vanilla. Serve at 16-18C. Drink now-2015. Food pairing idea: braised beef, leg of lamb.

Syrah 2010, Columbia Valley, L'École No 41, Washington State red, $33.25, SAQ #10709030. Shows the fruit-driven style of western

Washington State. This is pure fruit with blackberry and dark raspberry with spice on the finish. Tannins are soft and cuddly, but with a vibrant acidity. Serve at 18C. Drink now-2018. Food pairing idea: grilled steak, pepper sauce.

Red Willow 2009, Yakima Valley, Fall Line Winery, Washington State red, $38, SAQ #12185575. In the spirit of a Saint-Émilion, this cabernet franc and merlot dominated blend is a beautiful example of the cooler Yakima region. Despite the ripe and complex fruit, there is an underlying minerality that grounds the wine, keeping it fresh. The tannins, ripe yet grippy, give great length. Beautiful wine. Serve at 18C. Drink now-2020. Food pairing idea: lamb chops, filet mignon with spice.

WESTENDER
EVERYTHING VANCOUVER

APRIL 18, 2014

CITY CELLAR: FIVE-STAR WINES FOR YOUR WEEKEND
Kurtis Kolt — Westender

1. Charles Smith 2. Franc Arman 3. Le Vieux Pin 4. Domaine Maby 5. Barda

Whether jotting notes of wines I'm tasting in a Moleskine notebook or tapping away on my iPhone, I'll usually star particular wines that I think would be good to share in this column. When I look to profile a certain grape variety, region, style or theme; they almost always slide into place. Too often though, there are a handful of starred bottles that I haven't been able to pigeonhole into a particular theme, but they hover top of mind nonetheless. This week, a handful of those wines for you, with nothing in common except being delicious, charismatic, and dinner table-worthy.

Charles Smith 2012 Kung Fu Girl Riesling | Columbia Valley, Washington | $19.99 | BC Liquor Stores
Year in, year out, this is one of those wines you can always count on. Crisp and shimmering with candied lemon, grapefruit, pomelo and lemongrass. Don't dismiss Charles Smith's celebrated Riesling because the label's so fun and cheery; that's exactly the way Riesling's supposed to be. This highwire act between dry and off-dry will have you grabbing for chopsticks and anything they traditionally tuck into.

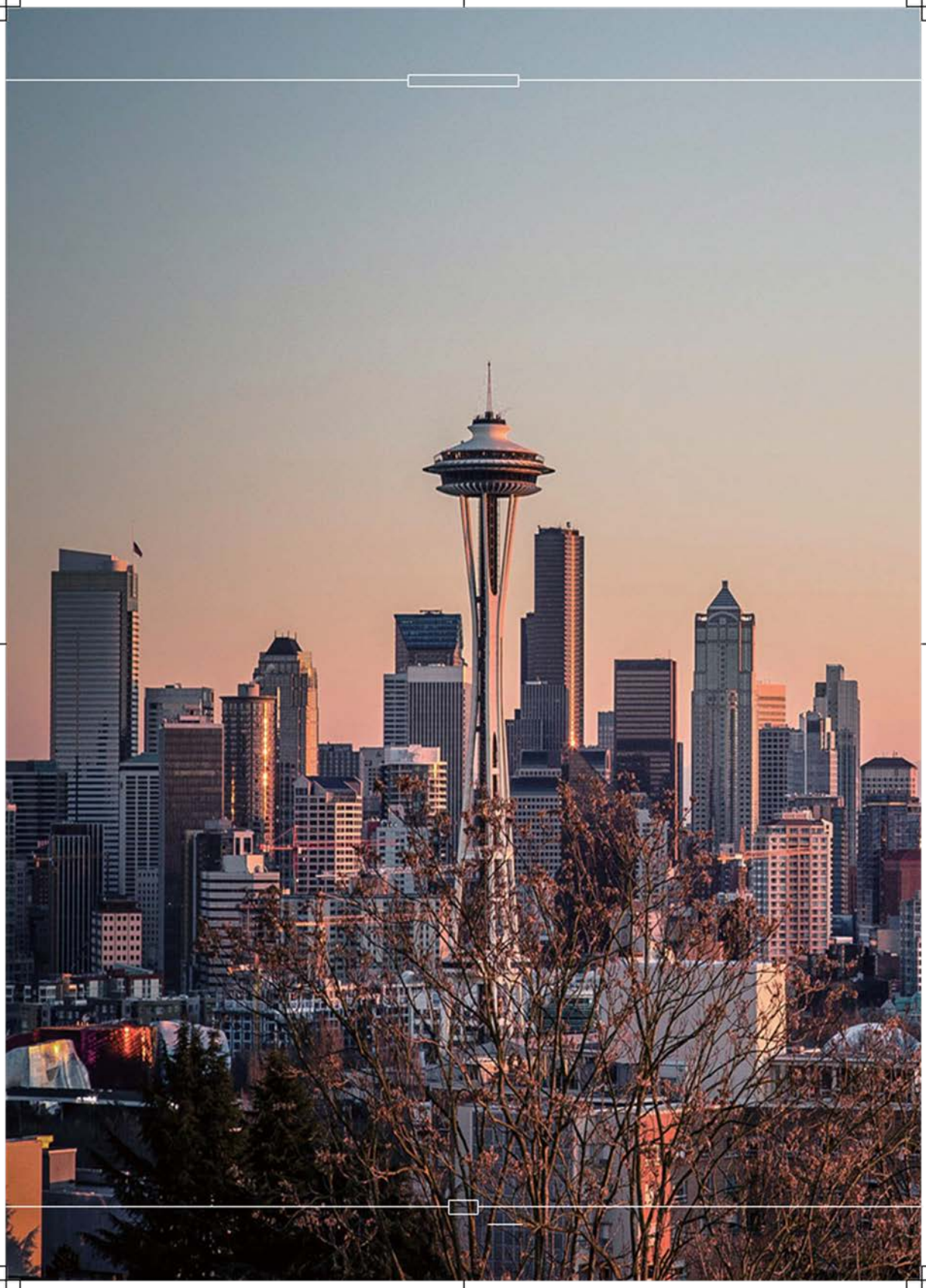
Franc Arman 2012 'Jano' Malvasia | Istria, Croatia | $30-ish | Private Wine Stores
So it turns out I'm a fan of Croatian Malvasia. Who knew? The aromatic white grape in question comes from mature vines quite close to the Adriatic Sea, a short commute away from more famous Italian takes on the variety. A smattering of fresh, citrusy herbs like lemon balm and sorrel envelope Mandarin oranges and Meyer lemons with a hint of an oily richness that will have it stand up to lighter curries and similar fare. Look for it at Kitsilano Wine Cellar or 16th Street Liquor Store in West Van.

Le Vieux Pin 2011 Syrah | South Okanagan, BC | $22/375ml or $45/750ml | Winery Direct/Private Stores
I've long been a fan of Syrah in British Columbia, often earthy and layered, chockablock with blackberries, currants, pepper and sage. Le Vieux Pin champions the variety quite well vintage after vintage, and I'm loving how this year they've done a slight departure from their usual big and muscular style, towards an elegant lift and a very civilized 12.7 per cent alcohol. The result still shares hallmark complexity and nuance, but now with a little more spring in its step.

Domaine Maby 2011 La Fermade Rouge | Lirac, Rhône, France | $27.97 | BC Liquor Stores
This blend of Grenache, Syrah and Mourvèdre grows a stone's throw from Châteauneuf-du-Pape and bursts with violets, lilacs, currants and Concord grapes. There's a slight dusting of dried thyme and just enough oak to lend backbone and overall structure. Smoked duck breast, charcuterie and sausage should fit alongside well.

Barda 2011 Pinot Noir | Patagonia, Argentina | $35-ish | Private Wine Stores
This Pinot Noir is grown way down in Patagonia, a breezy, cool climate region that treats the grape just fine. Put big, meaty Argentinian reds out of mind, because this little lady's light, bright and lively, with silky plums, a bowl of cherries and a pinch of nutmeg to finish things off. Put in the fridge for ten minutes before opening and start to think about revving up that barbecue.

As always, if you're having trouble tracking something down or just want to say hi, find me via KurtisKolt.com (http://www.KurtisKolt.com) or Tweet me @KurtisKolt.



taste WasHinGton in seattle

西雅图不醉夜

穿透森林的湿气，飞机降落在西雅图的海滨，48个小时后，我步入了"华盛顿州美食节"（TASTE WASHINGTON）的晨会，排队要了十只牡蛎，将它们由小到大码好在餐盘上，又来到milbrandt的酒庄摊位，让庄主帮着配了一杯冰镇的雷司令（reisling），手指抵着酒杯的冰凉处，正准备享用时电话响起，友人在那头问我，"你在西雅图呢？是去生孩子的？"我只是来吃喝的，带着执着的眼欧。此时牡蛎的奶香溢满口腔，柔软鲜甜，带着海水的咸凉，是国中餐厅不能给予的高潮。在太平洋上磨磨叽叽飞了十多个小时，仿佛只为等待这一刻。

EDITOR|屋尼先 TEXT&PHOTO|屋尼天 PHOTO|西雅图旅游局

第一家星巴克，西雅图是星巴克咖啡的发源地，星巴克的名字来源于19世纪美国文坛杰出大师赫尔曼·梅尔维尔的经典著作—《白鲸—莫比·迪克》的主人公，第一家星巴克位于派克市场内，其商标使用美人鱼的原因之一也是为了吸引渔夫们的注意。

地址：1912 Pike Place

❖ 星巴克

鲜少有人为满足口腹之欲来美国。这片土壤长满了圆头圆脑的植物，超市里尽是敞厚的鸡腿牛肉，冰淇淋按加仑出售，人们轻易捕到怒游于深海的大鱼。传统美餐在许多人眼里都缺乏层次，仿佛这群飘洋过来的清教徒只流连食物的嚼劲，丝毫不在意其间的化学反应。

但西雅图好像是个异数。它那点缺乏日光的极度太似中国的四川盆地。在四川，人们靠变着法子的吃辣来抵御湿气；在西雅图，人们设计了从最潮冷的海边起，蔓延到整座城的无死角星巴克咖啡网，用每隔十步的门店，用咖啡来驱寒。

西雅图人的血液里也一定透着咖啡的气味，那些在雨中从不撑伞的行人，手中都攥着一杯星巴克 —— 混冷也没那么可怕了。门店的密度就像鲁班设计的避雨亭，很少人真有功夫去避雨，但它的温度就是城市的温度，它的灯光透过街巷交织成网络，维系人们脑部的活力，激发他们造出波音大飞机，玩出现代摇滚乐。Pike市场至今仍保留着据说是全世界第一家的星巴克门店，店口门楣上的美人鱼标志也沿用最初的那一枚 —— 咖啡色作底，两条尾巴摆开来。小小的店堂总是人满为患，对面就是菜市。每天早上，金枪鱼、鲈鱼、黑鳕鱼跳满了冰板，带着海底两万里的气息。

西雅图的活力正是来自它挥之不去的湿气。任凭星巴克热动全世界。必须在濛濛细雨中，必须迎着海上的雾，喝一口咖啡，不计较味道，却足以领会城市精神。

华盛顿州美食节

TASTE WASHINGTON

一年一度的华盛顿州美食节每年三月底在西雅图世纪互联体育馆活动中心（CenturyLink Field Event Center）召开。中国游客可以通过上网订票：美食节官方网站

http://tastewashington.org/

该网站除了可以预定入场券之外还能预定专业美食美酒的讲座。活动地点：西雅图世纪互联体育馆活动中心。

❖ 觉味华盛顿州

3月底的西雅图，春光会惊现一小会儿。每天总有半小时，通常在下午或是傍晚，阳光从海面划入与第一大道垂直相交的巷子里。陡然发现，街上的行人也比往常多一点。这另有原因，这座森林雾都的胃正悄然翻腾着。一年一度的"华盛顿州美食节"（Taste Washington）拉开帷幕。西雅图的胃口可不容小看。两天里来自华盛顿州200多家葡萄酒庄、65家著名的餐厅，以及城中有头有脸的美食鉴赏家、顶级名厨齐聚城市西方南大街的世纪互联体育馆。

毫不夸张的说"美食节"将城市的美食地图，华盛顿州的美酒地图浓缩于展会现场。游人们只需凭着票在入口处领取属于自己高脚酒杯和餐盘，就可悠伴在这张餐叠酒的立体地图上，自由搭配。餐盘的设计正好挂住酒杯，人们得以腾出手来选酒，挑食，摆盘。对于旅行者来说，这是通往华盛顿州味蕾地的捷径。无需大费周折从海量地攻略中踢除那些"游客餐厅"，偌大的展厅就是西雅图的胃！那些藏在街巷深处让本地人洋洋乐道的巧克力屋，苹果派店，知名女大厨低调经营的小海鲜馆，如果按图索骥地找得花多少功夫，遇上美食节全大大方方地摆出阵仗，耍出绝活。大厨们来自坐镇，一边做餐一边与食客聊天，餐点都制成"迷你份"，没办法，太多美食在沸腾，胃里装不下的也要用眼睛狠狠吃一遍。


FISH-BAR


TACLE
WE PACK FISH TO GO FOR
48
SCALLOPS

❖ 牡蛎之约

刚从码头运来的新鲜牡蛎让人大饱口福。牡蛎的摊位上，十几米的展台站了7、8个工作人员，马不停到壮年肥硕的——码在餐盘上，然后拐入酒展的柜台。捧着一盘牡蛎的架势实在壮观，于是一路被热情的酒庄庄主拦下：

“牡蛎！”有人惊叫，“要配我们华盛顿州的葡萄酒产区 华盛顿州主要的“美国法定种植 区”（AVA）包括亚基马AVA、沃拉 沃拉AVA、哥伦比亚山谷 AVA、 普捷湾盆地（Puget Sound ）

蹄地开牡蛎。他们带着手套，用刀划开贝壳，动作干净利落，软体动物的奶香弥漫在整个角落。人们彬彬有礼，排到了就伸手拿一只，挤点柠檬汁，一口吃掉，一个种类就尝一只，其余的份额要留给后面的食客，这仿佛是一条不成文的规定。不解馋的人会重新排队，排到了依旧每种只拿一只。 有的牡蛎狂热者循环排队吃了一天，估计晚上睡觉都会带着海水味的鼾声。

我是酒鬼，当然不会错过这样的机会。所以并没像别人那样，抡起一只马上干掉，而是把搜集好7、8种不同的牡蛎——从三个月大的家的长相思！”

“我这里有绿皮诺，也不错，要不要试试看？”

我最终选了一款雷司令，躲到会场边的餐桌上慢慢享受。这是一顿朴素又惊艳的牡蛎大餐，新鲜度警醒大脑，咸味和矿物感相处融洽。略带海盐的柔软真适合与雷司令的冰甜交织啊！Milbrandt酒庄的雷司令种植于哥伦比亚谷的高地斜坡上，酸度高，口感通透。我咂了一口，意识到自己坐在北纬47度，西雅图市南大街800号，舌尖上涌起又散去的不是牡蛎和冰白，而是皮吉特湾的海水和哥伦比亚谷的砾石。

❖ 好酒

作为红酒产区，华盛顿州产区靠近加拿大，是北美的高纬度寒冷之地，在主要生长季节的日照时间平均每日要比加州多出2小时。平均17.4小时的日照时间，温和的气候使葡萄得以完全成熟，而温度较低的夜晚使得果实中酸度较高。比起加州的napa酒“饱含情欲”的果味，华盛顿州产区简直文艺坏了。雷司令清丽，赤霞珠高酸度，香气丰腴口感平衡。

在“华盛顿美食节”（TASTE WASHINGTON）我 真是大开眼界。整个州的葡萄酒人从山谷里驱车而来，在西雅图南大街800号体育馆摆出自己的摊位，热烈讨论着种植和酿造。这里的酿酒师们大多穿着格子衬衫牛仔裤，大多子承父业，自小学酿酒，其他兄弟姐妹则负责市场，销售。这种家庭式酿酒传统竟然得益于美国1920年禁酒时期的法令。即使如今在华盛顿州Milbrant这样的大型红酒公司，引进了技术人才和专业市场运营模式，但它们的核心成员依然是家族。展会上我遇到三个年轻人，一起创立了名为Sleight Of Hand的酒窖。每年产量大概也就够分亲朋好友的，却兴致勃勃地为新酒的品鉴制作了一张CD。酒标是一个诡异的印度人像涂鸦，呼应了几百米外的西雅图音乐博物馆里Jimi Hendrix画像上错愕的神态。

IT和摇滚乐是西雅图的肋骨，咖啡是它的血液，红酒却把青春的棱角都酿了进去。

AVA、红山（Red Mountain）AVA和哥伦比亚河谷（Columbia Gorge）AVA。以上种植区都具有其独特的气候、土壤和地理特征，其中，哥伦比亚山谷是比较著名的一个AVA，当地的夏季气候温和，温度适中，白昼较长，夜晚凉风习习，如此温和的天气中诞生了华盛顿最杰出的一些葡萄酒品种。

西雅图的美食

RN74

http://www.michaelmina.net

Theochocolate

https://w w w.theochocolate.com/locator

Salty's Seafood Grill

http://saltys.com

西雅图美酒

1.Ste.Michelle

https://www.ste-michelle.com

2.Milbrandt

http://www.milbrandtvineyards.com

3.Hedges Family Hedges

http://www.hedgesfamilyestate.com

BEST CHOICE 贪杯

一杯酒与一座城市

撰文 摩尼朱

摩尼朱 Monica Zhu

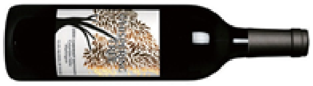
《WinePost玩物》微杂志创始人，WSET二级品酒师，葡萄酒及旅行撰稿人，乐于探索与葡萄酒有关的创意生活方式，寻找葡萄酒与内外世界的关联。

喝

美国NA PA产区的酒实在让我高兴不起来（按：NAPA酒在中国的定价）当然我自有原因——文青，NAPA酒通常表现出来的圆润、甜腻，“胸大无脑”，换作另一位成熟多金男来看也许便成了“风情万种”，声名显赫的美国NA PA酒充满富贵之气，耀眼或肤浅都如好莱坞电影，一种做定世界主角的气场，我曾以为那就是“美国酒”的代表，3月底的西雅图之行彻底改变了我的看法，美西海岸纬度跨越之广，使红酒的风味包罗万象，除了NAPA热衷将自家的“暴发娇娃”输送到世界各地，其他产区则基本只能满足本地需求，很少出口，也就意味着献献无闻。

华盛顿州就是一个清丽的产区，我飞赴西雅图，参加一年一度的“华盛顿美食节”（TASTE WASHINGTON）真是大开眼界，整个州的葡萄酒人从山谷里驱车而来，在西雅图南大街800号体育馆摆出自己的摊位，热烈讨论着种植和酿造，本地的酒农、品鉴家、侍酒师齐聚一堂，他们可不高兴搞贝法国人那一套——这些西海岸的高纬度酒农一定要玩出与西雅图精神契合的葡萄酒，蒙特利尔的风向，针叶林的气息成就了哥伦比亚谷的雷司令——不是德国雷司令那种决绝的酸，倒有几分浪漫，仿佛就是《西雅图不眠夜》里的梅格瑞安，消瘦、平胸、高个，微翘的鼻尖闪着灵光，流行乐也被注入红酒，展会上我遇到三个年轻人，创立了名为Sleight Of Hand的酒窖，每年产量大概也就够分亲朋好友的，却兴致勃勃地为新酒的品鉴制作了一张CD。

赤忱和怪咖，自由与认真，即使西雅图没有足以长出幽灵的Chateau（古堡），敞亮的集散集散谷（Walla Walla Valley）总是沐浴在日光下，我无法不动容的，还有那句本地酿酒师们总爱说的话：华盛顿州的酒就是华盛顿州的酒！

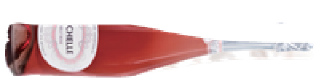


Milbrandt Whispering Tree Cabernet Sauvignon2009

这款十红来自华盛顿州南部哥伦比亚谷Milbrandt酒庄，以赤霞珠为主混酿梅洛和品丽珠，温润的气候造就了浓郁、丰满的赤霞珠，酒体色泽深红，含有车厘子、红梅和红茶的香气，红酒在橡木桶陈酿 6个月，入口饱满、滑润，平衡感好，丹宁柔和，建议醒酒后30分钟饮用，Milbrandt酒庄的雷司令同样令人惊艳，酒庄秉承家族传统，他们的名言即是：作为农民，没有什么比从头到尾控制品质和风格的产品更令人激动的！

Hedges Family Estate Red Mountain2010

Hedges Family相比本地其他酒庄，最突出的是它的法国血统，创始人中有一位法国女士，如今第二代传人酿酒师是她的女儿，这个红山（Red Mountain）系列性格鲜明，是Hedges家族用赤霞珠和梅洛进行混酿而成的，红山是哥伦比亚谷的子产区，它占尽优势，日照时间比纳帕谷还要丰沛，日夜温差也很大，这个系列全部采用红山种植的葡萄，酿造和装瓶都延续了法国酿酒的传统风格，口味也尽量往经典和优雅的勃艮第风格上靠拢。

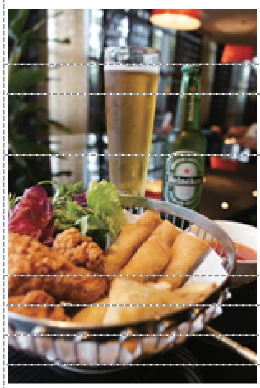


Michelle brut rose Columbia valley

这款酒算得上是西雅图人的“香槟”，产自华盛顿州的葡萄酒大户Michelle酒庄，葡萄的产地位于哥伦比亚谷高纬度的凉爽地区，自然条件与法国香槟区很像，因此赋予酒体良好的酸度，陈酿了18个月的粉红起泡酒，闻起来有明显的浆果的味道，刚入口的时候有点干，口感柔软，然后果味才涌上来，这款粉红起泡酒出自酿酒师Rick Casqueiro之手，他最擅长酿起泡酒，是一位学院派酿酒师，懂得用科技来严格控制口感，因此喝这款起泡酒，你会觉得平稳，但缺乏点惊喜。

FOOD TALK 美食情报

和球迷一起享美食



4年一遇的足球盛宴，32支最强国家队争夺大力神杯，你要怎么疯狂?眼下，上海外滩茂悦来登酒店6月12日至7月14日推出了只需100元的“狂欢世界杯套餐”，届时大堂酒廊双面大屏幕实况转播，喜力啤酒尽情畅饮，并搭配炸鸡、炸春卷及咖喱角等精美小食无限量供应，还有君度果的、经典巴西鸡尾酒、巴西芒果鸡尾酒、蓝色多瑙河等鸡尾酒可选择，此外，为了让来客共享这一狂欢时刻，酒店还特别推出世界杯精品互动活动之“猜胜负 赢大奖”活动，爱足球的你如果不愿意实在家里自己对着电视看球，不如加入和球迷一起狂欢的队伍，上海外滩茂悦来登酒店毗邻港口，景色优美，还有自然采光、口碑甚佳的游泳池，世界杯期间，不妨到此一游，详情致电：021- 31219999转6331。

去户外餐厅享受夏意

有些餐厅属于夏季，上海浦东嘉里大酒店全新概念户外餐厅The PATIO庭就是其一，今年夏天它全新开业，餐厅毗邻浦东嘉里城中庭，舒适的装修风格，提供特色鸡尾酒与美食，是和家人朋友度过一段惬意的休闲时光的好地方，屡获殊荣的手工自酿啤酒、3升装的巨型鸡尾酒、鲜榨果汁、“派对时光”套餐，还有“不妨一试”的西瓜炸弹，这些都可以在The PATIO庭的酒水单上找到，另外还有一系列美食，包括广式点心、烧烤串、意面和汉堡、汤面及素食等，浦东嘉里城中庭的活动多姿多彩，有小集市、儿童互动游戏、音乐节等，都将为The PATIO庭的客人带来夏意盎然的用餐体验。

详情致电021-61698886。

人参鸡汤配寿司

上海宝华万豪酒店的炎川餐厅新近开放，餐厅以日韩菜系为主，店内采用自然原木，中性色系和酶菇色系配搭得非常和谐，两间私人包间设有铁板烧，现场烹制的美味配以各式清酒品类及上乘葡萄酒，餐厅的寿司吧别具一格，每天新鲜出品各色刺身及寿司，地道韩式烧炉利用天然木炭作燃料，令菜式健康且兼具自然原味，韩国烧烤配有炎川特色烧烤酱及传统调味料——研磨椒盐，而所有晚餐均奉上两款大厨当日精选配菜，人参鸡汤更是严选6年白参、原只养鸡、糯米、红枣和栗子等食材，经6小时熬制而成，味道浓郁无比，新开业的上海宝华万豪酒店由国际知名室内设计公司Hirsch Bedner Associates（HBA）打造，设有多家餐饮，其中，全日餐厅都会怡膳呈献世界各地美食，而万豪中餐厅主打正宗时令粤菜和本帮菜，而大堂吧则适合享用下午茶及夜晚的鸡尾酒。

西雅图的胃

穿透森林的湿气，飞机降落在西雅图的海湾 48个小时后 我步入了"华盛顿州美食节"（TASTE WASHINGTON）的展会 排队要了十只牡蛎 将它们由小到大码好在餐盘上，又晃到milbrandt的酒庄摊位 让庄主帮着配了一杯冰镇的雷司令（reisling）手指抵着酒杯的冰凉处 正准备享用时电话响起，友人在那头问我 你在西雅图呢？是去生孩子的？

文 廖尼朱

只是来吃喝的 带着执着的胃口。

我此时牡蛎的奶香溢满口腔 柔软鲜甜，带着海水的咸鲜 ……在太平洋上空嗡嗡叫叫飞了十多个小时 仿佛只为等待这一刻。

星巴克的故乡

很少有人为满足口腹之欲来美国 这片土地长满了圆头圆脑的植物 超市里尽是整厚的鸡腿牛肉 冰淇淋按加仑出售 人们轻易捕到悠游于深海的大鱼 传说美食在许多人眼里都缺乏品位 仿佛这群飘洋过来的清教徒只流连食物的嚼劲 丝毫不在意其间的化学反应。

但西雅图好像是个异数。

它那点缺乏日光的潮湿太似中国的四川盆地 在四川 人们発奎着法子的吃辣来抵御湿气 在西雅图 人们设计了从最潮冷的海边起 蔓延到整座城的无死角星巴克咖啡网 用每隔十步的门店 用咖啡来驱潮。

西雅图人的血液里也一定流着咖啡的气味 就像在雨中从不撑伞的行人 手中都握着一杯星巴克——湿冷也没那么可怕了 门店的密度就像备战设计的避雨亭 很少人真有功夫去避雨 但它的温度就是城市的温度 它的灯光透过街巷交织成网络 维系人们胸部的活力 激发他们造出波音大飞机 玩出现代摇滚乐。

Pike市场至今仍保留着据说是全世界第一家的星巴克门店 店口门楣上的美人鱼标志也沿用最初的那一枚——咖啡色伯底 两条尾巴摇开来 小小的店堂总是人满为患 对面就是海市 每天早上 金枪鱼 鲭鱼 鳕鱼躺满了冰柜 带着海底两万里的气息。

这让人突然愉悦 西雅图的活力正是来自它挥之不去的湿气——海底的冰蓝和松针的呼吸 以及码头上银光闪闪的鲜鱼 任凭星巴克轨动全世界 正如四川人用海椒 野山椒 千辣椒 朝天椒"带坏"了川外的平原和高原 从烘焙和混合上来讲 星巴克咖啡比不上意式咖啡来的精致 但美国人要的就是"永远流动着"。

必须在濛濛细雨中 必须迎着海上的雾 喝一口咖啡 不计较味道 却足以领会城市精神。

赏味华盛顿州

三月底的西雅图 春光会惊现一小会儿 每天总有半小时 通常在下午或是傍晚 阳光从海面刺入与第一大道垂直相交的巷子里 猛然发现 街上的行人也比往常多一点 这另有原因：这座森林簇拥的城正悄然翻腾着 一年一度的"华盛顿州美食节"（Taste Washington）拉开帷幕 西雅图的胃口可不容小觑 两天里来自华盛顿州200多家葡萄酒庄 65家著名的餐厅 以及城中有头有脸的美食鉴赏家 顶级名厨齐聚城市西方南大街的世纪互联体育馆 毫不夸张的说"美食节"将城市的美食地图 华盛顿州的美酒地图浓缩于展会现场 游人们只需凭着票在入口处领取属于自己高脚酒杯和餐盘 就可倘佯在这张餐桑酒的立体地图间 自由搭配 餐盘的设计正好卡住酒杯 人们得以腾出手来说酒 给食，搭盘 对于旅行者来说 这是抓住华盛顿州味蕾腹地的捷径 无需大费周折从海量的攻略中搜寻那些"游客餐厅" 偌大的展厅就是西雅图的胃！那些藏在街巷深处让本地人津津乐道的巧克力屋 甜品酒店 知名女大厨低调经营的小海鲜馆 如果按图索骥得找得花多少功夫 碰上美食节全大大方方地摆出摊位 亮出绝活 大厨们亲自坐镇 一边做餐一边与食客聊天 餐点都制成"迷你份"没办法 太多美食在沸腾 胃里装不下的也要用眼睛狠狠吃一遍。

牡蛎之约

刚从码头运来的新鲜牡蛎让人大饱口福 牡蛎的摊位上 十几米的展台站了7 8个工作人员 马不停蹄得开牡蛎 他们带着手套 用刀剖开贝壳 动作干净利落，软体动物的奶香弥漫在整个角落 人们彬彬有礼 排到了就伸手拿一只 挤点柠檬汁 一口吃掉 一个种类就拿一只 总会得份额要留给后面的食客 这仿佛是一条不成文得规定 不餍馋的人会重新排队 排到了依旧每种只拿一只。有的牡蛎狂热者循环排队吃了一天 估计晚上睡觉都会带着海水味的新意。

我是酒鬼 当然不会错过这样的机会 所以并没像别人那样 拾起一只马上干掉 而是把搜集好7 8种不同的牡蛎——从三个月大的到壮年肥硕的——码在餐盘上 然后挤入酒展的柜台 儒着一盘牡蛎的架势实在壮观 于是一阵阵热情的酒庄庄主拦下：

"牡蛎！"有人惊叫 "要配我们家的长相思！"

"我这里有绿庞诺 也不错 要不要试试看？"

我最终选了一款雷司令 躲到会场边的餐桌上慢慢享受 这是一顿朴素又惊艳的牡蛎大餐 海水还没说干就一股脑儿得吃了下去 新鲜度堪称大赞 咸味和矿物感相处融洽 我不缺乏吃牡蛎的经验 在城里吃到的，常常是它们褪去香甜的呼吸后 这一次 略带海盐的柔软真想会与雷司令的冰甜交织啊！Milbrandt酒庄的雷司令种植于哥伦比亚谷的高地斜坡上 糖度高 口感温婉 我喝了一口 意识到自己坐在北纬47度 西雅图市南大街800号 舌尖上涌起又散去的不是牡蛎和冰白 而是皮吉特湾的海水和哥伦比亚谷的砾石。

第一家星巴克

西雅图是星巴克咖啡的发源地 星巴克的名字来源于19世纪美国文坛杰出大师赫尔曼·麦尔维尔的经典著作——《白鲸——莫比·迪克》的主人公 第一家星巴克位于派克市场内 以售卖烘焙好的咖啡豆和咖啡机为初衷 并首次提供现成的咖啡刚上烘焙师是为了吸引渔夫们的注意 第一家星巴克店内不仅悬挂着最初褐色双尾鳍的LOGO 还可见一尊纪念挂饰立于店内 这也是辨别第一家星巴克的标志 凡是携带从第一家星巴克店购买的咖啡豆 到世界任一一家星巴克店均可免费制作咖啡。

本页顺时针依次为：意大利餐厅第作是西雅图饮食文化的灵魂 Banchero是有80年历史的老字号 厨师正忙着把面团扭好； 西雅图人好甜 流行的多是传统口味。//////

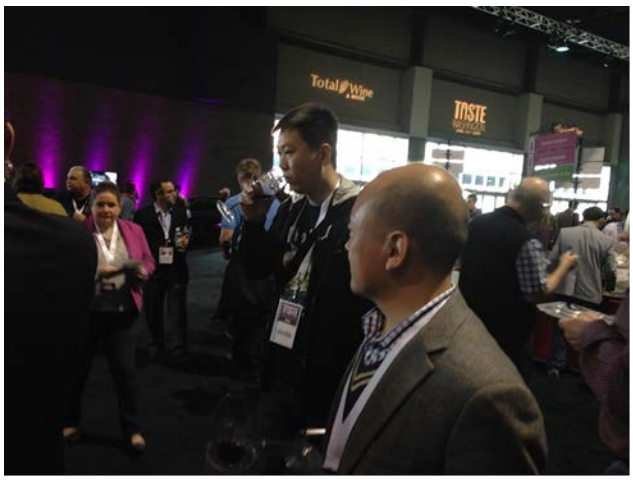
华盛顿州美食节（TASTE WASHINGTON）

一年一度的华盛顿州美食节每年三月底在西雅图世纪互联体育馆活动中心（CenturyLink Field Event Center）召开 届时 华盛顿州美食文化研讨会 顶级名厨厨艺展以及大型葡萄酒品鉴会等各项活动将同步进行 人们享受美食 领略华盛顿州的秀人风光 还可以倾听佳肴胸后的故事 活色生香的美味海鲜 800多种红酒 下一届华盛顿美食节将于将于2015年3月28日至29日召开。

中国游客可通过上网订票：美食节官方网站（http://tastewashington.org/）该网站除了可以预定入场券之外还能预定专业美食美酒的讲座 活动地点 西雅图世纪互联体育馆活动中心。今年的普通单日票价 80美元 普通双日票价 125美元 VIP单日票价 145美元 VIP双日票价 185美元 VIP会员可以享受提前入场 以及VIP专享休息区。

Taste Washington Canada-China Photos

Taste Washington visit.



Taste Washington visit.

Wine and food pairing dinner.

Visit to Columbia Crest winery.

Visit to Milbrandt Vineyards winery.

Visit to Milbrandt Vineyards winery.

CONTACT INFORMATION

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PROJECT #3

Project Title: USA Pear Show in China

Partner Organization: Pear Bureau Northwest

PROJECT SUMMARY

After 20 years of efforts by the pear industry, Northwest Horticultural Council, and USDA APHIS, market access to China was granted for the first time for USA Pears in January 2013. Because Chinese consumers are accustomed to the crisp Asian pear varieties, the Pear Bureau was faced with introducing USA Pears as a new product to the market, with the top constraint being the lack of consumer awareness regarding the multiple varieties available, flavor attributes, nutrition information, and ripening attributes of USA Pears – addressing the constraint will continue to require a lot of education. USA Pears – or western pear varieties – are very different in taste, appearance and eatability (i.e. western pears need to ripen) than the Asian pear varieties grown in China. Therefore consumers may not have ever seen a western pear variety and it is considered an exotic fruit to them.

The USA Pear Road Show in China capitalized on the timing of the market opening to take advantage of the opportunity to kick off the second full season in the market. On top of the Pear Bureau's existing plans and promotional activities for the season – which included in-store promotions, public relations, and technical trade assistance – the extra push provided by the Road Show generated interest, enthusiasm, and excitement for both consumers and retailers. The Road Show was a focal point of the Pear Bureau's promotional program and initial launch into the Chinese market. It also served as a demonstration to the trade of the Pear Bureau's dedication to providing promotional support in the market.

PROJECT APPROACH

The opening ceremony for the USA Pear Road Show promotion in China was held on November 15, 2014 in Beijing. By the end of the activity on January 28, 2015, 55 promotion days were completed in Beijing and Shanghai at 20 locations of participating retailers including Sam's Club, Yi Tong Long, Bei Chen, Jenny Wang, Aeon, RT Mart, Nong Gong Shang, E-Mart, CenturyMart, and Walmart.

The first stop of the truck's mobile showcase was the Sam's Club located in Shijingshan district of Beijing. An inauguration ceremony was organized and officiated by representatives from the Pear Bureau, Sam's Club, and the US Embassy in China. Several thousand consumers visited the Road Show and over 3,000 samples were distributed in the opening weekend alone. Media also attended the event and press briefing that followed.

Approximately 60,000 Chinese consumers sampled USA Pears over the course of the promotion. In addition to singing and dancing performances (paid with matching funds) that helped attract consumers' attention to the Road Show, the most popular activity throughout the period was the USA Pear Coloring Activities. Over 5,000 children with their family members participated at the activity throughout the show period. Over 90,000 USA Pear leaflets were distributed to Chinese consumers and the Road Show video was exposed to approximately 150,000 consumers. The Road Show generated good media exposure through PBNW's public relations efforts in China. The event was also featured in the USA Pears Newsletter distributed to the fruit trade in the country.

Participating retailers were pleased to have participated in the events to promote USA Pears, with many commenting on the innovative approach of PBNW in conducting such an activity in China – the first of its kind among all imported fruit to organize a large-scale, open-air activity outside their stores in Beijing and Shanghai.

The consumer evaluation was conducted via a total of 180 face to face interviews completed at the Road Show venues between November 16 to January 14 in Beijing and Shanghai. Consumers were randomly interviewed immediately after they sampled USA Pears on the spot to collect their opinion and preference regarding USA Pears, if they will purchase USA Pears in the future, which household members consume USA Pears, if parents will feed USA Pears to their children, their rating of the USA Pear Road Show, etc.

The Pear Bureau's representative in China, Louis Ng & Associates (LNA) oversaw the day-to-day development and implementation of the activity, negotiated with retailers, coordinated the promotional schedule, and supervised the agency executing the promotions.

The Pear Bureau home office had an oversight and project management role in the activity, approving the selection of the promotional company, truck design, and retail partners. PBNW worked closely with LNA to manage the budget and on reporting for the project.

This project did not benefit any non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

The Road Show promotions had a direct impact on the performance measure results, educating consumers about the attributes of USA Pears and influencing their purchase decisions. Throughout the promotions, the Master of Ceremonies introduced USA Pears to the audience and explained USA Pear varieties, availability, ripening characteristics, and recipe usage ideas. Demonstrators distributed leaflets with key information and provided the opportunity for consumers to sample ripe USA Pears. A USA Pear video also played throughout the promotions. The children's coloring contest kept families at the promotion for an extended period of time, maximizing their exposure to USA Pears.

After just 2.5 years of market access, USA Pears are still new to the China market. The Road Show activity served as a way to generate excitement for the product and introduce USA Pears to both consumers and the trade. The positive results of the expected measurable outcomes demonstrate the vast potential for continued growth not only in the featured cities of Beijing and Shanghai, but throughout the country.

PBNW's strategy for the Road Show was to conduct an activity that could introduce USA Pears to consumers on a large scale and provide promotional support to retailers to encourage the trade to increase their volumes of USA Pears. The Road Show achieved these goals, and in some cases, exceeded expectations: an estimated 120,000 consumers visited the 55-day promotion, with 60,000 samples being distributed. Retailers reported an average of 80.31% sales growth for USA Pears during the promotion. Export volumes for the two-month period were nearly triple the initial target.

In order to evaluate progress towards the achievement of the Road Show targets, 180 consumer interviews were conducted onsite during the promotions in Beijing and Shanghai. Results were as follows:

	Target	**Result**
A. % increase of Northwest Pear sales during the promotional period over the previous sales period	50%	80.31%
B. % of consumers who purchased USA Pears for the first time after the Road Show	5%	17.91%
C. % of consumers who consider health and nutrition important purchase decision motivators	10%	11.5%
D. # of consumers who became more educated about Northwest pears after staying 1-2 minutes	35,000	35,000
E. # of consumers who became more educated about Northwest pears after staying longer than 2 minutes	13,500	50,000
F. # of children who became more educated about Northwest pears during school promotions	6,500	N/A
G. % of more educated consumers who reported that the information will influence their purchase behavior positively to buy more USA pears	5%	76%
H. USA Pear exports for the promotional period (mid-November 2014 through mid-January 2015)	33,000 boxes	96,512 boxes

BENEFICIARIES

The Oregon and Washington growers and shippers of USA Pears are the beneficiaries of this project and the further development of the China market as a top export destination. The Road Show activity succeeded in reaching a large number of consumers with USA Pears' educational message, with 76% reporting that the information provided will influence their purchase decisions and 17.91% of purchases during the promotion period being new customers.

Activities with this type of broad reach are essential to continue to develop the Chinese market and maximize growth in a market that has potential to become a top 3 market for the industry. PBNW anticipates that export volumes to China will surpass 500,000 boxes in the next 3-5 seasons.

During the 2014/15 season, Russia – formerly the 3rd largest market for USA Pears – closed the market to U.S. products. The industry turned to China and other export markets to increase their volumes and fill the void left by an over 450,000-box market. In addition, the West Coast port strike delayed shipments during a key period of USA Pears' window in many export markets. In spite of these challenges, the Global Trade Atlas shows that China imported 204,750 boxes of USA Pears worth $4.8 million during the season, and the overall average price per box for the season's exports reached

the second highest level of $22.66. The USA Pear Road Show and PBNW's promotional support inspired confidence in the trade to handle increased volumes of USA Pears.

LESSONS LEARNED

PBNW experienced challenges in the timing of the Road Show, learning to anticipate unexpected issues arising in the Chinese market. While the kickoff event was initially planned for early November, the APEC meeting November 10-11 in China created a delay because of restrictions and measures in Beijing due to the number of Presidents and Heads of countries visiting. As a result, the start date of the Road Show was postponed to November 15.

In addition, due to the new rules launched by the Beijing government in April 2014, trucks that are over 5 metric tons are not allowed to enter the 5th Inner Ring Road of the city of Beijing. Nearly all of the planned Road Show venues were located within the 5th Inner Ring Road. Therefore, a smaller truck had to be secured for the events. The deposit for the initial truck rental was transferred towards the new truck. The initial designs were adapted to the new truck's specifications. In addition, it was negotiated to get two free big outdoor tents for the Road Show with tables and chairs.

The weather conditions and smog pollution were also a challenge for an outdoor activity. Due to the delayed kickoff, the promotion was pushed into mid-January, when weather turned colder and smog warnings increased. PBNW plans for future activities in the region to take place in October and November for improved weather conditions.

PBNW also learned that activities attracting kids and families are key elements to a successful promotion. In spite of weather and smog issues, an estimated 45,000 participated in the children's coloring contest, which kept families engaged and provided PBNW a more extended period to communicate information to the consumers.

ADDITIONAL INFORMATION

Project Cash Match: $18,919.88

Video clips and photos are available in the following link:
14-15 Road Show Photos and Videos.zip

CONTACT INFORMATION

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PROJECT #4

Project Title: Market Research to Support Blueberries to Asia

Partner Organization: Washington Blueberry Commission (WBC)

PROJECT SUMMARY

Washington blueberry growers and exporters need detailed information on the market for blueberries in Korea, China, and India. These Asian markets are likely to be important outlets for Washington's growing blueberry production in the years ahead, but without detailed information on distribution, importers, retailers, handling and storage, competition, consumer purchase behavior and other factors, the WBC is not in a position to choose where to invest its own resources in market development and promotion.

The project is timely because Washington blueberries are likely to soon gain access to these new markets. In Korea, other U.S. states have access and have started shipping product. Oregon was the first and year one exports of Oregon fresh blueberries to Korea totaled approximately 500,000 pounds. The recent implementation of the U.S.-South Korea Free Trade Agreement has given a boost to these market access requests. Based on Oregon's experience, Washington recently requested to be added to the list of states eligible to ship blueberries to Korea and the WBC expects to receive approval within the year. (IMPORTANCE). Washington does not have market access to China as yet, but expects that market to open within a few years. And with ongoing negotiations for the Trans Pacific Partnership agreement likely to come to fruition within a year or two, there could be a real opportunity for market access in Vietnam. All three are solid markets for other U.S. fresh fruits and vegetables and should offer tremendous opportunity for Washington's blueberry growers. The WBC prefers to approach new markets with research studies first. Formal research will increase the likelihood that WBC and its members enter each market successfully. Researchers can assess potential import, wholesale, and retail partners to determine the most suitable trade partners for Washington blueberries. Similarly, the research can help identify the most effective promotional tools for each market. The health benefits of blueberries will likely be a major emphasis of future WBC promotions in all three markets but how best should the WBC convey health benefit messages?

This project does not build on previously funded work.

PROJECT APPROACH

The Washington Blueberry Commission completed activities related to this project over a three-year period. Activity commenced in 2014 with research and a market visit to China. A second market visit to China occurred in early 2015 and the final report on that country was delivered in May 2015.

The second study (on India) began following completion of the China project. A market visit to India took place in October 2015 and the study on that market was delivered at the end of the 2015 calendar year.

The third research project (Korea) was initiated in early 2016. A market visit to Korea took place in March 2016 and the final study on the Korean market was delivered in June.

For each market study, the Commission's work included:

a. Desk research – a contractor conducted desk research on each market for blueberries. That research included an examination of domestic production, consumption, imports and exports, consumer trends, market access, and other factors. Sources for this effort included the Global Trade Atlas, USDA/FAS Attaché and GAIN Reports, U.S. Commercial Service reports, the CIA World Factbook, the Food and Agriculture Organization, and a variety of other online trade and consumer publications. For information related to blueberry market access, the researcher consulted the USDA's Phytosanitary Issuing and Tracking System (PCIT), World Tariff, and the GlobalMRL database. That last system was used to develop a report on pesticide maximum residue level gaps and regulatory discrepancies that could affect U.S. blueberry exports.
b. Market visits – For each country study, desk research was followed by market visits that included blueberry industry representatives from the state. Meetings were held with leading importers, wholesalers, retailers, food manufacturers and government officials covering fresh fruit, dried fruit, frozen products, and processed ingredients. Cities targeted included Shanghai, Beijing, and Guangzhou in China, New Delhi and Mumbai in India, and Seoul in Korea.

The research studies and market visits all confirmed that opportunities exist for Washington State blueberries in each market. However, the scope of opportunity varies by market and product. In China and Korea, trade opportunities for

Washington blueberries will improve greatly once market access is secured for fresh berries. The availability of fresh blueberries from Washington would likely strengthen awareness of Washington as a blueberry supplier and reinforce demand for frozen and dried product.

In India, Washington State is already able to ship fresh blueberries but the logistics are a challenge to ensure product freshness and quality. That market appears to offer greater immediate potential for frozen and dried product. These and other findings are detailed in the final reports delivered for each country.

Industry members and in-country contractors played significant roles in each country study. As mentioned, a delegation of industry members accompanied researchers to each country for market visits and trade meetings. These included:

- Brenton Roy – Oasis Farms (fresh, organic blueberry grower)
- Terry Dorsing – Royal Ridge Fruits (fresh and processed blueberry supplier)
- Alan Schreiber – Washington Blueberry Commission
- Rebecca Weber – Washington State Department of Agriculture
- Steve Mowat – Washington blueberry broker/exporter

Researchers also relied on in-country contacts for assistance with trade meeting arrangements and logistics. These partners included:

- LiHai Dong (China) – Washington State Department of Agriculture representative in that market
- Danny Kim (Korea) - Washington State Department of Agriculture representative in that market
- Devna Khanna, i2i Group, India – Western US Agricultural Trade Association representative in India.

The scope of the project only benefitted blueberries.

GOALS AND OUTCOMES ACHIEVED

For each country study, the project consisted of the following activities:

a. Desk research – a contractor conducted desk research on each market for blueberries. That research included an examination of domestic production, consumption, imports and exports, consumer trends, market access, and other factors. Sources for this effort included the Global Trade Atlas, USDA/FAS Attaché and GAIN Reports, U.S. Commercial Service reports, the CIA World Factbook, the Food and Agriculture Organization, and a variety of other online trade and consumer publications. For information related to blueberry market access, the researcher consulted the USDA's Phytosanitary Issuing and Tracking System (PCIT), World Tariff, and the GlobalMRL database. That last system was used to develop a report on pesticide maximum residue level gaps and regulatory discrepancies that could affect U.S. blueberry exports.
b. Market visits – For each country study, desk research was followed by market visits that included blueberry industry representatives from the state. Meetings were held with leading importers, wholesalers, retailers, food manufacturers and government officials covering fresh fruit, dried fruit, frozen products, and processed ingredients. Cities targeted included Shanghai, Beijing, and Guangzhou in China, New Delhi and Mumbai in India, and Seoul in Korea.
c. Analysis and Reporting – following the market visit, the research contractor analyzed all collected data, including market access and MRL reports, to determine findings related to market opportunities, challenges, and risks. The findings were detailed in a comprehensive market report per country.

The original grant proposal included the following Expected Measurable Outcomes:

The **goal** of this project is to provide research that enables the WBC to develop an export market development strategy in key Asian target markets. Ultimately, success will be determined by increased exports.

Washington state blueberry producers do not currently export to any of the three markets targeted with this project. Therefore the **benchmark** for export sales value to each market is $0. By the end of the three years of the project, Washington blueberry exports will exceed $1,000,000 in value to Korea, $2,000,000 in value to China and $200,000 to India. These value figures represent the **target**.

Progress has been made toward these export goals though precise export figures for the start are difficult to obtain. Blueberry exports are recorded at the national level and will combine figures for all exporting states. However, Washington and Oregon are market leaders for export of frozen and dried blueberries to Asia. When looking at recent trade statistics through the Global Trade Atlas and USDA GATS, the following exports have been recorded:

China – US frozen and dried cultured blueberry exports to China have exceeded $2,000,000 combined over the last three years. For 2016 year to date on dried blueberry exports alone, the US has exported over $1.1 worth of product (GATS). It is estimated that Washington may account for about one-third of those exports.

India – The United States exported over $200,000 worth of dried and frozen blueberries to India in 2015. Nearly all of the exports were of dried blueberries. However, exports have been steadily increasing over the past five years. It is estimated that Washington may account for about one-third of those exports.

Korea – The United States exported over $14,000,000 in frozen blueberries alone to South Korea in 2015, nearly tripling exports of this commodity since 2011. Exports of dried blueberries to Korea totaled over $4.8 million in 2015. Again, it is estimated that Washington accounts for about one-third of those exports.

While Washington State has not likely met the export targets set out at the time of the proposal, blueberry exports from the state to each target market appear to be increasing. This would grow further if fresh market access for blueberries is obtained in China and Korea. At the time of the original proposal it was hoped that market access for Washington fresh blueberries would have been secured by this date.

The goal for the project, as stated above, was to "provide research that enables the WBC to develop an export market development strategy in key Asian target markets." The WBC believes that this goal was met. Three comprehensive research studies were completed that helped the Washington blueberry industry connect with buyers in each market and furthered an understanding of market opportunities. Several trade leads were generated as a result and it is likely that some new business for exporters has been secured. Ultimately, significant export growth will likely still hinge on securing market access for fresh blueberries to China and Korea which would allow Washington suppliers to compete with other origins in those large markets. While fresh access is prohibited, Washington blueberry exports are constrained.

	Baseline 2013	Goal 2014-16	Outcome 2014 -16
China	~$285,000 in dried and frozen blueberry exports	$2,000,000 in increased exports	~$400,000 in exports of frozen and dried blueberries
India	~$30,000 in dried blueberry exports	$200,000 in increased exports	~$100,000 in dried and frozen blueberry exports
Korea	~$3,000,000 in exports of frozen and dried blueberries	$1,000,000 in increased exports	~$6 million in exports of frozen and dried blueberries

Source: Export data all derived from USDA GATS

Aside from the figures above, no progress was made in fresh blueberry exports. Washington State is still prohibited from shipping fresh blueberries to China and Korea. Though fresh blueberries can be shipped to India, the logistics for such exports are a challenge and, to date, no exports have occurred.

BENEFICIARIES

The Washington Blueberry Commission and its membership have benefitted from this project. Research findings were made available to the industry.

Trade leads were generated during each market visit. These were forwarded to industry members for actions and some of them remain open. The WBC is aware of trade leads with:

China (2) – one important fruit ingredient importer for processed blueberry ingredients, and one importer for frozen blueberries. The Washington Blueberry Commission is receiving approximately 5 sales leads a month from China.

India (2) – one fresh blueberry importer and one dried blueberry importer and wholesaler

Korea - The Washington Blueberry Commission is receiving five sales leads a month from South Korea for processed blueberry products.

LESSONS LEARNED

The WBC considers this project to have been a success. An important contributing factor to that success was the direct engagement of industry members in the market outreach. Industry members traveled to each market and participated in meetings. This allowed for clear representation of Washington's blueberry industry and products and an honest assessment by exporters of each market's potential. Industry participation should be encouraged in all such research projects.

On the negative side, however, it could be argued that these research studies were potentially completed prematurely. China and Korea are not yet open to fresh blueberry shipments from Washington State and market visits to those two markets could have been stronger if participants were in a position to also represent fresh exports. Without knowing the timeline for a market access agreement importers could not commit to interest.

There were no unexpected outcomes or results.

Export goals that were set as expected measurable outcomes were not achieved however there are no real lessons learned that would apply to others. The original goals were largely dependent upon Washington State securing market access for fresh blueberries to China and Korea. That has not yet happened. Nevertheless, Washington continues to ship frozen and dried blueberries to all markets and those exports appear to be increasing. Moreover, the three projects helped raise awareness of the availability of Washington blueberries, which should help increase demand in the years ahead.

ADDITIONAL INFORMATION

In 2014, 2015 and 2016 the Washington Blueberry Commission contributed to travel costs for three trade missions. The cost were $6,070.69 for the trip to China, $4,260.36 for the trip to India and $5,291.70. Additionally, the Commission spent approximately $2,000 on development of promotional materials and sample shipping costs.

Additionally, the WBC provided significant in-kind contribution to this effort in terms of donation of industry time for the travel time of the various members of the industry that went on the trade mission. It is hard to place a time value on, but three members for three trips for 8 days or 72 person days.

During the course of this SCBG the Washington Blueberry Commission decided to expand this effort with the contractor and provide additional funds to work to open up these three markets for additional exports in 2015 and 2016. For China and South Korea the focus is on allowing fresh blueberries to enter both markets and for India the focus is for tariff reductions. The fee for South Korea is $10,000, China is $10,000 and for India it is $5,000 for each year so the combination of two years is an additional $50,000 spent in the general area of expanding export markets in China, South Korea and India.

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PROJECT #5

Project Title: A model for Incubating Beginning Growers & Teaching Sustainability Practices

Partner Organization: Viva Farms

PROJECT SUMMARY

The average age of the Washington farmer is 57, and many farmers will retire in the next 20 years. Young people and Latino farm workers have great potential to carry the specialty crop industry into the future, but confront financial, educational, cultural, and language barriers.

Viva Farms, a bilingual agricultural business incubator in Skagit County, will increase the success of beginning and Latino specialty crop growers by providing in-depth assistance in every aspect of specialty crop production. The project will focus on providing training in organic production; tractor/equipment use, safety, and maintenance; accessing wholesale markets; food safety/Good Agricultural Practices (GAP) and business development. Viva Farms will incubate 25 new specialty crop producers and host workshops that will reach an additional 80 regional producers. Viva Farms will also work with WSU Small Farms Program to carry out a program assessment measuring the community, social, and economic impact of the incubator. The assessment will culminate in a published case study, and will be presented and distributed at industry outlets and conferences throughout Washington. The study will document a replicable incubator model and will inform the development of beginning and immigrant farmer training programs throughout the state.

Washington's specialty crop production faces a generational crisis: Per the 2007 agricultural census, the average age of farmers in Washington is 57, which is on par with the national average. In the next 20 years, 70% of all farmers are expected to retire. To replace retiring farmers and meet the market demand for local and organic specialty crops, Washington needs well-trained new producers, both operators and labor. Fortunately, there are two demographics that have the potential to carry agriculture, and specifically specialty crop production, into the next generation: young people and Latino farm workers.

However, beginning and Latino farmers face many challenges when trying to establish a new specialty crop operation, including gaining access to land, education, equipment, capital, and marketing channels. Latino farmers face additional language and cultural barriers. In Washington, only 4.1% of all farms are owned and operated by Latino farmers (USDA Agricultural Census, 2007), even though Latinos provide 83% of all US agricultural labor (US Department of Labor, National Agricultural Workers Survey, 2002). Furthermore, Latinos are extremely underrepresented in organic specialty crop production. Skagit County is the largest producer of specialty crops in western Washington, and organic production alone is valued at $11,520,913, the highest value west of the Cascades (WSU, Current State of Organic Agriculture in Washington State, 2012). Yet out of Skagit's 44 WSDA certified organic farms, only two are Latino owned and operated, even though 17.3% of Skagit population is Latino, and most work in agriculture (US Census, 2010). While Latinos clearly have the agricultural experience and motivation needed to start specialty crop operations, the financial, cultural, and language barriers that stand in the way are often insurmountable. Given the foundational role that Latinos play in specialty crop production and the problem of impending farmer retirement, Washington needs more experiential and enterprise-based educational bridges to help Latino farm workers become highly skilled farm owners and farm managers.

Viva Farms was founded in 2009 to address the specific needs of new and Latino farmers, and to cultivate the next generation of Washington farmers. Viva Farms is Washington's most comprehensive bilingual farm business incubator, and addresses each of these barriers by leveraging high-quality technical assistance and providing access to land, education, equipment, capital, and markets.

The proposed project complements, but does not overlap with, the 2012 WSU Small Farms Team SCBG titled Increasing Latino Farmer Specialty Crops Sales through Intensive Direct Marketing and Cross Cultural Training. The 2012 project focuses specifically on direct marketing for existing Latino producers. This project uses a farm incubator model to help launch new farmers and train farm labor.

PROJECT APPROACH

Project Administration:

During the period of this grant, Viva Farms staff went through several staff changes, including Farm Manager, Produce and Sales Manager, Development and Communications Manager, and Executive Director. Two founding staff members

left, including the Executive Director. Some of these changes resulted in delays in Project Administration, especially from late 2014 through early 2015.

In October 2015, an Amendment to the grant agreement was approved. This amendment covered three sections: *Period of Performance, Agreement Management*, and *The Project Plan*. The Period of Performance was extended to September 29, 2016. This extension allowed for completion of previously delayed or missed activities, including the hiring of the grad student and completion of the case study. The Agreement Management section was amended to list Executive Director Michael Frazier as the Viva Farms Agreement Manager. Finally, the Project Plan was amended to reflect new targets for some of the expected Measurable Outcomes; new dates of completion for certain activities; and extended the dates for all the activities related to the graduate student.

Work Plan Activities:

Meet with subcontractors and partners to finalize work plan. In January 2014, then Executive Director Ethan Schaffer reported that Viva Farms met with subcontractors and partners to finalize work plan. At that time, Viva Farms was expecting to work with WSU to find a graduate student to make a case study on the efficacy of Viva Farms. The partners began developing case study parameters by creating 2014 annual goals and metrics for measuring success. They identified strategies and measurable outcomes for each of the following goals, with the intention that the graduate student would evaluate them in the fall of 2014:

- Incubate successful farmers by increasing their profits and commitment to farming.
- Provide excellent education programs.
- Grow the farm stand into a financial supporter of Viva Farms as well as an outreach and educational tool for customers and Viva farmers.
- Increase fundraising efforts through effective grant writing and donor management.
- Develop long-term and strategic vision for Viva Farms.
- Assist farmers in achieving success post-Viva.
- Provide support for Latino and beginning farmers throughout Skagit Valley.

Despite discussing this plan early in the grant period, hiring a graduate student did not occur for the 2014 school year, in part due to injury of the ED over the holidays. In fact, recruiting a WSU grad student for the project did not occur at all during 2014, despite plans first for a spring 2014 start, then a spring 2015 start. In third quarter 2015, a contract amendment was negotiated with WSDA that included an extension of the period of performance to September 2016 to allow time for a graduate student to complete the study with a January 2016 start date. Kate Smith was recruited to complete the study. By that time, many priorities had shifted at Viva Farms, especially with respect to the farm stand. Efforts to turn the farm stand into a source of financial support for the farm had failed. In fact, the farm stand operated at considerable loss in 2014, due to both a large staff and waste of perishable inventory. Further, the farm stand was seen by many local farmers as a source of unfair competition. To ensure a large inventory, produce was being purchased from Charlie's Produce, the same company that supplies most of the local grocery stores in the area. It was selling conventional, non-local food far more than any local organic food grown at Viva Farms. It was also an outdoor farm stand lacking proper cold storage, which contributed to large quantities of waste. As a seven days per week, 10 hours per day operation, the farm stand required a large staff to operate it. For these reasons, the farm stand was scaled back considerably in 2015, only open 3 days per week, and only selling produce from Viva Farmers and a few other small local farms with whom Viva has a relationship. The marketing focus was shifted to wholesale markets.

Co-facilitate Skagit's WSU Cultivating Success Ag Entrepreneurship course; provide additional business planning assistance to incubator applicants enrolled in the course.

Viva Farms facilitated WSU's Cultivating Success class in winter of 2014. The course ran from Jan 9, 2014 to Mar 24, 2014. Student enrollment was 24, with an attendance average of 18 students. This class was also offered to students at Skagit Valley College (SVC) as part of the Sustainable Agriculture Education (SAgE) certificate. Four students enrolled in SAgE completed the course. Area farmers, business owners, and distributors were engaged to lead discussions and presentations.

Viva Farms facilitated the course a second time during the winter of 2015, from Jan 8, 2015 – Mar 26, 2015. Student enrollment was 28, with an attendance average of 19 students. Nine SVC SAgE students completed the class.

Review applicants' business plans; self-assessment surveys, select producers; sign leases; assist with and submit applications for business licenses, farmer's markets, organic certification, WIC Farmers Market Program, and insurance coverage. Hold farmer orientation meeting.

Twelve farm businesses signed leases in early 2014. Each farm business went through an orientation meeting that covered organic practices and standards, Viva Farms policies, and a review of crop selections.

1. Pure Nelida: Owned & operated by Nelida Martinez & Lizette Flores. Pure Nelida grows 72 Varieties of veggies and flowers.
2. Lozano Farms: Owned and operated by Santiago Lozano. Lozano Farms specializes in strawberries and raspberries.
3. Martina & Regino's Farm: Owned and operated by Martina Gutierrez. Martina and Regino's farm sells strawberries and green beans.
4. Funny Farm: Owned and operated by Britany Fink. Funny Farm grows beets, onions, carrots, and cauliflower.
5. Ali's Farm: Owned and operated by Dr. Ali Inad and Ghazi Adood. Ali's Farm sells a variety of vegetables and fava beans.
6. Ladyfield Farm: Owned and operated by Abbey Bloom-Esposito. Ladyfield grows ornamental plants for wholesale.
7. Buena Berry: Owned and operated by Mauricio Soto. Buena Berry grows blackberries, raspberries, and strawberries.
8. Sustenance: Owned and operated by Beth Meenaghan. Sustenance specializes in artichokes, winter squash, tomatoes, okra, chard, kale, and beans.
9. Arguta: Owned and operated by Anne Baxter. Arguta specializes in cold hardy kiwis.
10. Sabino's Farm: Owned and operated by Sabino Flores. Sabino's Farm grows chilacayote, chiles, beets, lettuce, and squash.
11. Lucy's Nursery: Owned and operated by Lucia Villegas. Lucy specializes in flowers and lilies.
12. Earthfire Farm: Owned and operated by Bruce Lindsay. Bruce grows lettuce, kale, onions, garlic and peas.

Outreach fellow Leigh Newman-Bell assisted four farmers to apply for WIC; five farmers apply for farmer's market vending. She also helped Pura Nelida get additional insurance to bring prepared foods to the farmer's market.

During the first two calendar quarters of 2015, fifteen farm businesses signed leases at Viva Farms. Each farm business went through an orientation meeting that covered organic practices and standards, Viva Farm policies, and a review of plant selections. 2015 farm businesses include:

1. Pure Nelida: Owned & operated by Nelida Martinez & Lizette Flores. Pure Nelida grows 72 Varieties of veggies and flowers.
2. Sustenance: Owned and operated by Beth & Kevin Meenaghan. Sustenance specializes in artichokes, winter squash, tomatoes, and cucumbers.
3. Sabino's Farm: Owned and operated by Sabino Flores. Sabino's Farm grows chilacayote, chiles, beets, lettuce, and squash.
4. Lucy's Nursery: Owned and operated by Lucia Villegas. Lucy specializes in flowers and lilies.
5. Matthew Cioni and Giana Walkim: Matt and Giana grow a variety of market vegetables, including mixed greens and peas.
6. Jason Crowell: Jason grows a variety of mixed market vegetables.
7. David Kim: A variety of mixed Asian herbs.
8. James Hanika: James grows a variety of mixed vegetables, including beans, peas, squash, corn and tomatoes.
9. Lozano Farms: Owned and operated by Santiago Lozano. Lozano Farms specializes in strawberries and raspberries.
10. Martina & Regino's Farm: Owned and operated by Martina Gutierrez. Martina and Regino's farm sells strawberries and green beans.
11. Buena Berry: Owned and operated by Mauricio Soto. Buena Berry grows blackberries, raspberries, and strawberries.
12. Earthfire Farm: Owned and operated by Bruce Lindsay. Bruce grows lettuce, kale, onions, garlic and peas.
13. Arguta Farm: Owned and operated by Anne Baxter. Arguta specializes in cold-hearty Kiwi's.
14. Boldly Grown Farm: Owned and operated by Jacob Slosberg and Amy Frye. Amy and Jacob grow cut flowers and winter storage crops. They operate a winter CSA.
15. Jonquil Farm: Owned and operated by Jonelle Schermerhorn. Jonelle grows squash and cucumbers.

James Hanika, who signed his lease early in 2015, decided not to farm at Viva after all due to his time commitment at a new job, bringing the total number of signed leases to 14.

During the first two calendar quarters of 2016, twelve farm businesses signed leases at Viva Farms. Each farm business went through an orientation meeting that covered organic practices and standards, Viva Farms policies, and a review of crop selections. 2016 farm businesses include:

1. Pure Nelida: Owned & operated by Nelida Martinez. Pure Nelida grows 72 Varieties of veggies and flowers.
2. Sustenance: Owned and operated by Beth & Kevin Meenaghan. Sustenance moved to a monocrop model, growing ½ acre of perennial artichokes and selling wholesale only.
3. Sabino's Farm: Owned and operated by Sabino Flores. Sabino's Farm grows chilacayote, chiles, beets, lettuce, and squash.
4. Matthew Cioni and Giana Walkim: Matt and Giana specialize in culinary herbs and some mixed market vegetables.
5. David Kim: A variety of mixed Asian herbs.
6. Lozano Farms: Owned and operated by Santiago Lozano. Lozano Farms specializes in strawberries and raspberries.
7. Martina & Regino's Farm: Owned and operated by Martina Gutierrez. Martina and Regino's farm sells strawberries and green beans.
8. Arado Farm: Owned and operated by Mauricio Soto. Formerly Buena Berry, Arado grows blackberries, raspberries, and strawberries.
9. Arguta Farm: Owned and operated by Anne Baxter. Arguta specializes in cold-hearty Kiwi's.
10. Boldly Grown Farm: Owned and operated by Jacob Slosberg and Amy Frye. Amy and Jacob grow cut flowers and winter storage crops. They operate a winter CSA.
11. Jonquil Farm: owned and operated by Jonelle Schermerhorn. Jonelle grows squash and cucumbers.
12. Cabrera Farms: Francisco Cabrera. Francisco Cabrera grows several varieties of lettuce.

Review/finalize production plans; coordinate group purchases of spring supplies (propagation materials, tools, seeds, etc.); provide 1-on-1 field preparation support to new tractor operators.

In spring of 2014, Viva Farms coordinated group buying for berry flats and pints, as well as produce boxes. Four farmers purchased 700 raspberry half pint flats, 2,400 pint flats, 9660 pints, and 40 waxed produce boxes. In early June, Viva Farms purchased a shipping container for storage to make better use of bulk purchasing and long-term dry storage.

In 2015, all the farmers had production meetings with new Produce and Sales Manager Erin Mercier regarding expected production, marketing and sales. Operations Manager Rob Smith coordinated the purchase of spring supplies, such as composted horse manure, wood chips, and organic fertilizer.

Hold two 30-hour Tractor and Farm Safety courses at Viva Farms, once per grant year.

Tractor safety courses were originally intended to be held during spring of 2014 and 2015. However, the 2014 class was cancelled due to low registration. Farm and Tractor Safety was held at WSU Skagit County extension during April – May 2015. This is the usual location for this course, although Viva Farmers are required to attend this course to use the tractors at Viva Farms, unless they can show they have prior experience driving tractors. Amendment 1 to the grant agreement amended this workplan activity to tractor safety courses being held in spring of 2015 and 2016.

WSU Skagit Extension director Don McMoran writes: "We had 22 participants this year in the 2016 WSU Skagit County Extension Gearing Up for Safety Course. There was a nice mix of youth, adults and Latino participants. All participants were able to pass the 70-question written test with a 70% or better, 80% on the pre-operational exam and 90% or better on the driving skills test over the 5 weeks and 20 hours of the course. This was one of the best groups we have ever had and I think it shows in the evaluations."

Ongoing: Daily, request-based assistance with pest, disease, weed, irrigation and field equipment management; organic compliance questions; marketing/sales and business management.

These activities comprise most of the day-to-day work at Viva Farms. Here are some highlights from the 2nd quarter of 2014.

Consultation with WSU entomologists: In early spring, Viva Farmer Nelida Martinez noticed severe plant damage around the roots of her squash. She discovered Crane Fly Larva, something previously unseen at Viva Farms. Through the established partnership with the Washington State University Mount Vernon Research Center, the help of WSU entomologists Dr. Lynell Tanigoshi and Dr. Beverly S. Gerdeman was brought in, they were able to identify the pest and help Nelida and other Viva Farmers develop an immediate solution as well as a remediation plan for next year. Nelida was already aware of one way to organically treat the pest using an organic approved product called Entrust. This product is incredibly expensive, but Nelida and other Viva Farmers were able to reduce the cost significantly by purchasing in bulk then divvying up amongst the farms. Additionally, farm manager Mauricio Soto provided expert guidance and training on using concentrated organic sprays to ensure that farmers used the product safely and effectively. Viva Farmers saw immediate results and were able to salvage their plantings. In the Skagit Valley, farmers have excellent resources at the Washington State.

Washington State University Northwest Extension and Research Center. However, research and extension services are not always accessible to beginning or Spanish speaking farmers. Viva Farms plays an essential role in the community by connecting and building relationships between the Latino farming community and WSU researchers and resources. The joint use of Entrust is a great example of how operating in close proximity at the incubator facilitates collaboration and allows multiple small farms to achieve economies of scale often unobtainable by new farms.

Cover Cropping: Vacant plots were planted with nearly four acres of buckwheat. This planting will help manage weeds and the long-term health of the farm. With the new organic certification it is essential to establish good soil building practices.

Demonstration Garden: New methods for planting systems were demonstrated to farmers. By setting up a half acre of beds mulched in plastic and planted in squash, farmers can understand the costs of using mulches versus manpower to maintain weeds. Viva is showing farmers how to find customers before planting, by preselling the squash planting to Pagliacci's, a pizza chain in Seattle.

Organic Certification: Finally, the most important achievement this quarter was becoming certified organic! The inspection was conducted on May 13, all farmers met with the inspector to go over their recordkeeping and farming operations. As a group, Viva will need to work on better record keeping for seed purchases and record keeping in general.

Sales: Viva Farms operates a retail farm stand and a wholesale program that sells to local restaurants, grocery stores, ice cream makers, and schools. The wholesale program has seen 23% growth in sales this year. There are several new clients and a frozen sherbet sold at Molly Moon's in Seattle made exclusively from Viva Farms Strawberries. These sales greatly increase the likelihood of success among the farmers.

Here are some highlights from the 3rd quarter of 2014.

Cover Cropping: Cover crop from 2nd quarter buckwheat planting was disked in, and have been worked in two additional times from dropped seed. Viva is currently with farmers to get fields cleaned and prepped for a winter rye planting.

Organic Certification: The certified transitional acres transitioned into organic this quarter.

New and Growing Farmers: Viva has signed a lease for one new farm business – The Crow's Farm. Matthew Cioni and Giana Wakim are growing on one acre with fall plantings like garlic and mixed vegetables for spring. They plan to sell to restaurants. Lucia Villegas, of Lucy's Nursery will expand her farm from .25 acre to .50 of an acre. Mauricio and Senaida Soto of Buena Berry, will expand from .60 acre to 2.6 at Viva Farms.

In 2015 – and in general – request-based assistance is a major part of the job at Viva Farms during the growing season. Both Operations Manager Rob Smith and Farm Manager Mauricio Soto are busy every day helping with equipment, offering advice about weed and pest management and irrigation. The Produce Manager works full time at marketing and sales.

Ongoing: Monthly incubator farmer meetings covering topics such as organic production, food safety and post-harvest management.

This activity was originally written as Bi-weekly, but amended to Monthly with Amendment 1 to reflect reality. Bi-weekly meetings are challenging with respect to both farmer time and staff time. Most of the incubator participants have jobs in addition to running their farm at Viva Farms. However, during the period covered by this grant, the monthly meetings have become more organized and useful, and have an agenda. During the growing season, there is usually more to discuss than there is time for, including production and planning issues. Sales processes often take up much of the time, as the meetings are a good time to answer questions with as many farmers as possible present.

Quarterly individual meetings on production, marketing/sales and business administration progress and challenges.

Quarterly meetings with individual farmers are informal and generally held on an as-needed basis. Some farmers engage frequently with Viva Farms staff, and may be in the office weekly. Other farmers are less present, and may interact only by phone or email. Factors affecting the amount of time staff interact with any particular farmer include the size of the farm business, type of crop grown, and whether the farmer also has another job, whether that job is full time or part time, and what kind of shift they work. Typically, the berry farmers with multiple acres in production are frequently interacting with staff about these issues during the berry season.

Quarterly individual records check in to assist with record keeping and compliance.

These meetings began formally during the spring of 2014, when farmers met one-on-one with Operations Director, Shannon Carmody, to organize and prepare for the initial organic inspection. Each farmer also met one-on-one with the Oregon Tilth Organic Certified inspector to discuss their farming practices and business.

All the farmers met with the Operations Director again in September 2014 to discuss sales and record keeping as they relate to organic certification. Many of these meetings focused on creating systems to differentiate between conventional sales and organic sales.

In 2015, the organic certification for Viva Farms was renewed on April 1. The organic inspection was conducted on May 19th. Farmers were encouraged to bring their records up-to-date before that date. Organic certification and record keeping was discussed later in 2015 at the December 2 farmer's meeting.

Prepare quarterly progress reports for WSDA on project outcomes.

Quarterly reports were submitted to WSDA throughout the period of performance.

Assist WSDA organic inspectors with interpretation as needed.

Originally, Viva Farms expected to become certified organic under the WSDA. However, WSDA does not offer certification for incubator programs now, and Oregon Tilth has an established program. Oregon Tilth inspector John Hollinrake has worked with incubator farms and speaks basic Spanish. Viva Farms staff helped translate as needed, but encouraged the interaction and relationship building between Hollinrake and each farmer.

Hire WSU graduate student. Develop case study parameters and create study work plan. Finalize research methods and data collection timeline.

This activity was delayed again and again throughout the grant period for reasons that were discussed earlier in the report. In January 2016, Kate Smith began the case study. As the Northwest Small and Latino Farm Educator with the WSU Extension Small Farms Program/Skagit County Extension, Kate was already very actively involved with Viva Farms. She serves as the translator at farmer meetings and many of the workshops, and works directly with many of the Latino farmers on paperwork or other areas where they need assistance and translation. Due to the nature of the surveys and interviews being conducted for the case study, this was ideal because there was already a level of trust between Kate and the Latino farmers.

For the period of Quarter 1 2016, Kate's tasks included:

- Conducting a literature review of current publications on Farm Incubators, Participatory Learning, Program Evaluation, etc.
- Refining research questions, project design and methods; accumulating data from past surveys; conducting interviews with previous participants to add to the data, using a revised version of the Viva End of Year Survey.

- Contacting NIFTI (National Incubator Farm Training Initiative). Kate intended to include some questions on her surveys from the upcoming national farm incubator survey.
- Applying through the WSU Internal Review Board to get the evaluation approved as an ethical approach to research. Kate found that an evaluation would be counted as exempt from going through the elongated process.

For her dissertation, Kate plans to write about the Contributions of Farm Incubators to Sustainable Food Systems.

For the 2nd quarter of 2016, WSU graduate student Kate Smith reported:

- Data Collection is currently underway with interviews with current and past Viva Farms participants
- Data analysis platform has been chosen and data entry has begun
- Draft of case study has been started
- She applied to present at the Tilth conference leading a panel session on Farm Incubators (after approved she will reach out to have someone from Viva participate on the panel)

Kate completed her work study plan during this timeframe. It is included as an attachment.

Coordinate, aggregate and transport bi-weekly product deliveries to retailers, restaurants and institutions in North Puget Sound.

In 2014, Viva Farms completed the wholesale program on October 1. Sales increased nearly 15%, from $39,791 in 2013, to $46,468 in 2014. Viva Farms sold more produce through the Puget Sound Food Hub, adding two more delivery days to the wholesale delivery schedule. The wholesale program added several new customers in Bellingham and Seattle, including Molly Moon's ice cream, which accounted for 10% of 2014's wholesale sales and provided wonderful promotional opportunities.

Increased sales also brought more challenges. Viva Farms exceeded the capacity of the delivery van, which is a standard size passenger van with the seats removed. The farm partnered with Community Action to rent a larger delivery van when delivering more products. Organic certification provided access to new customers in higher-end markets. One lesson learned was that farmers needed training in grading and packing to be prepared for these new markets.

In 2015, the Produce Manager brokered sales and deliveries for farmers through three different wholesale markets: The Puget Sound Food Hub, Viva Farms wholesale, and the Viva Farms farm stand. Viva Farms purchased $12,443 worth of produce from incubator participants for sales through the Puget Sound Food Hub. The Food Hub provides web-based centralized purchasing, invoicing, and distribution for farmers and buyers throughout the Puget Sound region. Deliveries from Viva were made twice per week to the Food Hub distribution center at Bow Hill Blueberries.

Viva Farms also runs a wholesale program directly to several locations in Seattle, including Molly Moon's Ice Cream and Stockbox Grocery. Produce was delivered to Seattle customers every Tuesday and Friday.

Viva Farms changed the business model of the farm stand somewhat in 2015, committing to selling only produce from Viva farmers and a few other local farms. For this reason, the ability to stock the farm stand fully was limited compared to other years, and so the hours of operation were reduced. The farm stand was open Thursday, Friday, and Saturday from 11 am to 7 pm. An unseasonal storm with high winds damaged the farm stand in August, abruptly ending the strawberry season and causing the farm stand to be closed for one weekend in August. Viva Farms purchased $14,643 worth of produce from Viva farmers for sale at the farm stand. That amount breaks down to $6,803 for July, $5,668 for August, and $2,172 for September.

Due to the unusually warm and dry summer in 2015, wholesale produce sales continued into October, and sales on the Puget Sound Food Hub continued into November. At the end of 2015, sales had increased nearly 41% over 2014 – from $46,468 to $70,473.

2016 was not actually a reporting period for this activity, but at this writing, 2016 sales are at $127,464, an 81% increase over 2015.

Quarterly meetings on case study data collection.

The first meeting was held on April 29th. WSU graduate student Kate Smith presented her research to date. After this meeting, her project plan was approved by her advisors at WSU.

Annual review (generate and/or review each farmer's Profit/Loss report, revise business plan for next season, discuss spin-off readiness); pre-CPA tax preparation.

During Oct-Dec 2013, Viva Farms staff met with all 12 farm businesses to evaluate their farms and businesses for 2013. The total acreage in production by Viva Farmers was 47.675 (up from 44 in 2012). This includes land both on and off-site – Viva Farms itself was not fully leased. Most farmers saw increases in their profits. However, Viva's most successful farm, Lozano Farms, saw little increase due to pest problems. This sparked discussion of better farm-wide pest, weed, and disease management. The staff planned to implement an Organic Systems Plan (OSP) for 2014, to outline preventive measures, expectations of Viva incubator participants, and record keeping requirements. The OSP will allow Viva Farms and all incubator participants to become organically certified, increase profit, and find new markets.

Operations Director Shannon Carmody met with each farmer in September of 2014 to discuss sales and recordkeeping, and to evaluate farm businesses for 2014. Two farm businesses left Viva at the end of 2014. This includes Ali's Farm, owned and operated by Dr. Ali Inad and Ghazi Adood. Ali and Ghazi found they lived too far away from Viva to be present at the farm often enough to care for their crops. Brittany and Craig Fink-Minklin, who owned and operated Funny Farm, also left at the end of 2014 due to a move to Wenatchee, WA.

End-of-season annual reviews were conducted with 13 of 14 farm businesses at the end of 2015. Of the 14, two left and 12 remained for the 2016. The farms that left included Earthfire Farm, owned by Bruce Lindsay. A retired USDA soils scientist, Bruce found that working ½ acre on his own was too much work. He had a change of heart early in 2016, but Viva was fully leased by then. However, another farmer who was not using all her land allowed Bruce to use a portion. Bruce also volunteered his time at Viva in many areas, especially helping with the land-based practicum, which was in its first year in 2016. As a volunteer, he is a valued asset to the Viva team. He will again be leasing ¼ acre in 2017. The other farmer who left at the end of 2015 was Jason Crowell. Jason's experience at Viva Farms convinced him that farming was not what he wants to do. In some ways, this counts as a success for an incubator farm - it allowed Jason to give farming a try for a season without too much financial commitment, and helped him make a lifestyle choice.

Fifteen farmers began farming at Viva Farms in 2015. Lucy's Nursery, a cut-flower business, left much earlier in the season after she could acquire land off-site.

Final Data Collection Meeting

In 2016 the final data collection meeting for the case study by WSU graduate student Kate Smith was held September 23rd at Viva Farms. The discussion included:

- Update on data collection progress
- Ask for support following up with a few past participants that Kate had not been able to reach
- Scheduling of 2 staff interviews
- Create a calendar for drafts, edits, proofs and final draft of case study
- Plan for presentation at Tilth Conference
- Brainstorm case study distribution plan

During the meeting, Kate and the staff decided that Executive Director Michael Frazier would be the Viva representative on the panel discussion at Kate's presentation at the Tilth Conference in November in Wenatchee, WA.

Analyze data and draft case study report
Edit, proof, fact check final draft of case study. Publish case study.

WSU graduate student Kate Smith compiled the results of her case study into a Preliminary Report, which is attached. Kate also produced a one page infographic to illustrate the results of the study. This document is also attached.

Distribute case study to agriculture organizations, publish online (Viva Farms, WSU SFT and other websites) and present at conferences. Amendment 1 noted: Report will be presented at appropriate conference that may fall outside of grant timeline.

WSU graduate student Kate Smith presented her report at the Tilth Conference in Wenatchee, WA on November 13th. This is the program description of her presentation:
Tilth Conference 2016
Session D, Sunday November 13th 9am-10:15am
Farm Incubator Training Programs: Contributions to Sustainable Food Systems
Farm incubators have surfaced as one method for training the next generation of farmers. How are these programs designed and are they working? What kinds of contributions are farm incubators having toward our sustainable food systems? How do we measure the impacts of these programs environmentally, socially and economically? Hear from incubator organizers from around Washington State in a panel discussion followed by a presentation on incubator evaluation with a preliminary Impact Evaluation Report of Viva Farms, presented by WSU Graduate student Kate Smith. Attendees can expect to learn more about farm incubator programs around Washington as well as ideas for program impact evaluation.

Kate gave her presentation, followed by a panel discussion. The members of the panel included Michael Frazier of Viva Farms, Matthew McDermott of Cloud Mountain Farm, and Kyong Soh of Tilth Alliance Farmworks. The presentation was well attended and generated good discussion and questions from conference attendees.

Pictures from the conference, the info-graphic, and a copy of the preliminary report are available at www.VivaFarms.org.

Don McMoran, Director of WSU Skagit County Extension, coordinated and facilitated the tractor and equipment operation and safety classes in 2015 and 2016.

Dr. Marcia Ostrom, PhD, Director of the WSU Small Farms Program, was responsible for selecting and advising the WSU graduate research student, Kate Smith, and overseeing the Viva Farms case study in consultation with the Viva Farms team.

The period of performance for this grant covered a transitional period for Viva Farms. Co-founder and Executive Director Ethan Schaffer left late in 2014, with Michael Frazier taking the role of interim Executive Director. Presented with an opportunity to pursue graduate studies at WSU, Operations Director Shannon Carmody left in January 2015. Production Manager Rob Smith moved into the role of Operations and Incubator Director, and Michael Frazier became Executive Director. Two new staff members joined the team in 2015: Produce and Sales Manager Erin Mercier and Development and Communications Manager Beth Meenaghan. It was necessary to hire a new Produce and Sales Manager in March 2016, when J.R. Staton joined the team. Despite these transitions, everyone has worked hard to stay on track with the project's goals, and the WSDA has worked closely with Viva Farms to amend the contract as appropriate. The support of the WSDA and project partners WSU Skagit County Extension and WSU Small Farms team was significant and greatly appreciated throughout this time.

The scope of this project only benefitted specialty crops.

GOALS AND OUTCOMES ACHIEVED

Outcome 1:
Goal: Establish new specialty crop producers in Skagit County with an emphasis on socially disadvantaged producers.

Viva Farms added only one new producer in 2016 because the farm was fully leased with continuing producers, due to existing farm businesses requesting more land and land resource limitations at the current site. Six of twelve producers in 2016 were Latino. However, Latino farmers were responsible for over 50% of the acreage leased at Viva Farms, as well as for over 50% of sales.

Of the farm businesses who finished the 2016 season at Viva Farms, 7 have been operating at Viva Farms since at least 2013; five of these are Latino owned. Lozano Farms, owned by Santiago Lozano, is "launching" at the end of 2016, and will be operating his farm business on land leased elsewhere in Skagit County.

Outcome 2:

Goal: Beginning Latino and specialty crop producers increase knowledge of organic production systems; farm equipment operation, safety, and maintenance; Good Agricultural practices (GAP); wholesale marketing; and business management.

- Viva Farms met the target to provide daily one-on-one technical assistance and training to 25 incubator participants over the first, second, and third years of the grant period.
- In each year of the grant period, Viva Farms assisted farmers with taxes, obtaining business licenses, and carrying insurance on an as needed basis. In the end-of-year evaluations, Viva Farms included survey questions to create a complete picture of all producers to see if they are maintaining a business license, filing Schedule F, and carrying insurance. This data was collected for 2015, but is on written documents and has not been collated. The surveys have not been carried out yet for 2016.
- All incubator participants had access to land, equipment and infrastructure. In 2014, storage was identified as a new piece of infrastructure needed at Viva Farms to provide farmers with space to dry, store, and cure produce. In 2015, a large barn convenient to the property was available for drying garlic and storing winter squash.
- Viva Farms routinely purchases many items in bulk to save money for every farmer, including items such as boxes for produce and berries, cover crop seeds, and fertilizer.
- End-of-course surveys are completed whenever a workshop is held. Through 2016, 96% of participants report increased knowledge.
- Farm and Tractor Safety Course was held at WSU Skagit County Extension during April-May 2015 and April-May 2016.

Outcome 3:
Goal: Increased number of Latino-owned certified organic specialty crop farms in Skagit County.
Viva Farms achieved the goal of 6 Latino-owned certified organic specialty crop farms operated at Viva Farms in 2014, 2015 and 2016.

Outcome 4:
Goal: Increased knowledge amongst producers, support groups and government agencies of best practices for developing specialty crop farm incubator programs for beginning and socially disadvantaged producers.

WSU graduate student Kate Smith has completed a Viva Farms Case Study, and has published her preliminary report titled *Farm Incubator Program Impact Evaluation*. Her findings were recently presented at the Tilth Conference in Wenatchee, WA on November 13, 2016, followed by a panel discussion with representatives of three incubator programs, including Viva Farms. Kate also produced a one-page infographic to summarize the survey data. The report and the infographic are attached to this report.

Outcome 4: Kate Smith's study will not be complete for several more months. At this time, Viva will not be able to meet the requirements of distributing to all non-profit organizations and government agencies serving beginning and socially disadvantaged producers in WA. The case study will need to be presented at one more agricultural conference, and at least one media outlet will cover the case study findings. The current preliminary report has already been made available on the Viva Farms website, and will soon be available on the WSU Farm and Food System Program Webpage.

Viva Farms and WSU completed all the activities and goals for the project, with a few exceptions that were addressed by Amendment 1 to the contract. The primary goal that had to be adjusted was the number of participants. Viva Farms reached a ceiling on available space before the project could reach the number of participants anticipated. When the project began in 2013, there was no time-limit established for farmers to remain at Viva Farm, and little incentive for the farmers to move their business off-site. This meant the rate of new producers replacing departing producers was not as high as initially anticipated.

The WSU Tractor and Farm Safety course also did not draw as many participants as initially anticipated.

Outcome 1:

The goal for Outcome 1 was "establish new specialty crop producers in Skagit County with an emphasis on socially disadvantaged producers." As written in the original proposal, the target was "25 individual producers *per grant year* incubated at Viva Farms, *10 new and 15 continuing*. The increase in participation will bring the incubator to full capacity with approximately 5 new producers replacing graduating producers each year. At least 50% will meet the USDA definition of a socially disadvantaged producer."

By 2015, it was clear we could not meet these numbers. There are four factors that impact how many producers we are incubating during any grant year: 1 – interest from new potential participants; 2 – how much land each farmer is leasing; 3- how much land we have available; 4 – whether existing participants are "graduating" or moving on for other reasons.

When Amendment 1 to the contract was written in 2015, the target for Outcome 1 was changed to read: "*15* individual producers per grant year incubated at Viva Farms, *5 new and 10 continuing*." There were 15 farm businesses operating at Viva Farms in 2015.

Between existing farmers increasing acreage, and some experienced new farmers starting with relatively high acreage, Viva Farms was fully leased in 2016 with only 12 incubating farms participating – and the farm had to turn away interested individuals. In many cases, the incubator farms are operated by more than one individual – usually two family members, but in some cases, business partners. In that way, Viva Farms has met the metric of "15 individual producers." Fifty percent of the 2016 farm businesses meet the USDA definition of socially disadvantaged.

Outcome 2:

The goals and targets of this outcome were broad and varied. Goals include:

- Beginning and Latino specialty crop producers increase knowledge of organic production systems
- Farm equipment operation, safety, and maintenance
- Good Agricultural Practices (GAP)
- Wholesale marketing
- Business management

The targets are listed below. Progress towards those targets is indicated in **bold**. Unfortunately, Viva Farms does not have baseline data from 2013 for this data, and 2016 surveys have not yet been conducted. The information below reflects data from 2014 and 2015.

- Deliver daily one-on-one technical assistance and training to 25 incubator participants over the 2-year grant period. **Amendment 1 extended the project through the 2016 growing season, so Viva Farms is counting three years for the project.**
    - All 25 will gain access to land, equipment and infrastructure
    - **Viva Farms has met this goal. There has been a total of 26 independent farm businesses operating at Viva Farms in the time frame spanning from 2013, the baseline year. Additionally, many of the businesses have two or more active participants in the program.**
- Obtain WA state business licenses. **In 2014, 12 farmers completed end-of-year surveys. Of these, 10 reported having a WA state business license. In 2015, out of 13 surveyed farmers, 9 reported having business licenses. One farmer had one formerly but had not renewed.**
- Report farming income on IRS Schedule F. **In 2014, 3 farmers reported filing Schedule F. In 2015, 7 farmers reported they planned to file Schedule F for the 2015 tax year.**
- Carry comprehensive liability and product insurance (group and/or individual). **In 2014, 2 farm businesses reported carrying liability and product insurance. The number remained the same for 2015.**
- Reduce input and marketing supply expenditures by 15% through group purchase. **Viva Farms has established regular group purchasing of both marketing supplies and field inputs such as fertilizer, manure, and seeds. Most farmers are taking advantage of the group purchasing, and buying their supplies from Viva Farms. This is especially true of the smaller businesses. However, the recordkeeping from the farmers is insufficient to determine how much they have reduced their expenditures for these items.**
- Collectively, farmers will sell more than $200,000 in produce. **The incubator participants at Viva Farms reached this metric in 2015. Viva Farms is getting close to exceeding this value in a single year, and is on target to reach it in 2017.**
- All 25 will report increased knowledge and application of topics covered in a self-assessment. **Farmers report increasing knowledge in most areas – unless they considered themselves fully knowledgeable already. Both Viva Farms and the farmers continue to identify new areas where they need to improve knowledge.**
- 80 (later amended to 50) beginning specialty crop producers attend a 30-hour Tractor and Farm safety course and receive a passing grade. **20 participants attended tractor safety in 2015. 22 participants attended tractor safety in 2016.**

Outcome 3:

The goal was to increase the number of Latino-owned certified organic farms in Skagit County. The baseline was 2 Latino-owned certified organic farms operating in Skagit County in 2013. The target was to increase that number to 6.

There are currently 6 Latino-owned farms at Viva Farms that have organic certification under Viva Farms "umbrella." This means that Viva Farms holds the certification. All of the farm businesses at Viva Farms are farmed organically, and do all of the necessary recordkeeping, which is all part of the organic certification process for Viva Farms. Two of the non-Latino owned businesses have obtained their independent organic certification. Viva Farms expects four more farms to obtain independent organic certification in 2017, and further expects one or two of those to be Latino-owned.

Outcome 4:

The goal and target for outcome four are related to the research project conducted by WSU graduate student Kate Smith. Ms. Smith accessed the program impact of the incubator program at Viva Farms, including the economic impact and effective practices. Because her research was conducted later in the project than initially intended, she has not quite met all targets. However, her preliminary report has been distributed and the findings are attached to this report. Ms. Smith presented her preliminary findings at the Tilth Producers Conference in Wenatchee, WA on November 13, 2016. To meet the requirements of her graduate program, her project is still ongoing.

BENEFICIARIES

Socially disadvantaged and beginning farmers and ranchers have benefitted from this project.

The following information is from Kate Smith's "Viva Farms Case Study" report, beginning on page 4. The full report is attached.

Age

Participants reported mean (average) age of 42 years old. 25.9% of participants were 35 years of age or younger while 74.1% 35 to 64 years of age, and no participants were older than 65 years of age. The average age for all primary farm operators nationally is 58.3 years old (USDA Ag Census, 2012).

AGE	VIVA FARMS PARTICIPANTS % (2015)	BEGINNING FARMERS NATIONALLY 1 TO 5 YEARS ON CURRENT FARM (2012)
Less than 35 years	25.9%	14%
35 to 64 years	74.1%	70%
65 years +	0%	16%

Gender

Participant respondents at Viva Farms were 40.7% female farmers, while the nationally women represent only 18% of farmers (Ag Census 2012 Highlights, 2014). Generally, Incubator farms nationally support higher numbers of female farmers than the national percentage, with an average of 48% female farmer participants reported in 2015 (*National Incubator Farm Training Initiative*, 2015).

GENDER	VIVA FARMS PARTICIPANTS (2015)	BEGINNING FARMERS NATIONALLY 1 TO 5 YEARS ON CURRENT FARM (2012)	INCUBATOR FARMS NATIONALLY (2015)
Male	59.3%	82%	52%
Female	40.7%	18%	48%

Race/Ethnicity

Race/Ethnicity (n=27)	Viva Farms participants % (2015)	Beginning Farmers Nationally 1 to 5 years on current farm (2012)
White	48.1%	90%
Minority	51.9%	10%
Latino	22.2%	

Indigenous Latino	22.2%	
Asian American	3.7%	
Other	3.7%	

Education level

Viva Farm participants have a range of educational backgrounds from less than third grade education to university master degrees. Field programming has been shown as an effective educational strategy accessible to all, even those with limited or low levels of education (Davis et al., 2012).

EDUCATION LEVEL (N=26)	**VIVA FARMS PARTICIPANTS**
Less than High School	46.2%
Some College/Associates Degree	7.7%
College Graduate	30.8%
Graduate Degree	15.4%
PhD	0%

Previous farming experience before Viva Farms

As a program open to all aspiring farmers, participants of Viva Farms have a wide variety of experiences in agriculture previously ranging from no experience to those that have been farming all their lives. Experience ranged from no experience to 45 years (since childhood) with an average of 10 years of experience farming. As several participants worked as farmworkers before transitioning to farm owners, the level of field experience contributed to a high average.

EXPERIENCE FARMING (N=22)	**YEARS**
Average	10
Median	6
Minimum	0
Maximum	45

Goals for Farming

Participants enter the program with different initial goals for agriculture. Eleven (52.4%) of participants indicated that their goal when they started at their farm business was to eventually have farming be their primary source of income. Eight (38.1%) of participants identified their farming goal to have it be a secondary source of income while only two (9.5%) cited their goal for farming as quality of life. Many farmers commented that quality of life was part of their farm goals. No participants indicated that they started the program without the goal of owning their own farm but only to get a job in agriculture, although several participants since participating have worked in agriculture (see Table 5).

GOALS FOR FARMING	**N=21**	**PERCENT**
Primary Source of Income	11	52.4
Secondary Source of Income	8	38.1
Quality of Life	2	9.5
Job in Agriculture	0	0

Work on the Farm

31% of those farming in 2015 reported Full Time Seasonal work (more than 35hrs per week per operator) while 69% reported Part-Time work on their farm with work off the farm. Nationally, 77% of beginning farmers on current farm for 1 to 5 years worked off the farm (Ag Census 2012 Highlights, 2014)

Data was reported by program participants and/or collected by Viva Farms staff over the period of the project. Unfortunately, due to many personnel changes, especially during late 2013 and through January 2015 time frame, data collection was inconsistent, and there was loss of continuity in information. For example, solid baseline data for 2013 is incomplete either because it never existed, or no one knows where it is.

However, a consistent end-of-year survey process was established in 2014 and has been carried forward since that time. Survey questions have been adjusted as needed. For example, if the questions were not providing the information needed or intended, or participants were reluctant to answer them, the surveys may be adjusted from year-to-year.

Kate Smith describes her evaluation methods for the Case Study on page 3 of her report as follows:

"We used qualitative and quantitative methods to conduct the impact evaluation for this research project. This evaluation was conducted through interviews and surveys with current and past participants, participant observation as well as Viva Farms staff interviews. We analyzed responses and data from end of season interviews with 12 current participants and

10 interviews with past Viva Farms participants. The selection of our interview participants included all current and past participants.
Interview and survey questions were designed after Agriculture and Land-Based Training Association's End of Year Interviews and a study of University of Santa Cruz Apprenticeship in Ecological Horticulture conducted by Perez et al. in 2010 (Martin, Bernau, Lindsy, Perez, & Landeck, n.d.)
We analyzed responses and data from 2015 End of Year Surveys conducted in November and December 2015 with 14 2015 Viva Farms Participants as well as conduct interviews with 8 previous participants and 13 follow up interviews with current participants during spring and summer 2016. The case study also included unstructured interviews with Viva Farms Staff members and general participant observation. Ongoing participant observation included shadowing farmers during operations, attending professional development meetings and Monthly Viva Farmer meetings, all of which helped develop themes for analysis. This also allowed development of trust with participants to fill out farmer narratives. Data gathered from surveys and interviews was analyzed to create an impact analysis. Results were additionally compared and supported with data from National Incubator Farm Training Initiative annual survey results, USDA Agriculture Census data and Small Farm Viability research data.
Viva Farm staff contacted past Viva Farms participants via phone and email in May 2016 to share the purpose of the study and invite to participate in the study with a scheduled interview at their farm. In June 2016, we sent follow up emails and phone calls. Additional follow up included phone calls, messages, email invitations, and contact again from Viva Farms and from previous leadership. The interviews consisted of a visit and a structured interview that was audio-recorded with participant consent. We conducted structured interviews in person and over the phone when necessary. Interviews were recorded. Interviews ranged from 20min to 60 minutes. Interviews were conducted in Spanish (9) and English (13). I collected secondary data through survey results and Viva Farms materials. (Goldberger, 2008)."

LESSONS LEARNED

The staff at Viva Farms and WSU have not yet had the opportunity to discuss, as a group, the lessons learned from the WSDA SCBG grant. Since this project has run for three years, there are certainly lessons learned, some that have come up along the way and changes have been implemented. But there has not been a formal compilation of the lessons learned. Some of the biggest lessons learned have come to light while putting this final report together. These thoughts will be compiled and communicated to the staff, in order to develop improved processes moving forward.

No unexpected outcomes or results affected the project.

ADDITIONAL INFORMATION

Total In-kind match for Year 1:	**$37,492.00**
Farm manager and produce manager at .25 FTE for one year:	$17,600.00
15% administrative overhead for one year	$6,392.00
use of Viva Farms land and facilities for one year	$8,000.00
Tractor and equipment use for one year	$2,500.00
WSU small farms team administrative overhead for one year	$3,000.00
Total In-kind match for Year 2:	**$37,492.00**
Farm manager and produce manager at .25 FTE for one year:	$17,600.00
15% administrative overhead for one year	$6,392.00
use of Viva Farms land and facilities for one year	$8,000.00
Tractor and equipment use for one year	$2,500.00
WSU small farms team administrative overhead for one year	$3,000.00
Total In-kind match for Year 3:	**$37,492.00**
Farm manager and produce manager at .25 FTE for one year:	$17,600.00
15% administrative overhead for one year	$6,392.00
use of Viva Farms land and facilities for one year	$8,000.00
Tractor and equipment use for one year	$2,500.00
WSU small farms team administrative overhead for one year	$3,000.00

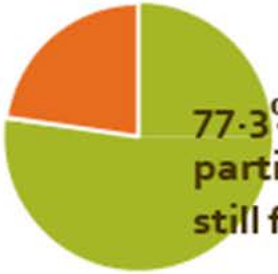
Total In-kind match over three years: $112,476.00

Viva Farms Incubator Impact Evaluation Preliminary Report

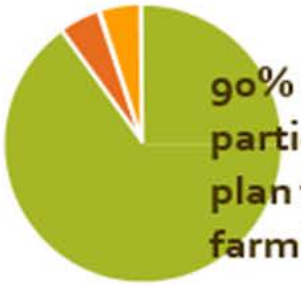
Prepared by Kate Smith, Washington State University

28 Farm Businesses incubated since 2010

2015



Future



Farmer Produce sold through Viva Farms

2015 Average Farm Size 1.56 acres

Participants farming in 2015 reported

95% Have increased access to healthy food for those with limited access

82% Maintain Organic Certification

76% Plant cover crops and pollinator habitat on their farms

100% Use water conservation practices including drip tape irrigation and mulch

68% Work in Agriculture or Food outside of running a farm business

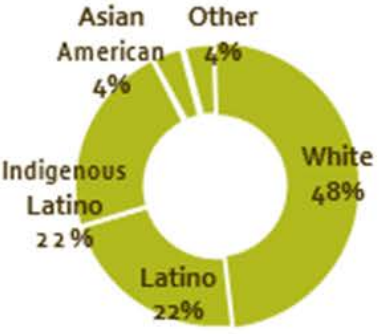
Participant Demographics

52.4% Plan to farm as a primary income

AVERAGE AGE

Viva: 40.2 years
Nationally: 58.3 years

RACE/ETHNICITY



This project was funded by the Washington State Department of Agriculture Specialty Crop Block Grant. Data was collected through farmer surveys and interviews with participants representing 22 of 28 farm businesses that have farmed at Viva Farms

WSDA Washington State Department of Agriculture VIVA FARMS WASHINGTON STATE UNIVERSITY

WSDA SPECIALTY CROP BLOCK GRANT
VIVA FARMS INCUBATOR CASE STUDY

Kate Selting Smith

Study Work Plan

In this project I will conduct a Case Study of Viva Farms as an incubator farm evaluating the social, economic and environmental impacts of the program. This will include a description of program operations and an in depth analysis of data collected from end of year interviews and surveys from current farmers, past participants and incubator staff.

Research Methods

We will use qualitative and quantitative methods in this research project. The selection of the study participants will include all current and past participants of Viva Farms. We will analyze responses and data from 2015 End of Year Surveys conducted in November and December 2015 with 13 current Viva Farms Participants as well as conduct interviews with 15 previous participants in May 2016. The case study will also include digital storytelling with current farm incubator participants in May 2016, interviews with Viva Farms Staff members, and general participant observation.

Data gathered from surveys and interviews will be analyzed to create an impact analysis. Results will be compared and supported with data from National Incubator farm Training Initiative annual survey results, USDA Agriculture Census data and Small Farm Viability research data.

Data Collection Timeline

Phase 1- January-March
Literature review of Incubator project evaluations Determine parameters of evaluation project

Phase 2- April-June
Data collection from 2015 End of Season Interviews Farmer Interviews- Previous Viva Farmers
-Digital Storytelling interviews with current farmers
-Follow up surveys with current Viva Farmers

Phase 3- July-August
Compile results from farmer interviews and surveys Analyze results
Apply to present at regional conferences

Phase 4- August- September
Design info graphics to display impact results for 2015 season impact Write Impact Evaluation Initial Findings
Submit Initial findings to WSDA under Specialty Crop Block Grant

Case Study Parameters

Viva Farms Training impact

- # of Viva Participants (current and past) farming in 2015/2016 (On/Off site)
- # of Viva Participants (current and past) working in Food System jobs
- Number of trainings provided per year by topic
- Number of total attendees and participants in trainings throughout 2015
- Total Farmer produce purchased and sold
- Number of markets reached
- Average years of Farming experience/average years at incubator

Economic indicators: Training new farmers

- Farmer Profitability
    - Value of Assets
  - Sales and Expenses (Average)
  - Expense to Sales Ratio
  - Percent of operators with net gain
- Jobs created/maintained
- Worked off the farm/Primary Occupation
- Sales range categorized for part-time, full-time etc.
- # Farmers accessing grants and loans

Social Indicators: Improving access to food and farming

- Contributions to Community Food Security
  - Quantity of food donated (Viva totals)
  - Quantity of food sold to food banks, daycares, schools (Viva Totals)
  - Contribution to family food security for participants
- Leadership roles taken in the community
- Increased access to farming
  - Racial and ethnic diversity of participants
  - Gender of participants
  - Age of participants
- Farmer Support Network
  - Membership in Farmer Organizations
  - Farmer Mentor

Environmental Indicators: Producing food in an ecologically sustainable manner

- Contribution to organic production
  - Number of Certified Organic Farms
- Implementation of sustainable production methods
  - Water conservation practices
  - Cover cropping
  - Soil testing and nutrient management
  - Utilization of practices that promote soil quality and health
  - Physical, cultural, and biological controls for pest and disease management
  - Planting of pollinator habitat
  - Improved nutrient cycling
  - Crop Rotation plan
  - Improved energy efficiency/green energy sources
  - Use of approved organic inputs
  - Non-use of synthetic or petrochemicals
  - Other environmental sustainability practices

- Focus on environmental topics in training (Viva training topics)
- Development of an environmental ethic- anecdotal
- Self-evaluation of knowledge

Data collection Tools

End of Year Surveys with 2015 Viva Farms Incubator participants:
End of Year survey interviews were conducted in December and November of 2015 with 2015 Viva Farms participants by Viva Farms staff. Surveys questions were created in collaboration with Viva Farm Staff and Kate Smith and were modeled after questions in from ALBA Farm Incubator End of Season Survey and the UCSC CASFS 2010 Alumni survey. Data will be compiled without participant names or business names and will be analyzed for economic, social and environmental impact indicators. See Appendix A for survey. Follow up interviews will be conducted with current farm participants in June 2016.

Past Viva Farms participant surveys:

In May and June 2016 we will conduct interviews with previous Viva Farms participants in reference to the 2015 growing season. Responses and data will be recorded on paper and with participant approval, through voice recording. Data will be compiled without names and analyzed for economic, social and environmental impact indicators. See Appendix B for survey.

Digital storytelling interview questions:
May 9th-13th, 2016 digital storytelling interviews will be conducted with incubator participants by Kate Smith in collaboration with WSU English Department Professor and six WSU English department students. Interviews will be conducted with three primary farm participants and additional participants secondarily. Video interviews may be included in the final case study report with participant approval.

- Tell us about your farm business.
- Why do you farm at Viva/why did you start farming at Viva Farms?
- What do you like most about farming at Viva?
- Why do you farm organically?
- Has the programming at Viva Farms helpful or useful?
- Has Viva changed the amount of risk you've had to take in opening your business?
- Has running your own farm improved the quality of food you and your family eat at home?
- Has participating at Viva Farms changed the way you farm?
- What does your farm look like 5 years from now?

Incubator Staff interview questions:
Incubator staff interviews will be conducted in May and June 2016 with 2 staff members to gather supporting data for the evaluation case study.

- How many participants farmed at Viva in 2015? In 2016?
- How did land use change at Viva Farms from 2015-2016?
- How many trainings were facilitated in 2015? What were the focus topics?
- How many total attendees participated in Viva Farms trainings throughout 2015?
- What was the total dollar value of produce purchased from Viva Farmers by Viva in 2015? Sold?
- How much produce ($value) was donated in 2015?
- How much food was sold to food banks daycares, schools in 2015?
- How many clients did Viva sell to that were food banks, daycares, schools, hospitals, and other community markets that increase food access?
- How many farms used cover crops in 2015?
- Did Viva do soil tests in 2015? How were the results used?
- What are some of the environmental farming practices that Viva promotes?
- Do you have any success stories that you have observed in farmer growth?

Viva Farms Case Study

FARM INCUBATOR PROGRAM IMPACT EVALUATION PRELIMINARY REPORT

SMITH, KATE

Prepared by Kate Smith

Masters Candidate Environmental Science
Washington State University

November 2016

Background and Context

Viva Farms is a non-profit farm incubator organization in Skagit County, Washington. The Viva Farms Incubator is located on a 33-acre piece of land leased from the Port of Skagit Property near Burlington, approximately 70 miles from Seattle and 30 miles from Bellingham. The farm incubator was founded in 2010 as a collaboration between the Viva Farms founders, Washington State University (WSU) Skagit County Extension, and the Port of Skagit. The Viva Farms mission is to launch the next generation of farmers. With the goal to reduce the barriers to entry for beginning farmers, Viva Farms provides access to the top five essentials for farming including land, infrastructure, markets, capital, and training.

Infrastructure includes access to a greenhouse, barn storage space, water, cooler, wash pack station, and computer access. Viva Farms collaborates with WSU Extension and other local organizations and agencies to offer farming workshops for the public and participant farmers. The Incubator Program is open to all beginning farmers who qualify and is structured and offered bilingually in Spanish to meet the needs of the Latino population in Skagit County. Viva Farms became Certified Organic in 2014. By 2016, all farmable land was leased by farm incubator participants. Since 2010, Viva Farms has incubated 28 individual farm businesses. Since the founding, Viva Farms has helped support over 500 beginning farmers through trainings and workshops.

Viva Farms operates a wholesale marketing program and a seasonal farm stand to sell participant farmers' produce. In 2015 Viva sold 75% of the produce it purchased from Viva farmers through wholesale markets, with another 25% of sales through the farm stand. Farmers also market their own produce through local farmers markets, CSAs, and wholesale accounts.

In order to participate in the Viva Farms program, participants must present a production plan and farm business plan. This can be achieved by taking the WSU Cultivating Success courses or through previous experience. Starting in 2016, Viva began facilitating the FIELD Program, a hands-on farming practicum program offered for credit through Skagit Valley College Sustainable Agriculture Education Program.

Participants are required to take the practicum course to farm a ½ acre of land as a group before leasing their own farm plot. Extensive farm experience can count towards fulfilling these requirements. After completing these requirements, participants are eligible to lease between ¼ acre and 5 acres of land through Viva when available.

The question of who will be the next generation of farmers has been a recent focus of national discussion and funding programs. In the United States, our current farmer population is aging with 62% over the age of 55 (USDA Agriculture Census, 2012). By 2030, it is estimated that 500,000 US farmers will retire, 25% of current American farmers (Lusher Shute, 2011). Farm Incubator programs have emerged as farmer training initiatives to support the new generation of farmers, with 119 operational programs around the United States in 2015 (National Incubator Farm Training Initiative, 2015). Farm Incubators are programs that aim to support new farmers gaining skills to launch a farm business by reducing barriers to entry including access to land, infrastructure, equipment, markets, capital and training (Massey, Sullivan, & Creamer, 2014). Although there has been much growth in beginning farmer training programs, there is little research that has focused on understanding the role they play in food systems and community development (Niewolny & Lillard, 2010).

In 2013 Viva Farms collaborated with the WSU Extension Small Farms Program on a Specialty Crop Block Grant funded by the Washington State Department of Agriculture to fund a graduate project to conduct an impact evaluation of the Viva Farms Program. This case study of the Viva Farms Incubator Program aims to evaluate the social, economic and environmental impacts of the program. This evaluation was conducted through interviews and surveys with current and past participants, participant observation as well as Viva Farms staff interviews. Our descriptive case study aims to assess the extent to which the Viva Farms Incubator Program contributes to a sustainable food system through successful training and support of beginning organic farmers.

As farm incubators surface across the country as a method to train the next generation of farmers, it is important to evaluate the effectiveness and impact of these programs to improve future programming and to share best practices. Funders and other partners are also eager to assess the value of investing in these burgeoning numbers of farm incubator programs.

Evaluation Methods

We used qualitative and quantitative methods to conduct the impact evaluation for this research project. This evaluation was conducted through interviews and surveys with current and past participants, participant observation, and Viva Farms staff interviews. We analyzed responses and data from the end-of-season interviews with 12 current participants and 10 interviews with past Viva Farms participants. The selection of our interview participants included all current and past participants.

Interview and survey questions were designed after Agriculture and Land-Based Training Association's End of Year Interviews and a study of the University of Santa Cruz Apprenticeship in Ecological Horticulture conducted by Perez et al. in 2010 (Martin, Bernau, Lindsy, Perez, & Landeck, n.d.)

We analyzed responses and data from 2015 End of Year Surveys conducted in November and December with fourteen 2015 Viva Farms Participants as well as conduct interviews with eight previous participants and thirteen follow-up interviews with current participants during spring and summer 2016. The case study also included unstructured interviews with Viva Farms Staff members and general participant observation. Ongoing participant observation included shadowing farmers during operations, attending professional development meetings and Monthly Viva Farmer meetings, all of which helped develop themes for analysis. This also allowed development of trust with participants to fill out farmer narratives. Data gathered from surveys and interviews was analyzed to create an impact analysis. Results were additionally compared with national data from the USDA Agriculture Census data.

Viva Farm staff contacted past Viva Farms participants via phone and email in May 2016 to share the purpose of the study and invite to participate in the study with a scheduled interview at their farm. In June 2016, we sent follow-up emails and phone calls. Additional follow-up included phone calls, messages, email invitations, and contact again from Viva Farms and from the previous leadership. The interviews consisted of a visit and a structured interview that was audio-recorded with participant consent. We conducted structured interviews in person and over the phone when necessary. Interviews ranged from 20min to 60 minutes. Interviews were conducted in Spanish (9) and English (13). Additionally, secondary data was collected through survey results and Viva Farms materials. (Goldberger, 2008)

Response Rate

According to Viva Farms records, 28 farm businesses have participated in the program since 2010. The program transitioned leadership in 2014 and the new practicum program began in 2016. Viva Farms provided contact information for all 28 farm businesses. We were able to contact and conduct interviews with 22 of the 28 farm businesses, a response rate of 79%. The remaining six participant farms were unreachable through various outreach methods including phone, email, and contact with previous organizational leadership. One participant declined participation in the interview, stating that her husband was no longer involved at Viva Farms. Two past participants who were unreachable appear to be currently farming. There was no observable pattern or response bias in the reason for not participating in the evaluation. If the total is adjusted for the two phone numbers that could not receive messages, 22 of the 26 farmers who were invited to participate in the study chose to do so. This leaves an adjusted response rate of 85% which is quite high and increases the likelihood that these results are representative.

TABLE 1. REASON FOR NOT PARTICIPATING IN INTERVIEW	**NUMBER OF PEOPLE**
Disconnected phone number	1
No answer and no message	1
No response to phone or email message	3
Declined interview	1

Participant demographics

Age

Participants reported a mean (average) age of 42 years old. 25.9% of participants were 35 years of age or younger while 74.1% were 35 to 64 years of age, and no participants were older than 65 years of age. The average age for all primary farm operators nationally is 58.3 years old (USDA Ag Census, 2012).

TABLE 2. AGE	**VIVA FARMS PARTICIPANTS % (2015)**	**BEGINNING FARMERS NATIONALLY 1 TO 5 YEARS ON CURRENT FARM (2012 AG CENSUS)**
Less than 35 years	25.9%	14%
35 to 64 years	74.1%	70%
65 years +	0%	16%

Gender

Participant respondents at Viva Farms were 40.7% female farmers, while nationally women represent only 18% of farmers (Ag Census 2012 Highlights, 2014). Generally, incubator farms nationally support higher numbers of female farmers than the national percentage, with an average of 48% female farmer participants reported in 2015 (National Incubator Farm Training Initiative, 2015).

TABLE 3. GENDER	**VIVA FARMS PARTICIPANTS (2015)**	**BEGINNING FARMERS NATIONALLY 1 TO 5 YEARS ON CURRENT FARM (2012)**	**INCUBATOR FARMS NATIONALLY (2015)**
Male	59.3%	82%	52%
Female	40.7%	18%	48%

Refugee/Immigrant

While we included this demographic metric in the interviews, we decided not to include these participant ratios in the report. There are no current national statistics on refugee/immigrant farmer ratios and additionally participant responses showed that the identification of the label immigrant or refugee varied based on the participant's own perspective of the reason for migrating to the US.

Race/Ethnicity

Race/Ethnicity varied greatly from nationally demographic breakdown. While nationally minority farmers make up only 10% of the population, 51.9% of Viva farmers are minorities.

TABLE 4. Race/Ethnicity (n=27)	**Viva Farms participants % (2015)**	**Beginning Farmers Nationally 1 to 5 years on current farm (2012 Ag Census)**
White	48.1%	90%
Minority	51.9%	10%
Latino	22.2%	
Indigenous Latino	22.2%	
Asian American	3.7%	
Other	3.7%	

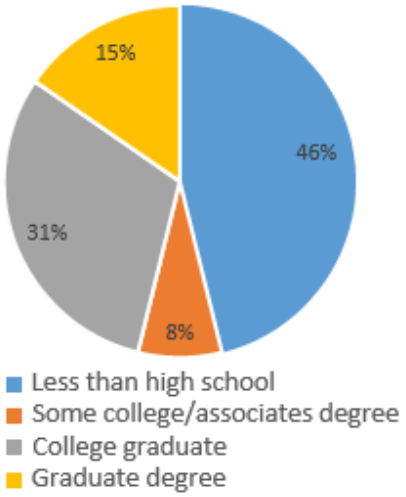
Education level

Viva Farm participants have a range of educational backgrounds from less than third-grade education to university master degrees. Field programming has been shown as an effective educational strategy accessible to all, even those with limited or low levels of education (Davis et al., 2012).

TABLE 5. EDUCATION LEVEL (N=26)	**VIVA FARMS PARTICIPANTS**
Less than High School	46.2%
Some College/Associates Degree	7.7%

College Graduate	30.8%
Graduate Degree	15.4%
PhD	0%

FIGURE 1. PARTICIPANT EDUCATION LEVEL



Previous farming experience before Viva Farms and Goals for Farming

As a program open to all aspiring farmers, participants of Viva Farms have a wide variety of experiences in agriculture previously ranging from no experience to those that have been farming all their lives. Experience ranged from no experience to 45 years (since childhood) with an average of 10 years of experience farming. As several participants worked as farmworkers before transitioning to farm owners, therefore that level of field experience contributed to a high average.

TABLE 6. EXPERIENCE FARMING (N=22)	**YEARS**
Average	10
Median	6
Minimum	0
Maximum	45

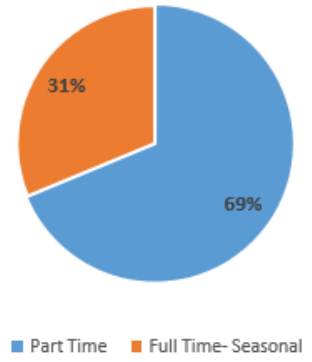
Participants enter the program with different initial goals for agriculture. Eleven (52.4%) of the participants indicated that their goal when they started at their farm business was to eventually have farming be their primary source of income. Eight (38.1%) of the participants identified their farming goal was to have it be a secondary source of income while only two (9.5%) cited their goal for farming as the quality of life. Many farmers commented that quality of life was part of their farm goals. No participants indicated that they started the program only to get a job in agriculture (without the goal of owning their own farm) although several participants since participating have worked in agriculture (see Table 8).

TABLE 7. GOALS FOR FARMING	**N=21**	**PERCENT**
Primary Source of Income	11	52.4
Secondary Source of Income	8	38.1
Quality of Life	2	9.5
Job in Agriculture	0	0

Work on the Farm

31% of those farming in 2015 reported Full Time Seasonal work (more than 35hrs per week per operator) while 69% reported Part-Time work on their farm with work off the farm. Nationally, 77% of beginning farmers on the current farm for 1 to 5 years worked off the farm (Ag Census 2012 Highlights, 2014).

FIGURE 2. PARTICIPANTS WORK ON FARM



Program Impacts

Percent of Participants Farming

A full 77% of respondents (current and past Viva Farms participants) reported farming in 2015, including three participants indicating that they farmed mostly for home consumption that year. That percent increased to 82% (eighteen) that farmed in 2016 and 90% of participants (nineteen) reported planning to farm in the future. Those that did not farm in 2015 or 2016, but indicated that they planned to farm in the future included those currently looking for land, planning to purchase land and/or developing their production plans.

FIGURE 3. PERCENT RESPONDENTS FARMING IN 2015 (N=22)

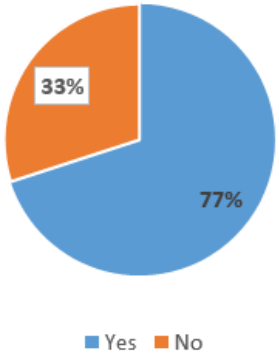
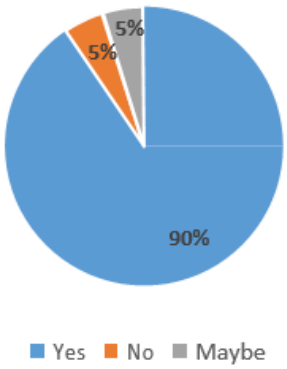


FIGURE 4. PERCENT OF VIVA PARTICIPANTS PLANNING TO FARM IN THE FUTURE (N=21)



Acres Farmed in 2015 and 2016

In 2015 Viva Farms participants reported farming on a total of 32.78 acres including 13.2 acres outside of Viva. The average acreage farmed was 1.56 acres with the smallest acreage at .03acres and the largest acreage at 10 acres. For the 2016 season, Viva Farms participants reported farming on a total of 47.71 acres. One participant shared the important role Viva Farms played in access to acreage:

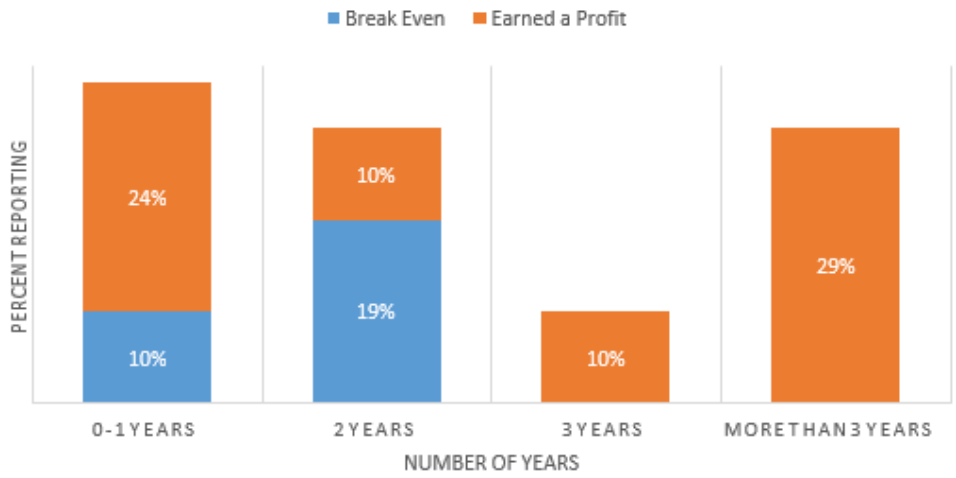
The biggest thing that Viva has done is in terms of entry, to have a farm at all. Without Viva, I wouldn't have done it. I looked at leasing from a farmer but it was in horse pasture and it would have been difficult and maybe wouldn't have had water or equipment and would spend time trying to find implements.

Economic Impacts of the Program

Years to Profit

Five (24%) participants responded earning a profit in the first year while two (10%) stated they were able to cover expenses and breakeven year one. Two (10%) farm businesses shared they were able to earn a profit and four (19%) were able to break even during year two. Two (10%) more participants reported earning a profit starting year three and six (29%) participants shared that it took more than three years to earn a profit.

FIGURE 5. NUMBER OF YEARS TO EARN A PROFIT

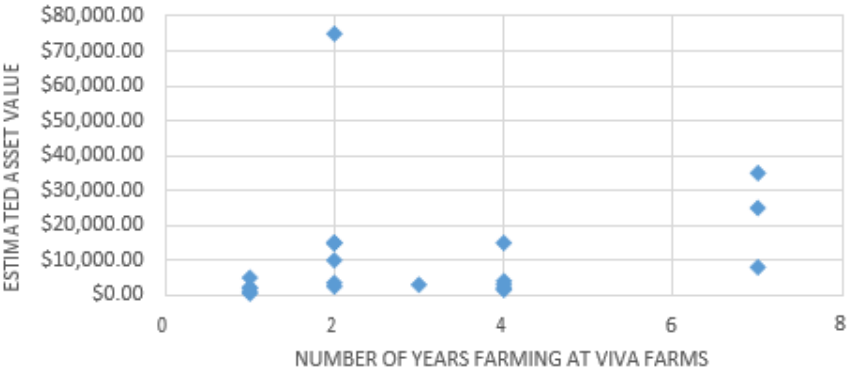


Total Assets

Participants reported an average total farm asset value of $11,581 with a median of $4,000. Participant assets include tractors, implements, tools, greenhouses, irrigation systems, storage containers, processing equipment and more. One farm shared the role Viva Farms played in their farm investments:

Being at Viva I think is the reason we could invest so much and acquire assets that are very specific to our business model and not have to acquire the basics. And I guess we will have to go back and acquire those basics once we move out on our own but it is partly what has allowed us to scale up to a certain stage that will hopefully allow us to reach financial viability sooner.

FIGURE 6. FARM ASSETS BY NUMBER OF YEARS AT VIVA FARMS



Participants accessing capital: Grants and loans

Since starting at Viva Farms, 32% of participants reported having applied for grant funding while 43% reported having applied for financing for their farm business. These access to capital opportunities have included USDA NRCS, USDA Value Added Producer, Community and local foundation grants. Financing has included local banks and credit unions, and the Viva Farms Matching Funds Program. Ten participants (45%) stated they had received financing or grants since participating at Viva Farms.

FIGURE 7. PERCENT RESPONDANTS THAT APPLIED FOR GRANTS AND FINANCING

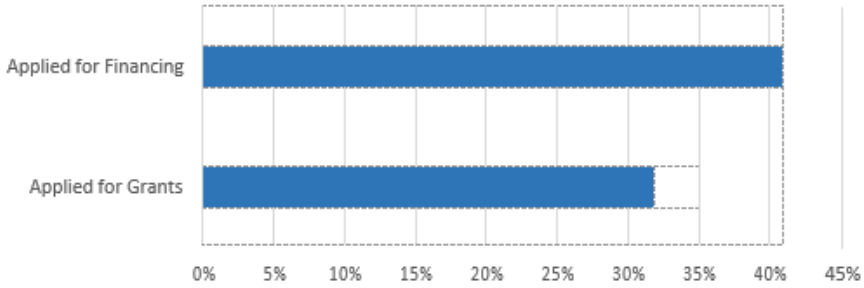
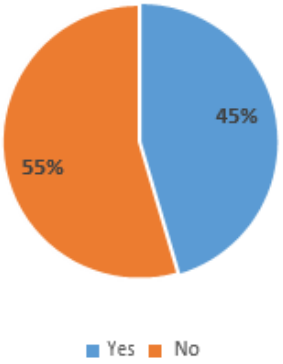


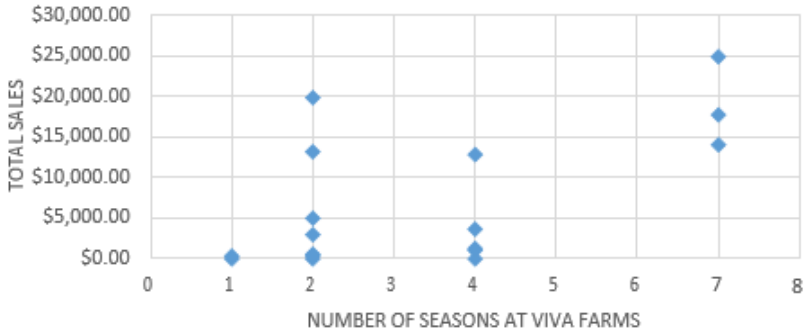
FIGURE 8. PERCENT RESPONDANTS THAT HAVE RECEIVED GRANTS OR FINANCING



Farm Revenue

Fifteen farmers reported farm revenue for 2015, with average total sales of $6,945.70, average expenses of $5,197.86 and an average net farm income of $2,865.75. These numbers are self-reported and may not include all sales outside of Viva Farms. The USDA average agricultural sales for beginning farmers with 1-5 years on the current farm was $106,197 with average expenses at $96,673 (Ag Census 2012 Highlights, 2014). Economically, the small scale of plots and operations does not currently compare with national averages of gross sales and income for farmers on current land 1-5 years in the USDA Agriculture Census, but we must take into account that national averages include generational farms with much larger tracts of land and infrastructure. National census average also indicates only years on the current farm and could include those that have previous farm management experience and have transitioned onto a new farm. These averages are comparable with other farm incubators. Average gross revenue per acre for Viva Farms participants farming in 2015 was $8860 and ranged from as little as $0 for a perennial crop not in production yet up to a high of $43,600 per acre.

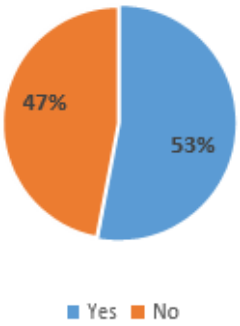
FIGURE 9. 2015 TOTAL SALES BY NUMBER OF SEASONS PARTICIPATING AT VIVA FARMS (N=15)



Percent of Viva Farms operators with net gain

Of the past participants that farmed for business (n=15) in 2015, 53% ended the season with a net gain. Responses differed based on whether farmer time and labor was included. Nationally, 39% of operators with 1 to 5 years on current farm reported a net gain, while 37% with 6-10 years on current farm reported a net gain (Ag Census 2012 Highlights, 2014).

FIGURE 10. PERCENT RESPONDANTS REPORTING NET GAIN IN 2015



Marketing Channels

Participants reported selling farm products through various marketing channels including the Viva Farms Wholesale program and Farm Stand, Puget Sound Food Hub, local restaurants, farm stands, stores, farmers markets, CSAs, schools, daycares, food banks and community organizations. The number of sales outlets per farm ranged between one and five, with an average of two of sales outlets per farm. Several participants shared the important role Viva has played opening markets and communicating with clients. One farmer shared:

> *The Viva Farms produce sales are very important, if it weren't for this we wouldn't be very successful, especially me, because I don't speak English well, so for me, it is an advantage, but I think also for the majority. Well for me this is a lot of help. If it weren't for this, since I don't speak English, it is really difficult to communicate to the markets.*

Environmental Impacts of the Program

Use of Sustainable Agriculture Practices

The Viva Farms program has a goal of training farmers to use sustainable agriculture practices applicable to their operation at Viva Farms and into the future. We measured participant utilization of sustainable agriculture practices as a measure of environmental impact, recognizing the environmental value of these practices through documented research. 76% of respondents utilized cover cropping, shown to improve soil health and fertility as well as contribute to reduce nutrient leaching and increased carbon capture (Poeplau & Don, 2015). 100% of participants utilized water conservation methods, primarily drip tape and micro sprinklers in their production. 82% (fourteen) of respondents farming in 2015 (seventeen) were certified organic under the Viva Farms organic certification. In 2016, two farms (15%) obtained their individual certification in 2016 while an additional twelve farmers (60%) responded that they are

interested in individual organic certification in the future. Even those that did not currently have their certification stated that they practice non-use of synthetic and petrochemicals on their farms. Additionally, 76% of respondents shared that they plant pollinator habitat, contributing to crop and pollinator diversity. While not a direct measurement of the environmental impact of these farms, the high adoption rates of these agricultural practices indicate a more sustainable and lower impact farming system in reference to soil health, water conservation, pollinator habitat, synthetic residues and water contamination, and carbon sequestration.

FIGURE 11.PERCENT OF RESPONDANTS REPORTING USE OF SUSTAINABLE AGRICULTURE PRACTICES (N=21)

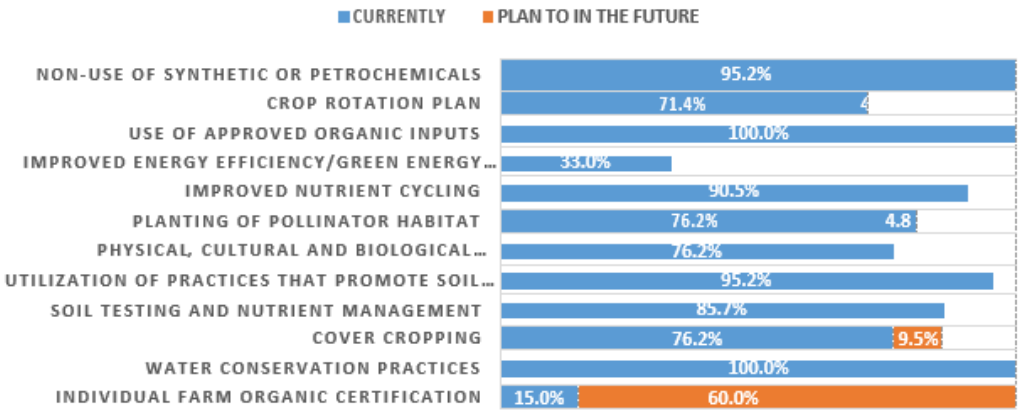
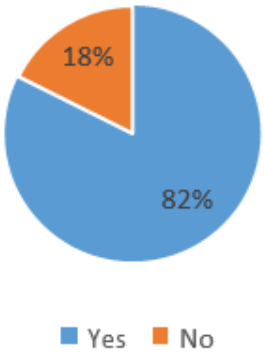


FIGURE 12. RESPONDENTS FARMING IN 2015 THAT WERE CERTIFIED ORGANIC (N=17)



Social Impacts of the Program

Social contributions to a Sustainable Food and Agriculture System

Outside of economic and environmental impacts, farm incubator programs and the participating farms have substantial social impacts. Participants shared impacts of the program for both the community and for them personally. In terms of food access, 90.5% of respondents shared that through their farm and/or work they had increased access to healthy food for those with limited access. Additionally, 60% of respondents shared that they had increased the worker safety for workers, often times including themselves and their families as previous farmworkers.

FIGURE 12. PERCENT OF RESPONDENTS REPORTING SOCIAL CONTRIBUTIONS TO A SUSTAINABLE FOOD SYSTEM THROUGH THEIR FARM OR WORK (N=21)

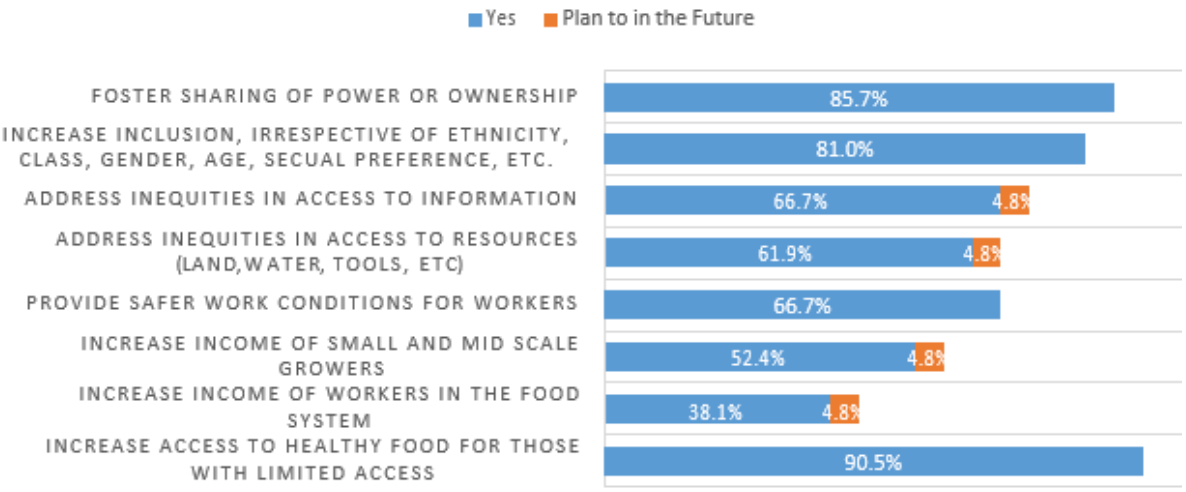


TABLE 8. PARTICIPANT ACTIVITY FOR A SUSTAINABLE FOOD SYSTEM

	Yes	Percent
Work in Agriculture and Sustainable Food System Field	15	68%
Volunteer work for Sustainable Food and Agriculture System	11	50%
Family Consumed Produce	16	73%
Shared, Bartered or Sold Produce to Friends and Family	14	64%
Sold or Donated Produce to Food Banks, Schools, Daycares and Community Organizations	9	41%

In 2015, 73% of respondents (n=21) reported that their family consumed produce they grew, 64% reported sharing, bartering or selling produce to friends and family and 41% sold or donated produce to food banks, schools, daycares and community organizations. In 2015 Viva Farms reported selling $9,045.40 in produce to local food banks. Although it is difficult to estimate the impact that these farmers and the Viva Farms program has on community food security, it is apparent that the fruits and vegetables produced at Viva Farms contribute to the local consumption of healthy food. Additionally, 68% of participants have worked in Sustainable Food System Field outside of running their own farm businesses and 50% of participants (eleven) volunteered in the community for a more sustainable food and agriculture system. These work and volunteer positions include work at food banks, farm stores, seed companies, service on community organizational boards, farmers market management, farm management and more. The contributions of these participants go beyond the farm and play a role in shaping a community food system that integrates sustainable agriculture and healthy food.

Skills useful in other areas of life

When asked whether the skills received and built upon at Viva were useful in other areas of life outside of business, 59% participants responded “yes.” The two most common responses included improved financial and budgeting skills and community involvement and networking. Other responses included helping to get a better job, gaining new knowledge to be used in the current job, and agricultural experience. Specific responses included:

> *General skills in entrepreneurship, collaboration and working within a system and responding to challenges and barriers.*

> *One thing that comes to mind immediately is the immense outreach and the community of people that I was able to meet, including farmers across the state.*

Financial skills and budgeting skills as well as managing and making lists. Those skills helped me be able to buy a house with land last year.

Beyond these social contributions, participants shared other ways the program had impacted them personally. These included the creation of community and a support network with other participants and local farmers, cross-cultural interaction, and an improved understanding of the food system. Additional observations included improvements in housing status of participants including purchase of land and houses. One farmer mentioned he was able to purchase a doublewide trailer with his first year earnings from Viva Farms. Three other farmers were able to purchase a house and land in 2016. A few additional comments from participants are listed below:

Culturally I learned more about farmworkers in the county…I realized how privileged I am and so many things that I take for granted.

Part of the community aspect was that it drew in farmers from the area that were interested in what was going on. We wound up getting connected with some people that had really valuable advice to give or were able to offer services to other farmers for a reasonable rate. Connecting with the broader community.

I think it has been a really good education for me as far as the logistics of food. We wouldn't be doing what we're doing without Viva. It's great having neighbors to exchange ideas and create friendships.

Reasons for leaving the program

Past participants were asked about reasons for leaving the program. Responses varied case by case but included reasons such as the family moved, they purchased land, they were ready to launch and lease their own farmland, they realized it was financially and physically unsustainable at their age, and they had frustrations or miscommunications with management. A common difficulty shared by several past participants was the time during the transition in organizational management, which impacted participants' decisions to continue with the program. Another participant cited a conflict with an organizer over crop management. Another participant that has been at the incubator since the founding shared "I wouldn't still be here if I had access to another place to transition to". This brings to attention the need for continued support after the incubator and recognition that the incubator alone cannot solve issues of access to resources for socially disadvantaged and beginning farmers (Calo & De Master, 2016). There must be collaboration and support from the farming community and agencies to aid in the transition after participation at the incubator. This also supports the need for a Viva Farms 2, an additional plot of land for experienced incubator farmers to transition to with less support but continued access to resources.

Program Reflections

Throughout the interview process, participants shared reflections on the value of the program. Some of the comments are shared below:

The program opened doors for those that want to continue experimenting.

The program was very useful. Although some of the projects were difficult due to my limited English skills, Viva Farms has everything to help a person start their farm business.

The program is very helpful for any farmer who wants to continue.

You learn everything, I think that I'm lacking a little bit on business and pricing, but we're learning. What helps me here from Viva, there is water, the cooler, there's a lot that helps me, the cooler, the tractor, these important things, including for me who doesn't have a tractor, for just starting I think it is a lot of help for everyone, for those who are starting. Because to buy a tractor it's, wow, a lot of money.

Viva was paramount in helping me get started. It pushed me to have a farm plan and figure out what I was doing.

Recommendations

Participants shared various recommendations during the interviews and surveys for improving the Viva Farms program. These recommendations are from both past and current participants and may not take into account changes that staff have recently put in place.

- **More technical assistance on farm and integrated support.** One participant shared that it would have been helpful to have had the Practicum Program available previously, as it would have given the support needed for an introduction to farming on a scale larger than gardening.
- **Increased long-term support for and communication with graduates.**
- **More structured activities to bridge cultural gaps and community building activities.**
- **Incorporation of other farming techniques outside of the commercial farming focus.**
- **More sessions on business planning and updating business plans in the offseason.**
- **Recognize and remember the work that went into creating Viva Farms and the efforts that farmers put in initially to build the opportunity.** One farmer shared *"We are here because of the people who extended their hearts and hands to create this. They opened the doors and markets, we built everything together. With unity there is strength."*

Conclusions

The Viva Farms program is a unique program that provides access to critical resources for beginning farmers. Viva Farms has been successful in training and supporting organic beginning farmers in Northwestern Washington, as shown by the 77% of participants who were farming in 2015 of which 82% were certified organic. The overwhelming responses showing that 90% of participants plan to continue farming in the future shows a commitment of participants to farming and the process of launching and building a farm business. Additionally, the Viva Farms Incubator has increased access to farming for minorities, those with limited levels of education, and women. The lower average farmer age also contributes to successfully meeting the mission of training the next generation of farmers. Through participant responses, it has been determined that the program contributes significantly to community food systems as well as the adoption and utilization of sustainable agriculture practices. Findings suggest that the Viva Farms program is meeting its goals and is contributing environmentally, socially, and economically to a sustainable food system.

These findings can be utilized for future program improvements and also for setting realistic baselines for farm incubator outcomes nationally. The sharing of this information will help to understand the challenges and successes of beginning farmers and improve future training. Additionally, this information and future evaluations can support programs to effectively communicate impact to funders, future farmer participants, and the community.

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PROJECT #6

Project Title: Promoting BioControl through Hands-On and Web-Based Training

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

Biological control has always been a part of tree fruit Integrated Pest Management (IPM) in Washington, but for four decades it has operated in an organophosphate dominated environment. Over the past decade, the insecticides used to control key pests in tree fruit production have transitioned to those safer to humans. However, an unanticipated result has been a destabilization of biological control in IPM programs, which has resulted in secondary pest outbreaks and additional pest control costs. Many crop consultants and orchard managers do not have an understanding of how biological control functions and how to conserve natural enemies within the new IPM programs. There is a great need to address the lack of knowledge of biological control and its value in tree fruit systems.

A five-year Specialty Crop Research Initiative (SCRI) funded grant, "Enhancing Biological Control in Western Orchard Systems", generated new information on the effects of organophosphate-alternative insecticides on biocontrol agents, developed new monitoring tools for natural enemies revealing their presence in orchards, and is developing models to predict when natural enemies are present in orchards. However, with the completion of that SCRI grant in 2013, its outreach activities also ended. Because of the persistent need for continued education about biological control in orchards the WSU Enhanced Biocontrol Outreach Team was determined to provide more outreach and education through this project. Crop consultants and growers need a means to determine the status of biological control in their orchards, knowledge of which organophosphate-alternative insecticides disrupt biological control and how that happens, and how to mitigate potential secondary pest flare-ups. Knowing what natural enemies are in the orchard is a first step, however, based on interactions during the SCRI project, many crop consultants, growers, and orchard managers do not recognize the different life stages of common natural enemies.

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

PROJECT APPROACH

Goal 1: *Increased knowledge and adoption of conservation biological control as part of IPM.*

Workshops: The WSU Enhanced Biocontrol Outreach Team conducted five biocontrol training workshops (each 4 hours long) in various locations in Washington State with a total of 67 participants (growers and consultants). To gauge how much knowledge participants gained from the training activities, survey answers given before the workshop were compared to results from quizzes held during the workshops. The participants already had a relatively sound knowledge of natural enemies prior to the workshop (66% correct answers before and 72% after), partly because some had taken this workshop during the previous year. Participants significantly increased their knowledge in other areas related to natural enemies, such as habitat needs and insecticide effects (53% and 25% increase in correct answers, respectively). All workshops were held in English, although there were a number of Hispanic participants who then helped one another in Spanish to comprehend the materials.

Online course: The online course, which is based on the content of the workshops, was partially developed. It is divided into two modules: the first module teaches about common natural enemies in orchards, their developmental stages and characteristics, their prey or hosts, and it lets users hone their skills in identifying important natural enemies; the second module describes monitoring tools and phenology models for natural enemies as well as effects of certain insecticides on them. The course ends with a case study that applies many of the new principles learned. Users will be able to earn pesticide applicator recertification credits upon passing a test. The completion of this online course has been delayed, but additional resources are being secured to complete it. To date, the online course version of the course's introduction has been completed and reviewed, with only minor edits needed. The storyboard, narration and video/image materials for the remainder of the first module are finalized as well as the storyboard and script for the second module. Narration and image materials still need to be compiled for the second module, before the storyboards can be transformed into the online course format.

In addition, the team has catalogued available images and documented any additional media needs. Numerous insect specimens were collected from the field and photos and videos have been taken. This activity overlaps with the development of a mobile ID app, where insect images and videos collected will be used.

Pesticide use analysis: USDA NASS data was gathered and analyzed for trends for the period of 2007-2011. The main focus for the analysis was the change in insecticide use for codling moth control in tree fruit. No NASS data were recorded in 2013, and the 2014 NASS records were not available at the time of this report.

The pesticide survey data show that the number of acre applications of organophosphate insecticides for codling moth control, the major pest in apples, decreased over the years 1991-2011 with a plateau between 1999 and 2007. The decrease in use of organophosphate insecticides was due to a reduction in the acres treated, a reduction in number of applications and an increased use of organophosphate-alternative insecticides that replaced organophosphate insecticides for codling moth control.

The total pounds of active ingredient of organophosphate insecticides has been steadily reduced since 1991, but declined dramatically in 1999 and in following years due to the adoption of codling moth mating disruptions and organophosphate-alternatives. The major change resulting from adoption of organophosphate-alternatives for codling moth control (insect growth regulators (IGR), spinosyns, diamides, and neonicotinoids) has been the reduction in pounds of active ingredients applied to orchards.

For 2009 and 2011, insecticide use data was compared between regions: Chelan/ Okanogan/ Douglas counties vs. Yakima/Benton counties vs. the rest of Washington State. The survey data indicated that more applications of organophosphates and organophosphate-alternatives (diamides, neonicotinoids, spinosyns, and insect growth regulators) to every acre for codling moth control in the Yakima/Benton region compared to the Chelan/Okanogan/ Douglas region. More focused outreach on effective codling moth control in the Yakima and Benton counties may help reduce the number of potentially unnecessary insecticide applications without jeopardizing fruit quality.

Goal 2: *Online and mobile ID guide for main tree fruit pests and natural enemies (eng & esp).*
Overlapping with the activities for the online workshop, the biocontrol outreach team has started the process of cataloguing media needs for developing an orchard insect pest and natural enemy mobile app. Also, insect specimens have been collected in the field to take photos that can be used in the online course as well as in the app. This objective has not been completed due to time constraints that arose from delays in the online course.

Goal 3: *Direct technology transfer of natural enemy monitoring tools to crop consultants.*
Seven cooperators participated in the natural enemy monitoring study in 2014. The cooperators were supplied with traps, lures, and other materials needed to monitor the green lacewing *Chrysoperla plorabunda*. Monitoring was conducted from March through September 2014. Five of the cooperators submitted monitoring data as well as spray records from their two orchard blocks they intended to compare. Data from four cooperators were analyzed, while one cooperator's information could not be used due to an incomplete data set combined with very low lacewing counts. Three of the cooperators were video-interviewed to capture their feedback regarding the new natural enemy traps as well as general considerations about biological control in orchards. Parts of those video interviews will be published after editing on http://enhancedbiocontrol.org.

Lacewing numbers captured in most pairs of orchard blocks did not reveal large differences due primarily to the similar insecticide control programs used. However, a general trend was that orchards using very "soft" pest control programs had the most lacewings, which confirms previous research findings. The general feedback from cooperators on use of traps was positive, similar to those from pest management consultants in 2012. The cooperators said they would embrace new monitoring tools for natural enemies once commercially available, but would like more clarification on the relationship between lacewing numbers in traps and the success of biological control. Additional research into these areas is needed.

J.F. Brunner, PI: Dr. Brunner oversaw the project, reviewed project activities, timelines, budget and reports, coordinated contacts with stakeholders, and provided conceptual guidance for objectives and goals.
A. Gadino, Co-PI: Dr. Gadino was involved in project management and activity coordination. She developed online course content, planned and conducted workshops and outreach, coordinated crop consultant collaboration activities and analyzed collected information from those collaborations.
U. Chambers, Co-PI: Dr. Chambers oversaw the project, reviewed and coordinated project activities and timelines. She generated course content and coordinates course development and implementation, plans and conducts workshops and outreach. She coordinated crop consultant collaboration activities and analyzed collected information from those collaborations during the second project year. She also generated the project reports.

W. Jones, web & communications coordinator: Mrs. Jones provided technical expertise for the online course development and compiled, generated and edited course materials, such as images and videos. She also assisted in workshop activities.

WSU Global Campus: WSU Global Campus, who has been a key partner in this activity, is the group that develops online courses for Washington State University and has expertise the original project team did not possess. This group has been assisting in assembling the course content into an interactive online format for this project.

Some of the natural enemies in tree fruit orchards also occur in other cropping systems and biological control principles are generally relevant to other cropping systems. However, the activities in this project solely address and focus on biological control in tree fruit orchards. Most non-specialty crops could benefit from the general principles of biological control presented in the online course but the more specific educational information would not directly apply to cropping systems, especially non-specialty crop systems. Workshops, on-farm natural enemy monitoring trials, online course and the natural enemy ID guide were only executed and promoted in the tree fruit industry in Washington State.

GOALS AND OUTCOMES ACHIEVED

Goal 1: *Increased knowledge and adoption of conservation biological control as part of IPM.*
Workshops: Biological training workshops increased the knowledge about biological control of the 67 participants. The participants honed their skills in identifying common natural enemies in orchards and significantly increased their knowledge in other areas related to natural enemies, such as habitat needs and pesticide effects.

Online course: The first online course version of the course introduction has been completed. About 90% of the materials for the remaining parts of the online course are assembled for their conversion into the online course format.

USDA NASS data from apple in Washington for the reporting period of 2007-2011 were used in the analysis and within these data only pesticides used for codling moth control were used. This analysis provides a baseline that can be compared with future NASS data to assess the trends in pesticide use and potential change in practice spurred by this and previous teams' efforts to promote biological control and use of softer, more selective pesticides for codling moth control.

Goal 3: *Direct technology transfer of natural enemy monitoring tools to crop consultants.*
The participating cooperators were able to become familiar with the novel way of monitoring for green lacewings in their orchards. During the video interviews, all cooperators indicated that the new lure-baited traps were easy to use, but require additional time to check. The cooperators also said that the information the traps captured made it easy to "see" biological control activity in the monitored blocks. However, they did wonder how the number of lacewing caught in traps might relate to biological control of aphids, the common prey of green lacewings. Further research is needed to address this question.

The data collected from the cooperators were analyzed and summarized in conjunction with the spray records they provided. Information sheets with graphs and tables showing the seasonal changes in lacewing captures in the two different apple blocks were sent to each of the cooperators. These information sheets highlighted the pesticides that negatively impacted lacewing numbers. Data of the other cooperators were included (anonymously) to provide comparison to other pest management programs and resulting lacewing captures. The team has not inquired if this information may have influenced subsequent pest management decisions in order to conserve lacewing populations.

A long-term goal of this project was to increase the knowledge and value of biological control in the tree fruit industry. The hands-on workshops that were conducted did measurably increase the knowledge base of the participants. Similarly, the team expects to broaden the knowledge and boost the implementation of biological control for the rest of the WA tree fruit industry once the online course is available to the public.

Another medium to a longer-term outcome of this project was that the developed online course would provide a foundational framework on biological control principles and training materials that could apply to online training courses for other cropping systems and localities. This is still possible once the online course is complete. Materials that were developed, expertise gained, and lessons learned could be applied to other cropping systems or even in urban horticulture settings.

Established Goals	Accomplished Goals
Goal 1 A: Conduct 10 workshops or have 100 people attending (offer in Spanish if requested)	5 workshops held (total of 67 participants), all workshops in English

Analyze participants' knowledge gain. Compare knowledge before and after taking the workshops. Follow up with interviews/surveys to document how participants may have altered their pest management practices.	6-53% knowledge gain, depending on subject area. No follow-up surveys or interviews conducted.
USDA NASS data comparison between 2007-2011 and 2013	USDA NASS data were only available for 2007-2011 and analyzed for that period; data for 2013 were not available as expected.
Goal 1 B: Create online course (English and Spanish) used by 50 individuals by September 2015.	Course development (in English) to approximately 90% complete (plus conversion into online format by WSU Global Campus). Monitoring course use will begin when the online course is completed and implemented.
Goal 2: Develop mobile ID guide for major tree fruit pests and natural enemies.	Goal not accomplished. However, images and videos for this guide compiled and catalogued.
Goal 3: Recruit 20 volunteers to evaluate natural enemy monitoring tools. Collect trapping data and pesticide use records.	Seven volunteers committed to participate; monitoring complete. Data and pesticide records provided by five collaborators; three collaborators were video-interviewed.

Workshops: With the hands-on workshops completed, about 60% (5 events with 67 participants) of the target audience (10 workshops or 100 participants) was reached. The workshop participants increased their knowledge about certain aspects of conservation biological control.

Online course: About 90% of the workshop materials have been prepared for conversion into an online format. This aspect of the project was certainly the most time-consuming phase, mainly as the team members went through a learning curve on how to best make slides come "alive" for an online and self-directed audience in a clear and intuitive, but engaging way.

Technology transfer: Many potential cooperators were contacted, but only seven volunteers (of the targeted 20 cooperators) committed to this additional effort in their daily operations. Nonetheless, the cooperators appreciated this hands-on learning opportunity and provided valuable feedback that will be shared with the tree fruit industry.

BENEFICIARIES

This project directly benefits the growers, crop consultants and pest managers in virtually the entire Washington state tree fruit industry with its roughly 233,000 acres. In addition, the online course will be available to the general public (not only in Washington state) and can be relevant to students and other groups not directly associated with the tree fruit industry, but who are also interested in conservation biological control.

To date, 74 crop consultants and pest managers have directly benefitted from this project by participating in the workshops or the on-farm lacewing monitoring trial. In addition, the video-interviews of collaborators from a previous on-farm trial (same setup as in this project) have been viewed 138 times on YouTube alone (videos were also viewed on the enhanced biocontrol website, but numbers are not available). With the rollout of the online course, the number of beneficiaries will increase significantly. As a longer-term outcome, this project can save costs by reducing the number of pesticide applications and protect worker health and the environment. However, no quantitative data on regarding the number of course users and pesticide applications before and after taking the course could be collected during this project period as the online course was not completely finished.

LESSONS LEARNED

The hands-on biocontrol workshops showed that most participants had adequate knowledge of natural enemies in orchards, but were less aware of the different developmental stages and the natural enemies' biology. Many workshop participants had misconceptions about some pesticides' negative effects on natural enemies. Overall, the workshop participants were very eager to learn more about biological control and felt that the workshops provided practical knowledge the participants would be able to apply to their orchard management. The workshop participants were very interested in using natural enemy traps and models and wanted to know when those new tools would be available to them.

Making an online course proved to be more time-consuming than initially expected. It takes a slightly different approach and skill to visualize the end result without having prior experience of developing an asynchronous online course. Clear communication of expectations and possibilities between the team developing the materials and Global Campus converting everything into the online format was crucial and resulted in the excellent implementation of the course introduction.

For the on-farm trials the volunteer cooperators were asked to choose pairs of apple blocks that were managed differently and in which to monitor lacewings. However, based on the provided spray records, most orchard block pairs turned out to use very similar management programs. Therefore the orchard pairs did not reveal large differences in lacewing numbers. The general trend was that orchards managed with "soft" pesticides (those known to have no or a low negative impact on natural enemies) had the most lacewings, confirming previous research findings. The general feedback was positive and the cooperators would embrace this new monitoring tool.

The online course, in particular the parts dealing with natural enemy life stages and identification, required more effort to gather visual media (photos, videos, images) than expected. This was especially true for the identification exercises and self-assessment and credit tests as it was important to use different images of the same natural enemy so that users would actually learn to identify an insect instead of just recognizing the same image use over and over. The number of in-house media resources was often limited, low in quality or just did not exist. Searching for adequate resources, obtaining permission to use them, and creating new media consumed more time than initially expected, contributing to the delay of the completion of the online course.

Although interested in new natural enemy monitoring tools, many crop consultants that were contacted were unable to commit to weekly monitoring of 10 lacewing traps in two different blocks due to their already busy schedule. This limited the number of participating collaborators from twenty to seven, a number further reduced to five due to incomplete sets of provided data.

ADDITIONAL INFORMATION

To date $56,381.18 of in-kind match has been utilized. This match comes from Dr. Brunner's salary for the time he contributed to this project. There was also in-kind contribution from WSU Extension to support WSU Global Campus personnel, but the exact dollar value spent so far for their time was not available for this report. However, the development of the entire course through WSU Global Campus is budgeted for $20,000.

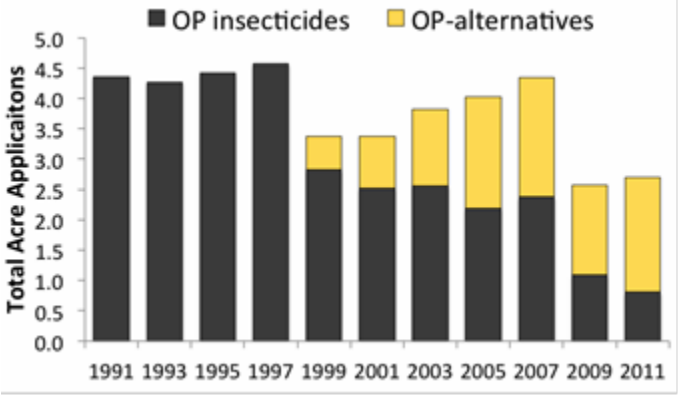


Fig. 1. Total acres applied for organophosphates (OP) and OP-alternatives to control codling moth in Washington State. (Acre applications = percent acres treated x average number of applications.)

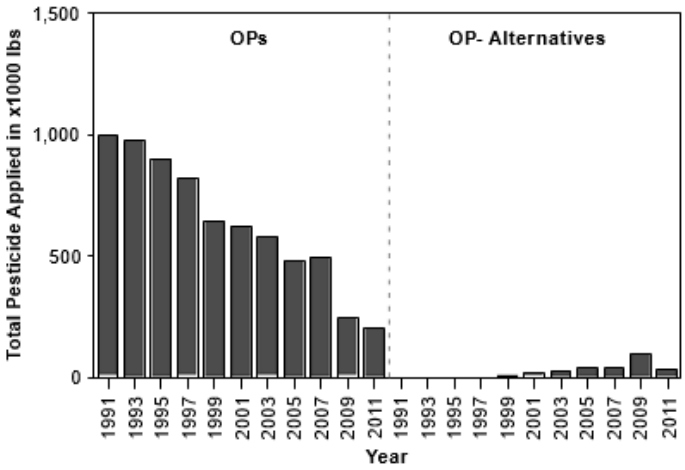


Fig. 2. Total amount of organophosphate (OP) and OP-alternative pesticides applied to control codling moth in Washington State.

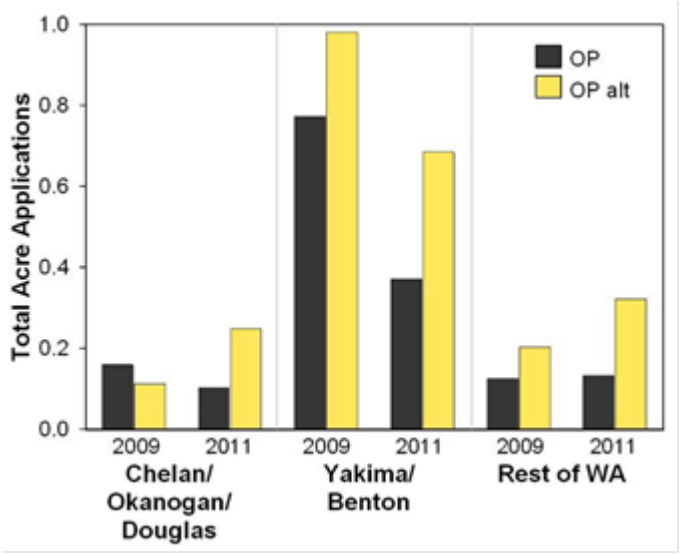


Fig. 3. Total acre applications of organophosphates (OP) and OP-alternatives (OP alt) to control codling moth in Washington State by region. (Acre applications = percent acres treated x average number of applications.)

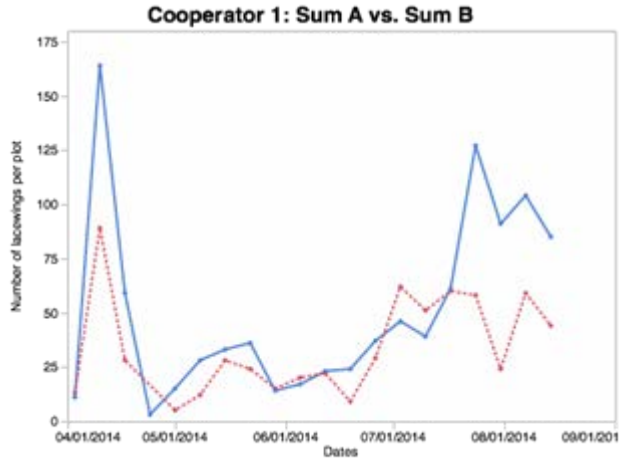
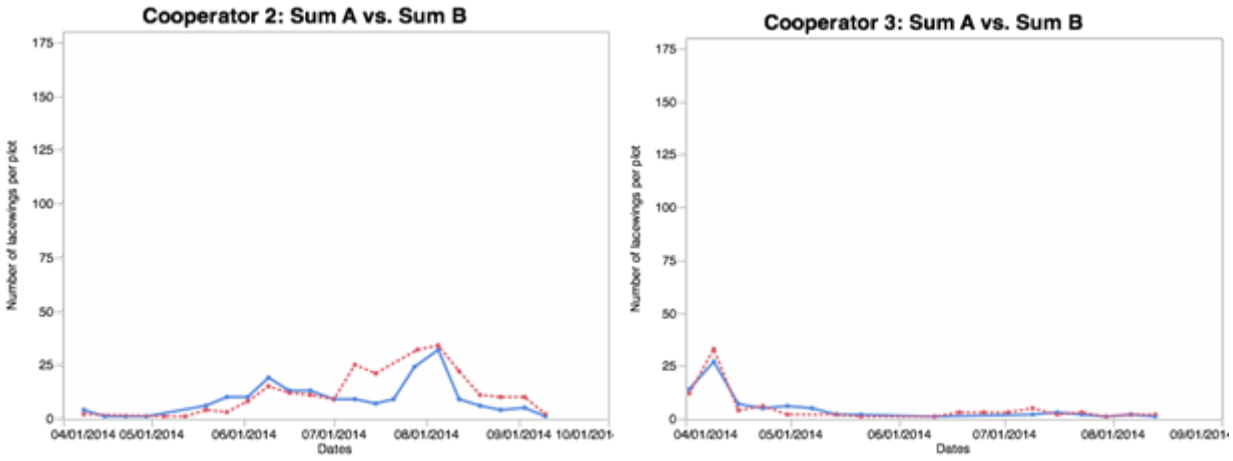
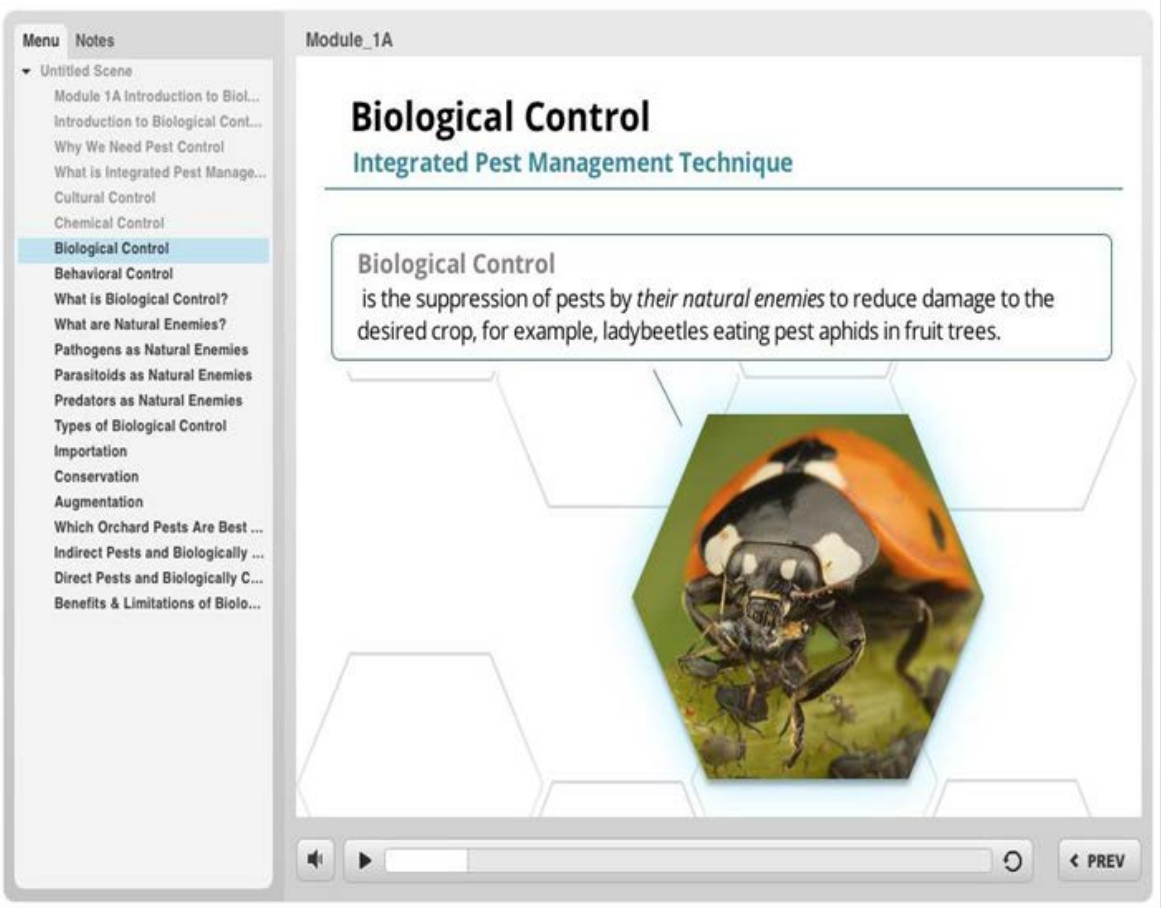
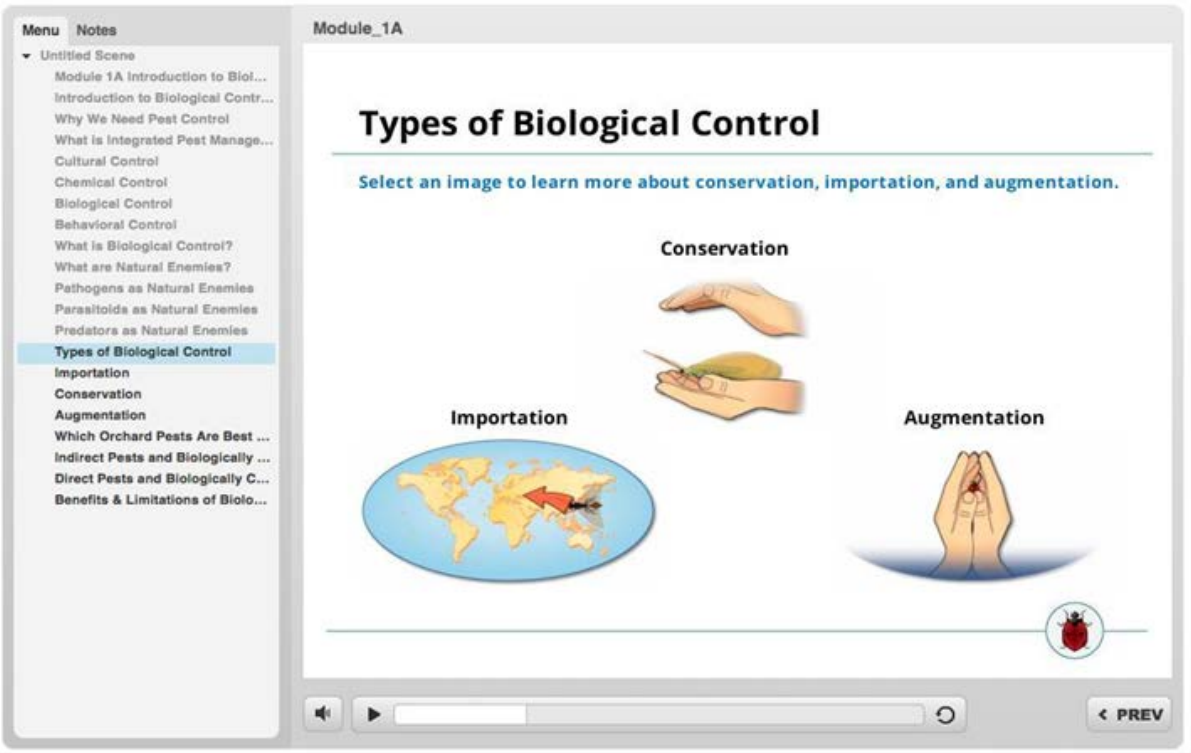


Fig. 4. Examples of cooperator lacewing trapping data. Blue and red line represent total lacewing numbers in two apple blocks that are differently managed for codling moth.



Below are screenshots from the online course introduction:





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PROJECT #7

Project Title: Expanding Access to Specialty Produce in the NW through Variety Trials

Partner Organization: Organic Seed Alliance (OSA)

PROJECT SUMMARY

There is a high demand for year round availability of locally grown specialty vegetable crops in Oregon and Washington. The two states hold similar climatic and agronomic challenges as well as highly sophisticated produce buyers that demand superior culinary qualities. Four key crops were identified by stakeholders as prime opportunities for expanding year round production in OR and WA - overwintering chicories, overwintering sprouting broccoli, winter cabbage, and storage onions. This multi-state project addressed the need by, 1) evaluating and promoting the agronomic and culinary qualities of these four priority crops, 2) developing markets for these crops by convening tasting/networking events and providing promotional marketing materials, and 3) facilitating access to seed of appropriate varieties. Market introduction of these crops provides farmers with increased sales during winter and early spring when income is normally low, and chefs, retailers, and consumers with expanded access to locally grown food. This project built off project partner's Northern Organic Vegetable Improvement Collaborative (NOVIC) and Organic Broccoli and Onion Trials (OBOT), two networks of breeders and farmers developing crops for the northern tier and NW region of the US. The long-term aim of this project was to address the need for developing organic and sustainable production practices and regionally-based domestic markets.

Washington and Oregon agriculture excels in production of high value specialty vegetable crops during the prime growing seasons, but the produce industry remains dependent on imported crops during the winter and early spring months. Farmers are eager to expand production of overwintering and storage crops to retain customers through the winter, "off-season". Chefs, produce retailers and the general public (through CSAs and farmers markets) increasingly demand locally grown vegetables of exceptional flavor and culinary qualities throughout the entire year representing a significant market opportunity. Overwintering chicories, overwintering purple sprouting broccoli, storage onions, and winter cabbage are four crops identified as prime opportunities to expand winter vegetable production by farmers, breeders and chefs in focus groups hosted at agricultural conferences and farmer's meetings in the Northwest (NW). Stakeholders also identified the need to identify varieties that meet both agronomic and superior culinary qualities adding value for both farmers and chefs alike. Winter crops often hold superior flavor in the NW, as cool temperatures tend to concentrate plant sugars offering superior culinary value. A NW produce distributor identified NW-grown cabbage as a priority in part due to impacts on the CA cabbage industry due to a new pest (the Bagrada bug). Produce industry experienced peak prices and gaps in availability of cabbage in 2013 due to this pest. Winter crop of purple sprouted broccoli is ideally suited to the NW climate and growing in popularity among chefs and retailers. OR and WA are major producers of onions, but growers have expressed a lack of access to well-adapted, good tasting storage varieties for the region. Farmers have been frustrated by loss of availability of some hybrid onion varieties. Regional farmers and seed companies are eager to identify open pollinated varieties of these crops that could be grown for seed facilitating regional seed security. Chicories are in high demand by NW chefs and gaining popularity among the gourmet food buyers. The goal of this project was to facilitate production and market expansion of the four prioritized crops by conducting variety trials, hosting farmer-chef variety evaluation and networking meetings, and supporting market introduction through promotion of these regionally produced crops. Farmers and produce sellers stand to benefit from access to optimum varieties of these crops as well as the marketing support to educate and promote these crops to consumers.

This project was the first of its kind supported by SCBGP.

PROJECT APPROACH

On-farm, replicated variety trials of purple sprouted broccoli, chicory, onion, and cabbage were conducted on organic farms in Western WA for two production cycles from 2014-2016. The variety trials provided produce of a wide range of varieties of each crop to use for the outreach and marketing events. Trial results supported farmers' introduction of appropriate varieties. All trials included both agronomic and culinary evaluations including participatory input from farmers and chefs on appearance and flavor evaluations. Trials were planted in a randomized, replicated design with three replications, and approximately 8-15 entries per crop in large enough plots to provide ample product for tasting, evaluations, and marketing purposes. Each year farmers were invited to view the crops in the field during the agronomic evaluations. A final report of results was published in the last year of the project and is being disseminated to stakeholders. The final trial report includes information on agronomic and culinary (flavor) evaluations and discussion of variety recommendations, production information, marketing information, and seed purchasing guidance to help facilitate introduction of these crops. The report includes information on seed sources and organic seed availability to

facilitate access to the varieties by farmers and regional seed companies interested in incorporating them into their production.

Several public events were hosted each year to engage farmers, chefs and retailers in the project. Varieties from the trials were presented for taste evaluation and feedback at the events, but the events were also highly social with chef-prepared dishes of the focus crops and a social atmosphere to encourage networking among participants. These events were hosted at regional conferences and on- farm field days to facilitate broad participation. These networking events served several purposes, 1) engaging participants in the evaluation of the crops, 2) serving as a networking opportunity for farmers and produce buyers to meet and develop relationships to foster market introduction, and 3) to generate press about the crops and project intent to facilitate marketing efforts.

Organic Seed Alliance (OSA) researchers McKenzie and Colley managed all project research activities including coordinating and evaluating variety trials and authoring final trial report. Several farmers participated by hosting the trials on-farm and collaborating in variety evaluations. Culinary evaluation methods were developed in coordination with Selman at Oregon State University (OSU). Selman also assisted in coordinating and hosting outreach events and engaging press and related project marketing activities. Selman hosts the annual Culinary Breeding Network in Portland, OR and through that event developed several promotional opportunities. Grondin served as a contracted support to plan and facilitate outreach events in WA hosted at OSA research field days and at several conferences including the Farmer Fisher Chef Connection. WSU and OSA partner on programs in Jefferson County, WA. Through this partnership WSU assisted in promoting and hosting farmer involvement in field evaluations and outreach events. Pacific Consumer Coop (PCC) supported promotion of the project through an article in the PCC sound consumer publication. The Port Townsend Food Coop supported the project by participating in several outreach events and working with local growers on introduction of the crops to market. Organically Grown Company greatly supported the project by providing financial support and collaboration in the development of purple sprouted broccoli, expanding trials and production of this crop under contract with their growers, and collaborating on development of marketing materials to facilitate product introduction into retail stores.

This project focused solely on specialty vegetable crops. All research and associated variety evaluation/ networking events only presented specialty crops for farmers and chef's to engage in tasting sessions. All project promotion emphasized the target project crops and seasonal expansion of produce availability.

GOALS AND OUTCOMES ACHIEVED

7.Describe the activities that were completed in order to achieve the performance goals and Expected Measurable Outcomes for the project.

Research activities/outcomes:

Variety trials of all four crops were successfully grown and evaluated on organic farms in WA for two production cycles between 2014 and 2016. Data was collected on all crops and a final report of trial results was written in fall 2016. The report is available on the OSA website and will be promoted through a press release and social media throughout fall of 2016.

Outreach activities/outcomes:

A total of 13 variety tasting events were hosted in OR and WA during the project period (6 in WA).

Tasting events were frequently hosted in conjunction with a conference or other event that would help draw the target audience. Participants completed tasting ballots evaluating the varieties for flavor and to provide feedback on qualities. The events were highly social to facilitate networking among participants. Facilitated discussions were led, when appropriate, about the crop and varieties of choice. It is estimated that at least 1500 participants engaged in the tasting events during the project period. Details of the tasting events included:

2013

2/2/13 - 2/7/13, Organicology (tasting and roundtable), Portland, OR. 850 participants (estimated at least 400 attended tasting). Chicory and Cabbage. Cabbage prepared three ways, raw, in cole slaw, and in sauerkraut.

2014

1/30/14 - 2/2/14, 7th Organic Seed Growers Conference (tasting and sessions), Corvallis, OR. 450 participants, (estimated at least 250 attended tasting). Chicory and Cabbage.

2/24/14, Farmer-Fisher-Chef Connection, Seattle, WA (30 participants in focused tasting session).
Cabbage.

3/14. OSA Port Townsend tasting event. 10 participants. Purple Sprouted Broccoli and chicory.

2015

2/5/15 - 2/7/15, Organicology (tasting and session), Portland, OR. 850 participants, (estimated at least 400 attended tasting). Chicory and Cabbage.

3/25/15 – Organically Grown Company. 10 participants. Purple Sprouted Broccoli.
9/22/15, On-farm Variety Trial Workshop and tasting, Orcas Island, WA (25 participants). Onions.
9/28/15, Culinary Breeding Network, Variety Showcase, Portland, OR. 100 participants. Onions.
10/3/15, Orcas Island Farm Tour, Orcas Island, WA. 25 participants. Onions.
10/14/15, Organic Seed Alliance Farm Tour, Chimacum, WA. 100 participants. Cabbage, onions.

2016

2/4/16 - 2/6/16, 8th Organic Seed Growers Conference, Corvallis, OR. 450 participants (estimated at least 300 participated in tasting). Cabbage and chicory.
3/9/16, NWREC Winter Vegetable Field Day, Aurora, OR. 75 participants. Purple Sprouted Broccoli, Cabbage, Chicory.
3/21/16, Farmer-Fisher-Chef Connection (session and tasting), Kenmore, WA. 100 participants. Purple Sprouted Broccoli.
9/27/16, OSA research farm field day, Chimacum, WA. 75 participants. Cabbage and onions.

Marketing activities/outcomes:

The food and farming media has been very interested and engaged in project promotion with a major push on press over the winter 2015-2016. OSA's communications team has covered the project extensively on social media and newsletters and engaged press in project promotion including food blogs, agricultural news outlets, radio shows, and retail news outlets including the Capital Press and PCC Sound Consumer. A marketing flier was created in winter 2015-2016 to promote purple sprouted broccoli and chicory. The flier was distributed at project outreach events, and distributed to retail outlets through sales of these two crops by produce distributor, Organically Grown Company. Media interest is a strong indication that the timing of the project was in alignment with trends in the NW food scene. Media related to the project since the project start included:

2013

- 10/1/13, Seed Broadcast http://blog.seedalliance.org/2013/10/01/4097/
- 4/8/13, Seed Broadcast http://blog.seedalliance.org/2013/04/08/purple-is-the-new-green-winter-sprouting-broccoli/

2014

- 3/5/14, Seed Broadcast http://blog.seedalliance.org/2014/03/05/taste-panel-tests-cabbage- varieties-and-discusses-seed-needs-of-the-pnw/
- 12/6/14, Edible Portland http://edibleportland.com/a-better-tomato-a-better-tomorrow/

2015

- 4/3/15, OPB.fm, http://www.opb.org/news/article/npr-plant-breeders-aim-to-save-northwest- from-bland-veggies/
- 4/3/15, Northwest News Network http://nwnewsnetwork.org/post/plant-breeders-aim-save- northwest-bland-veggies
- 4/9/15, Seed Broadcast http://blog.seedalliance.org/2015/04/09/expanding-spring-palates- through-participatory-breeding/
- 4/13/15, Voice of America http://www.voanews.com/content/plant-breeders-aim-to-save-diners-from-bland-veggies/2717061.html
- 7/1/15, ATTRA Newsletter https://attra.ncat.org/newsletter/weekly_harvest_070115.htm
- 7/6/15, Seed Broadcast http://blog.seedalliance.org/2015/07/06/new-purple-sprouting-broccoli- variety-trial-report/
- 10/16/15, Seed Broadcast http://blog.seedalliance.org/2015/10/16/osa-community-helps-evaluate-and-celebrate-fall-harvest/
- 12/8/15, Seed Broadcast http://blog.seedalliance.org/2015/12/08/new-2015-western- Washington-variety-trial-report/

2016

- 2/11/16, Heritage Radio Network http://heritageradionetwork.org/podcast/bridging-the-gap-from-plant-breeders-to-eaters/
- 2/22/16, SeedQuest https://www.seedquest.com/news.php?type=news&id_article=73802&id_region=&id_category=&id_crop=
- 3/10/16, Capital Press http://www.capitalpress.com/20160310/seed-alliance-helps-develop- better-organic-varieties

- 3/28/16, Seed Broadcast http://blog.seedalliance.org/2016/03/28/purple-sprouting-broccoli-now- in-season/
- 4/1/16, PCC Sound Consumer http://www.pccnaturalmarkets.com/sc/1604/breeding-better- organic-produce-locally.html
- 4/2/16, Good Food NW http://www.goodstuffnw.com/2016/04/new-kid-on-block-purple-sprouting.html

The long-term project goal was to expand year-round access to regionally grown vegetable crops in the NW supporting farmers, food industry and eaters in the region. This project facilitated expansion of a select number of crops and promoted regionally grown foods, but there are certainly many more crops that could additionally be expanded in the future through additional research and marketing efforts. The long-term success of these four crops may also be supported through additional research to refine production practices, address pest and disease issues, and continue to breed for improved traits for the region. The long-term market success of storage crops (onion and cabbage) may also depend on improved infrastructure for successful handling and holding of these crops in the winter.

The impacts of this project were assessed by conducting an online survey and through direct interviews and feedback from project participants including the farmers who hosted trials and event attendees (farmers, chefs, retailers). Participants were asked whether they have increased production of the four focus crops since 2012 and if so, then by what percentage. Of the respondents 58% reported an increase in cabbage production, 42% reported in increase in chicory production, 42% reported an increase in onion production, and 50% reported an increase in purple sprouted broccoli production. Interestingly, the lowest percent increase was in scale of cabbage production ranging from 15 to 75% increase while chicory and purple sprouted broccoli levels were 100-900% increase. The significant growth in production of these two crops is likely a reflection of the fact that these crops were much less common in 2012 and has significantly expanded in the market over the last 4 years. It is also promising that on average more than half of the growers surveyed have increased production in the four project focus crops indicating a significant increase in access to winter produce in the PNW. One farmer reported an increase in production of Purple Sprouted Broccoli from 2 to 20 beds representing a 10-fold increase. Another farmer commented, “chicories have proven to be a wonderful crop-extremely diverse, hardy and seasonal. (We are) trying out Purple Sprouting Broccoli for the first time this year, however it is hard to justify the lower return per square foot of broccoli and cabbage given the high risk of clubroot and black leg in the area, particularly overwintered.” This comment does point out that winter Brassica production in OR and WA can pose additional disease management risks particularly with the outbreak of Black leg (Phoma lingum) in 2014. Farmer’s feedback also included comments that there is a need for more organic cabbage and onion varieties bred for overwintering and storage qualities.

Project partners collaborated closely with Organically Grown Company (OGC) throughout the project period on breeding, variety trials and market introduction of purple sprouted broccoli. In 2016 OGC and OSA created a marketing flier to support retailers introducing the crop. OGC also expanded production with three growers in OR and sold over 1341 cases of the crop for the first time representing nearly $38,000 in farm-gate value and higher for retail sales. OGC marketing staff were thrilled with the response from retailers and the high demand for the product. OGC also reported a 10% increase in onion sales and 15% in cabbage sales during the project period, but flat on chicory sales. The produce buyers report a steady demand for storage onions, but a lack of sufficient supply to fill the gap.

Overall the project goals of expanding production of the four crops were achieved as indicated by grower surveys and verbal feedback. Growth in purple sprouted broccoli and chicory sales are much higher in terms of percent growth than cabbage and onion reflecting the fact that these crops are newer to the market offering a greater potential for increase in production. The cabbage and onion market are much larger than the other two crops, so a modest increase potentially represents a more significant total increase in quantity and value. Lastly the positive reception of the food and farming press covering this topic is an indicator that this trend will continue into the future.

The original project goal was to result in increased production of winter cabbage, storage onions, overwintering sprouted broccoli and chicories. It was projected that at least 30 farmers would adopt or expand these crops or varieties during the project period. It was anticipated that this number would expand in the coming years as buyers (eaters) gain awareness of the superior qualities and local availability of these crops resulting in increased demand. It was also projected that the project would result in a 30% increase in sale of these four key winter crops by the end of the project period compared to a baseline of sales in 2012. Based on a survey of project participants farmers reported expanding production of all four crops more than 30%. Produce retailers however reported expanded sales of purple sprouted broccoli and chicory by more than 100%, but much less expansion of cabbage (15%) and onion sales (10%) according to a large distributor and less growth reported by smaller retail buyers.

BENEFICIARIES

The primary beneficiary of this project is specialty organic produce growers in OR and WA. It is estimated that the project outreach activities reached at least 1500 target beneficiaries including farmers, chefs and retailers. This project additionally benefited eaters, particularly those seeking locally grown and organic food year around. Expanding production of these crops has the potential to expand income through critical off-season months when farmers traditionally experience low income and high expenses as they invest in inputs for the following season. This project also extended linkages in the food community among those who introduce new germplasm, to those who grow the crops, to those who prepare the food with the outcome of increased regional production, marketing and knowledge of specialty vegetable crops resulting in long term regional food production and economic security.

Sales of purple sprouted broccoli clearly made the greatest gain in economic impact based on market growth with OGC reporting an estimated $38,000 farm gate value in their purchases alone in 2015. This crop was not part of their market in 2012. One retailer, the Food Coop, reported an increase of 277 of PSB valued at over $1,000 retail value sourced from a single farm. The percent growth in cabbage and onions seems to be unclear with 10-15% growth reported by one source and flat sales from another. However these two crops represent a very large potential market where a modest increase may have a larger financial impact.

LESSONS LEARNED

A strength of this project was engaging a large number of stakeholders in networking events in a social context which raised awareness and even created a buzz around the core project goals of increasing access to regionally grown produce year around and introducing new, regionally adapted crops. The social networking aspect also posed a minor challenge in tracking the true outcomes of the project as it is difficult to say how many new sales or production contracts were a direct result of the project versus the general trend in the local food movement. An interesting learning moment was the importance of engaging retailers and distributors in conversations about crop traits in addition to the farmers and chefs. Many prior variety-tasting events have focused more on the farmer-chef interaction and discussion about culinary qualities, which is valuable. However the retailers often asked different questions such as, “How long will it be available for? How would we present it on a market shelf? Will the buds hold up in a bulk bin?” These are different questions that demonstrate the need for a crop to fit the full chain of stakeholders to become a mainstay in the marketplace.

One thing this project did not do is exploring what other crops might also serve the winter market need. OSA also did not consider how these crops fit ergonomically into rotations or other potential impacts of increasing production of these four crops, such as the disease management of overwintering brassicas. It would be interesting to follow up this project with research that addresses the whole farm impact of winter production and explore additional crops that could expand year round access to produce in the Pacific Northwest.

The level of interest and participation from retail produce-industry participants stimulated conversations about which traits they prefer in the crops. This provided good feedback to the seed company and plant breeding participants and broadened their perspective of the importance of engaging this sector in breeding for a new crop or new market niche and facilitating market introduction of new varieties.

Tracking the contact information for all participants at the variety tasting/ networking sessions was difficult because many of these sessions were hosted at conferences or other events where participants were attending the broader event and chose to participate in the tasting event, but had not signed up for the tasting in advance. For this reason, it was a challenge to follow up with each individual participant to measure project impacts. OSA did reach out to the participants that could be tracked. Most of these contacts were from smaller events or those hosted at the OSA research farm where registration was in greater control. The responses from these participants in the impact assessment survey correspond well with the feedback from individual farmers, chefs and retailers that provided feedback in conversations.

This project was a two-state project combining funding and outcome objectives for the Oregon Department of Agriculture and Washington State Department of Agriculture Specialty Crops Grants. Support from the two states was beneficial as it did allow broader outreach to achieve impacts by working with stakeholders across both states and developing complimentary activities prioritized by each agency’s program. Coordinating project activities and budgets across two separate sources of funding was also a challenge at some points and good clarity and coordination of activities and budgets is recommended.

ADDITIONAL INFORMATION

A total of $21,200 in matching funds were contributed as in-kind donations of OSA staff time and financial contributions from Organically Grown Company as originally proposed in the project budget: $9,000 Funds for purple sprouted broccoli variety development from Organically Grown Company ($3,000/yr). $13,200 Partial salary and fringe for Micaela Colley, PI, to lead in development of a NW variety improvement collaborative, developing network of

stakeholders for project events and facilitating new production/marketing activities ($3,960). Kristina Hubbard, OSA Communications Director to lead in project promotion and communications ($6,600). Cathleen McCluskey, OSA outreach associate to design, layout, and publish report of project results for public outreach $2,640 total.

Additional in-kind services were provided by Organically Grown Company for support of on-farm field trials of purple sprouted broccoli; hosting a variety tasting at the OGC headquarters, and co-developing and distributing a marketing flier to promote the crop introduction into retail sales, valued at $5,000.

The publication of results from the on-farm trials, Vegetable Crops for Season Extension in the Pacific Northwest: Variety trial results 2014-2016, is available on the OSA website at:
http://seedalliance.org/index.php?mact=DocumentStore,cntnt01,download_form,0&cntnt01pid=54&cntnt01returnid=129

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PROJECT #8

Project Title: Market development and production research for the Cider/Perry Industry.

Partner Organization: Northwest Cider Association (NWCA)

PROJECT SUMMARY

Washington is the largest producer of apples in the U.S. (156,000 acres) and accounted for 48% of the U.S. supply in 2011 (U.S. Department of Agriculture, 2014), and has the potential to become the leading cider apple producing state. Cider (0.5% to 8.5% alcohol by volume) remains the fastest growing alcohol market segment in the U.S., and the volume of cider produced in Washington State grew by over 17-fold between 2007 and 2014, from 44,387 to 759,282 gallons, a 48% growth rate per year. This project addressed constraints to the expansion of the cider industry in Washington, i.e., lack of significant quantities of affordable cider apples, effective management options for apple anthracnose canker in western Washington, and post-harvest quality of machine harvested cider apples.

The number of cideries in Washington increased from 4 in 2008 to 59 in 2015, a 15-fold increase, and accounts for 9% of the cideries currently in the U.S. (Brown, 2014; Miles and Peck, 2014; Northwest Cider Association, 2014; U.S. Association of Cider Makers, 2016). However, since the only use of specialized cider apple cultivars is for making cider, growers need reliable information regarding orchard management systems and impact of harvest methods on juice and cider characteristics before planting significant acreages.

Project K 741 (2011-2013) provided basic information to a cider industry in need of supporting research to continue its development. The current project K 1270 expanded the range of information available to growers and cider makers, particularly in the areas of variety selection and mechanical harvest.

PROJECT APPROACH

Varietal evaluation: During the project period the WSU team harvested, pressed, and collected juice samples from 70 cider apple varieties. Juice samples were analyzed for tannins (%), oBrix, pH, specific gravity (SG), and malic acid (g.L-1). The cider variety orchard was maintained (pruned, weeded, and fertilized). Full bloom date and bloom abundance were recorded in April and May. Trees were rated for productivity (except 2015) as well as recording the actual weight of fruit at harvest for each variety. Additionally, a new replicated research orchard planted 2014-2016 was maintained, trees surveyed for anthracnose infection, and treated with insecticide for an infestation of leafhoppers. The new orchard planting was completed in February 2016 (planting was split into two phases due to a shortage of rootstocks in 2013). Results were recorded and summarized in presentations at state and national meetings (Appendix: Presentations). A listing of nurseries specializing in cider apple varieties was updated. Varietal evaluation data is complete through 2015 and a publication has been drafted in 2016.

Machine harvesting: On September 29 2015 and 2016 a machine harvest trial was conducted using a Littau over-the-row mechanical small fruit harvester designed for raspberry harvest. The cultivar was 'Brown Snout' in a closely spaced trellis planting on strongly dwarfing rootstock. The goal was to compare the time and labor needed for hand harvest vs. machine harvest. Juice analysis was done of fruit pressed immediately at harvest, and after storage of 2 and 4 weeks, respectively, to determine the effects, if any, on storage of machine harvested fruit (which suffers considerable bruising in the harvest process) compared to hand harvested fruit. The data for 2015 and 2016 were analyzed and compared, and a journal article has been published (see Appendix). C. Miles and T. Alexander attended CiderCon 2016 in Portland, OR February 2-5, 2016 and gave presentations on machine harvesting at the Advanced Orchard Workshop on February 3. They also attended and gave presentations at the American Society for Horticultural Science (ASHS) Annual Conference in Atlanta, GA, August 8, 2016.

Production cost models: An enterprise budget for cider apple production in central Washington has been published as an extension bulletin (see Appendix). The assumptions and key results of the enterprise budget for western Washington serves as the baseline for a partial budget analysis on the costs and benefits of mechanical harvest, and this Extension publication is in press. S. Galinato attended CiderCon 2016 in Portland, OR February 2-5, 2016 and gave a presentation on production costs at the Advanced Orchard Workshop on February 3.

Review and compile research about anthracnose of cider apples in marine climates: Apple anthracnose canker is caused by the fungus Neofabraea malicorticis and is the primary disease impacting apple production in western Washington. Since anthracnose canker does not occur in eastern Washington, there is limited information regarding management of this disease in Washington. A literature search was conducted and information regarding control and management of this disease was compiled, and the webpagehttp://treefruit.wsu.edu/crop-protection/disease-

management/apple- anthracnose/ was updated with this new information. The cider orchard at NWREC was managed in accordance with this new information, and experiments have been designed to test methods to control apple anthracnose cankers. W. Garton gave a presentation on management of apple anthracnose canker at the Advanced Orchard Workshop on February 3 at CiderCon 2016 in Portland, OR February 2-5, 2016, at the American Phytopathological Society Division meeting in LaConner, WA, on June 29, 2016, and at the American Society for Horticultural Science (ASHS) Annual Conference in Atlanta, GA, August 8, 2016.

The WSU team is a significant partner on this project. They have collected all data outlined under the Research Project Activity workplan and have analyzed data and published final results. Preliminary findings have been published in reports and presented at workshops and conferences in Washington and nationally. C. Miles attended CiderCon 2014 and 2015 in Chicago, IL, and the entire cider team attended CiderCon 2016 in Portland, OR February 2-5, 2016. Miles, Garton, and Alexander gave presentations at the CiderCon Advanced Orchard Workshop on February 3, 2016 and also gave poster session presentations at CiderCon and at ASHS.

This project does not benefit non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

2014-2015: The established cider research orchard was maintained, and a new replicated cider research orchard was planted April 4, 2014, which included 58 varieties previously established and 6 recommended varieties not previously evaluated. Full bloom date and bloom abundance was recorded for all varieties. Harvest of the cider variety trial was completed by November 10, 2014; the machine harvest trial was conducted on October 16, 2014. Harvested fruit was stored briefly and pressed within 4-7 days of harvest for each variety. Fruit samples were chopped in a shredder (MuliMax 30, Zambelli Enotech, Camisano Vicentino, Italy) and pressed in a bladder press (40 liter Enotechnica Pillan, Camisano Vicentino, Italy). Juice samples were collected in 500 ml plastic bottles at the time of pressing and frozen (5oF; -15oC) until harvest of all varieties was completed. Pressing of all samples was completed by November 18, 2014. Juice samples were thawed to 68oF (20oC) and analyzed for tannins (%), oBrix, pH, and malic acid (g.L-1). Juice analysis was completed by December 12, 2014, and data entered and analyzed. Preliminary results were presented at the national CiderCon (Chicago, IL), February 2015. Orchard maintenance was performed in the cider test block and in the new orchard.

2015-2016: Harvest of the cider variety trial was completed by October 26, 2015; the machine harvest trial was conducted on September 29, 2015. Juice was pressed by November 2, 2015 and analyzed following the same procedures as in 2014-2015. Juice of 12 selected varieties were fermented as single varietal ciders, bottled, and stored for future sensory evaluation. Planting of the new cider research orchard, consisting of 2 replications, 3 trees each, of 65 different varieties, was completed with the addition of trees to fill in all replications. Regular orchard maintenance, e.g. pruning, spraying, etc. was performed in both established and new cider research orchards. An Extension publication on the costs and benefits of mechanical harvest is in press. S. Galinato attended CiderCon 2016 in Portland, OR February 2-5, 2016 and gave a presentation on production costs at the Advanced Orchard Workshop on February 3. A literature search was conducted and information regarding control and management of apple anthracnose canker was compiled, and the information was updated on the web page http://treefruit.wsu.edu/crop-protection/disease-management/apple-anthracnose/. Results of this project were presented at CiderCON, the national meeting of cider makers, orchardists, and researchers held in Portland, OR, February 2-5, 2016, at the Advanced Orchard Workshop (February 3) and at poster sessions February 4-5. Approximately 200 participants at the Orchard Workshop, and 1,200 at the conference. In addition, a production cost model was completed to present at cider workshops. Presentations on mechanical harvest and apple anthracnose canker were given at the American Society for Horticultural Science Annual Conference. Atlanta, GA, August 8-11, 2016.

The long-term goal of increasing the Washington market share for cider apples (target: by 2033 there will be at least 40 cider orchards in the region, encompassing 400 acres) is still to be met. According to Statista Research and Analysis, as of September 2016 there were a total of 53 cider producers operating in Washington (https://www.statista.com/statistics/300851/us-number-of-cider-manufacturers-by-state/). There were an estimated 204 acres of cider apples produced in Washington State in 2010 and 256 acres in 2011 (Northwest Agriculture Business Center informal survey 2013).

GOAL	TARGET	BENCHMARK	RESULT	NOTE	MEASURE
New cider apple/pear producers	25	current	25+	(1)	Survey of orchardists and nurseries providing seedlings
New planting of cider varieties	100 acres	current	100+	(1)	Survey of orchardists and nurseries providing seedlings
New NWCA cider makers	10 new members	Currently 31	63 current members 32 increase	(2)	NWCA records
Domestic cider sales	50% increase	17 million gals	56 million gallons	(3)	U.S. TTB data
Varietal evaluations	2 years data	30 varieties	30+	(4)	Publication
Mechanical harvest	Implementation	2 orchards adopting	0	(5)	Survey orchardists

NOTES:

(1) **Definitive survey data not available at time of report. Preliminary reports from WSU scion wood sales and reports from nurseries indicate a considerably higher number of producers and total acreage of cider apple varieties. A single orchard in Washington planted 50 acres.**

(2) **October 2016 membership in Washington, Oregon, Idaho, and Montana**

(3) **2015 data, 2016 data not available**

(4) **See publication list**

(5) **No orchards have adopted, but orchard establishment has not been reached. Confident orchards will** begin adopt mechanical harvest within 3-5 years.

All research data has been analyzed and two publications are complete, two are in press, and one is in preparation. The number of cideries and acreage of cider apples have increased over the course of this project.

BENEFICIARIES

Cider apple growers and cider makers have benefited from the information resulting from this project, as well as the support industries that serve cider production, and the staff employed at cideries and orchards.

Variety evaluation: Data collected on bloom date and bloom density help growers to select varieties that bloom together to assure cross pollination; data collected on productivity and harvest date help to estimate the potential yield of each specific variety, to time the harvest, and to select varieties with more reliable fruit production. Juice analysis helps growers and cider makers to select varieties with a desired mix of juice characteristics for their cider fermentations.

Mechanical harvest: Data collected on juice quality and the time per person to harvest each plot (machine vs. hand harvested plots), efficiency of fruit picking (ground falls, machine/hand harvest, post- machine cleanup), juice analysis of post-harvest storage fruit, and damage to fruit and trees are all significant in the consideration of growers to adopt a form of machine harvest for cider apples.
Production cost models: Information incorporated in the production cost models allows current and potential growers to assess the viability and potential success of cider orchard plantings involving different variables of orchard design and management.

LESSONS LEARNED

Project staff improved the timing of optimum fruit harvest for each cultivar in the variety trial by tracking the weekly field observations of soluble solids and other ripeness criteria (e.g. seed color, skin color, fruit drop) and recording them for comparison to establish full ripeness. This was critical to harvest timing in 2015 and 2016 because climate conditions at harvest both years were not typical of previous years.

Positive results of the project include: 1.) the completion of an extension bulletin on production costs for cider apple orchards in central Washington, 2.) a partial budget for machine harvest compared to hand harvest with Extension publication in press, 3.) update of web page http://treefruit.wsu.edu/crop- protection/disease-management/apple-

anthracnose/, 4.) collection of data for the ongoing evaluation of specific cultivars for hard cider production, including the fermentation of selected ciders and evaluation of varietal ciders, and 5.) publication of mechanical harvest paper.

Negative results were the problems, budgetary and logistical, associated with obtaining a mechanical harvester more appropriately designed for tree fruit to test for cider apple harvest.

In the new replicated cider research orchard, anthracnose cankers were observed in the young trees that potentially damaged their growth. Multiple anthracnose cankers were also observed in the established cider apple research orchard. The presence of new anthracnose cankers was an ongoing serious problem and research is needed to develop effective management options.

A new mechanical harvester to test in the research orchard was not secured. The Littau mechanical harvester belonging to the station which had been used in previous mechanical harvest trials to complete the mechanical trials was utilized. Adoption of mechanical harvest appears unlikely without significant additional information. Information gaps include long term potential impacts of mechanical harvest on tree health and productivity. Additionally, lack of suitable, available equipment, and high capital investment cost of equipment are primary factors limiting adoption, especially when equipment has not been tested on cider apples.

ADDITIONAL INFORMATION

MATCH		
Item	**Budget**	**Actual**
SBS Imports cash donation	$3,000	$3,000
Fruit Smart	$3,500	$3,500
NWCA Board meetings	$21,000	$28,245
SBS In-kind	$8,000	$8,000
WSU In-kind	$24,287	$18,000
WSU Bio-ag	$7,500	$7,500
Total	**$67,287**	

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PROJECT #9

Project Title: Control of Spotted Wing Drosophila and the Asian Blueberry Markets

Partner Organization: Whatcom Farm Friends

PROJECT SUMMARY

Blueberries have become Washington State's most rapidly growing commodity. With 7,000 acres of full bearing blueberries in production and an additional 4,000 acres of non-bearing to not yet fully bearing plantings, it is critical that Washington State not only keeps its current market share but expands it as rapidly as possible. Washington State's proximity to established markets in the Pacific Rim provides an excellent opportunity to increase export sales in Asia. Unfortunately, the recent incursion of a small insect into Washington State has severely jeopardized the ability of farmers to market blueberries into this new market. The spotted wing drosophila (SWD), which is the first insect to directly attack the fruit, does so just prior to harvest. At this critical time, the blueberry industry is lacking adequate tools to deal with this new threat. Chemical treatments to fight SWD do not have adequate MRLs necessary to ship fruit to Canada, South Korea, Japan, the EU and Taiwan while maintaining insect control.

In 2012, Washington as well as California and Oregon had fresh blueberries rejected from Pacific Rim countries due to SWD control efforts that resulted in MRLs over the acceptable limit. As a result of these events, USDA APHIS has told the blueberry industry that countries that did not have detections in 2012 would increase their scrutiny of blueberries in 2013. Countries that did have detections over violative MRLs in fresh blueberries expanded surveillance to include processed blueberries.

The goals of this project were to: 1) conduct field research to generate residue decline curves which will allow the blueberry industry to develop more effective pesticide use patterns using currently registered products to control SWD without violating MRLs and 2) fund field trials to generate efficacy data for new products for control of SWD. This included separate trials for organic blueberries. Organic blueberries have an especially large challenge with SWD control as they have a single product, spinosad (Entrust) and the over reliance on a single product threatens to result in levels that could exceed established MRLs.

The primary goal for this project was to generate pesticide residue data so that degradation curves could be generated that would allow growers to make informed decisions on how to meet MRL (maximum residue levels) for various pesticides required to grow blueberries for export markets. It was estimated that two years of data was needed to complete this project. The project was outlined in the fall of 2013 and data was generated in the 2014 and 2015 growing seasons. Data was disseminated at the 2014 and 2015 Washington Small Fruit Conference held in Lynden each December. A set of recommendations for the Washington blueberry industry on how to meet foreign MRLs based on the results of this project was completed in the spring of 2016.

This project was not built on a previous SCBGP project.

PROJECT APPROACH

Field trials were set up in the three major growing regions of Washington for a three year period. These projects were coordinated with scientists in Oregon and Michigan so that results could be compared with those states. At regular intervals the samples were collected (seven times per location) and shipped to a pesticide analytical lab and the residues were analyzed. Each year a summary report was prepared for the five locations. At the end of the three year period a final report was prepared and distributed to the industry. The reports included residue decline curves for each insecticides for each location. The final report included a summary residue decline curve that was the combination of all of the data from all of the locations and it provided recommendations to the blueberry industry on how to apply insecticides in a manner that would allow export to specific markets. In some cases the report recommended some pesticides to not be used by growers if the blueberries were destined to certain markets. The insecticides used in the trial were malathion, methomyl (Lannate) imidacloprid, spinosad (Entrust) and zeta cypermethrin (Mustang Max), phosmet (Imidan), carbaryl, thiamethoxam (Actara) and spinetoram (Radiant). The markets that were considered included Canada, Japan, Korea, Hong Kong, Taiwan and Australia. Although there were six countries prioritized, the results could be applied to any country's MRLs.

Alan Schreiber, Lynell Tanigoshi and Steve Midboe conducted field trials in Franklin, Skagit and Whatcom counties, respectively. Samples were shipped to the Synergistic Pesticide Laboratory for analysis. These results were provided to Dr. Schreiber and Oregon State University's Joe DeFrancesco. Camille Holladay of Synergistic Pesticide Laboratory and Alan Schreiber developed a final report for the industry including how to meet MRLs with the generated data.

No other commodities but blueberries will benefit from this project.

GOALS AND OUTCOMES ACHIEVED

Project Activity	**Responsible Party**	**Timeline**	**Progress**	**Status**
Contracts prepared with all project contributors	Henry Bierlink	October 2013	Contracts are signed	complete
Conduct telephone interviews to assess tonnage that sustained rejections due to MRLs for use as baseline information in evaluating project	Alan Schreiber Henry Bierlink	November 2013	Interviews Conducted	complete
Continue tonnage information collection	Alan Schreiber Henry Bierlink	12/5-6/2013	Finished phone interviews	complete
Conduct field trials that generate residue decline curves for the leading 10 active ingredients in three locations: Skagit, Whatcom and Franklin counties	Alan Schreiber Lynell Tanigoshi Steve Midboe	During growing seasons of '14 and '15	Field trials set up First evaluation was completed Second evaluation completed	2014 field work completed, 2015 field work completed.
Data would be disseminated at annual meeting for growers' benefit.	Henry Bierlink, Alan Schreiber, Lynell Tanigoshi	Winter 2013-2014	First mtg on October 22, annual grower meeting on Dec 5th	complete
Reports documenting the accumulated data from 2 yr. given at annual meeting	Alan Schreiber, Lynell Tanigoshi	Winter 2014-2015	First mtg on October 22, annual grower meeting on Dec 5th	2014 and 2015 Reporting complete
Final reports disseminated at annual meeting	Bierlink, Schreiber	Winter 2015-2016	December Small Fruit Conference in 2014 and 2015 featured a report on the project.	completed
Submit reports to WSDA	Bierlink, Schreiber	Quarterly, Annual, Final	Quarterly and Annual reports are submitted.	Ongoing, final report submitted

The report does not include long term outcomes other than exports are expected to increase over time as a result of this project and other factors.

On December 1st there was a report given to the Washington blueberry industry describing important issues from 2015. Imports for 2016 will not be available until a little under a year from now. Blueberry exports appear to be increasing but it is too soon to calculate how much has occurred since the conclusion of this trial.

As a result of this project, Washington blueberry exports now have tools that allow them to "deal" with a large number of blueberry MRLs that formerly were trade impediments. Growers can use insecticides that they previously were not able to use in certain export markets.

BENEFICIARIES

The beneficiaries of this project include growers raising blueberries for the export market, handlers who export blueberries, exporters who ship the fruit and those entities that receive Washington exported blueberries.

It is too soon to quantify the economic impact of this project. Overwhelmingly, Washington exports processed blueberries, most frozen, but also dried, concentrate and some pureed products. The 2015 crop has and is being shipped. The 2016 crop is still in storage and a significant amount has not been processed and or packaged.

LESSONS LEARNED

WA Blueberry growers benefited through the cooperation with Oregon and Michigan. Growers are very, very appreciative of this project and the data that were generated from it. For growers active in the export market this project is like gaining several new insecticide registrations. One problem discovered during this project is that some MRLs for some countries are so low that the growers cannot possibly meet them and growers need to work with the registrants of

those products and the individual companies to work with those countries to try and get those MRLs raised. This project could only address about half of the insecticide MRL obstacles the industry faces.

There weren't any unexpected outcomes or results that affected the project.

All goals were achieved except quantifying the beneficial outcomes and not enough time has passed to quantify those benefits.

ADDITIONAL INFORMATION

Farmers provided $32,000 in in-kind match by cooperating with Research on their farms. The WBC invested $77,000 in cash to advance the research project.

COST CATEGORY	Grant Funds	Invoiced to Date	Balance	Total Project Cost
Salaries	$3,210	$3,127.50	$82.50	$3,210
Benefits	$481	$469.13	$11.87	$481
Contractual	$96,309	$96,403.37	-$94.37	$96,309
TOTAL	**$100,000**	**$100,000**	**$0.00**	**$100,000**

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PROJECT #10

Project Title: Mechanizing red raspberry pruning and cane tying

Partner Organization: Washington Red Raspberry Commission (WRRC)

PROJECT SUMMARY

Cane management in red raspberry production is highly labor intensive. Labor availability is uncertain at best and labor cost is increasing. Currently, Washington growers estimate the pruning and tying (Fig. 1) cost in red-raspberry production to be from $600 to $800 per acre. In addition, labor is at risk for chronic and acute injury. Mechanization has the potential to substantially reduce labor use from cane management. In this project, WRRC contracted with WSU to develop a systematic approach for cane management through horticultural modifications and engineering solutions. New horticultural systems for physically separating one-year and two-year old canes were investigated. These systems were evaluated for their feasibility to allow mechanized pruning of two-year old canes while maintaining the desired level of yield. In addition, techniques were developed to bundle one-year old canes together and tie them to the trellis wires. WSU expects that the successful completion of the project will lead to a practical cane management system. In the long term, commercial adoption of the system will improve economic sustainability of WA red raspberry production. The system will also have potential to be adapted to other WA specialty crops such as black raspberry and blackberry.

Fig. 1: New (year-1) canes bundled together after old (year-2) canes have been pruned.

This project impacts all red raspberry growers in WA who use the floricane production system - the entire industry relies on manual labor to prune and tie canes. This combined operation represents about 35% of the total variable costs of production (MacConnell and Kansiger, 2007). The project generated industry-applicable techniques to improve labor productivity and reduce labor demand. The project's main emphasis was in researching and developing technologies to mechanize or automate training and pruning operations. Success in this objective will lead to a machine that can dramatically reduce labor demand and costs, amounting to as much as $300 to $500 per acre per year for combined pruning and cane tying. These savings will lead to millions of dollars of economic benefit to the $30+ million dollar per year WA red raspberry industry, which will substantially improve the competitiveness and long-term sustainability of the industry. Farmers were expected to see the benefit from engineering solutions within four to five years of this funding.

This project addressed the "*Preserving Key Resources – Labor, [Land, or Water]*" priority by developing horticultural and mechanization technologies for reducing labor requirements for red raspberry production. Increased mechanization will create higher skilled jobs (with higher pay) in a safer work environment. In addition, mechanization will reduce direct involvement of humans in fruit production, which has a potential for "*Improving Food Safety*."

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

PROJECT APPROACH

Horticultural Study:

Test red raspberry plots were planted in the beginning of this project and have been maintained following commercial practices in field operations including irrigation, nutrient application and cultivation. A red raspberry plot established and maintained at WSU Prosser (Fig. 2) included several red-raspberry varieties, which provided a test ground for various engineering and horticultural studies in eastern WA thus avoiding the need for frequently travel to western Washington for prototype evaluation.

Fig. 2: Red raspberry plot established at Washington State University's research farm, Prosser, WA

In collaboration with WSU weed scientist Dr. Tim Miller, yield data was collected weekly in 2015 by variety based on different cane burning chemistries (Table 1). It was found that three varieties tested had significantly different acidity (TA, titratable acidity) following the cane burning which was highest in the variety Wakefield (2.06% acidity).

Table 1: Cane Burning Fruit Quality by Cultivar (2015 Harvest Season). Bri is a measure of sweetness (soluble solids), TA is titratable acidity which, along with pH measures fruit acidity, anthocyanin measure fruit color, with higher numbers indicating darker fruit, and phenolics are an indicator of fruit antioxidants.

Cultivar	Brix	TA	pH	Anthocyanin	Phenolics
		%		mg/g	au/g
Chemainus	12.35 ^{b}	1.85 ^{b}	3.6 ^{a}	0.57 ^{b}	1.67 ^{b}
Meeker	14.09 ^{a}	1.59 ^{c}	3.6 ^{a}	0.56 ^{b}	1.95 ^{a}
Wakefield	13.46 ^{a}	2.06 ^{a}	3.4 ^{b}	0.64 ^{a}	1.93 ^{a}

**Different letters following the numbers in a column represent a statistically significant difference between varieties for the given quality measure*

Cane weight was measured in June, 2016 across the three varieties (Table 2). Biomass of primocane and fruiting lateral differed by cultivar but not by herbicide treatment, while floricane biomass did not differ by either cultivar or herbicide treatment. These results indicate that the herbicide treatments had neither a negative nor positive effect on plant growth.

Table 2: Weight of cane and laterals

Primocanes (g)			
Wakefield	39.4 [a]	Aim once	31.6
Chemainus	32.4 [ab]	Aim twice	35.5
Meeker	30.9 [b]	Treevix	30.3
		Nontreated	39.5
Floricanes (g)			
Wakefield	43.8	Aim once	34.7
Chemainus	38.1	Aim twice	36.8
Meeker	36.4	Treevix	38.3
		Nontreated	47.9
Laterals (g)			
Wakefield	76.9 [a]	Aim once	47.6
Chemainus	29.6 [b]	Aim twice	47.7
Meeker	29.6 [b]	Treevix	39.8
		Nontreated	45.9

Plant size (diameter around the canes in a plant) is an important parameter for optimizing the design of a bundling and tying mechanism. In the winter 2015, the diameter of plants was measured after floricanes were pruned out (Fig. 3). In the two years old test plot established for this project, the plant diameter varying from 4 to 11 cm.

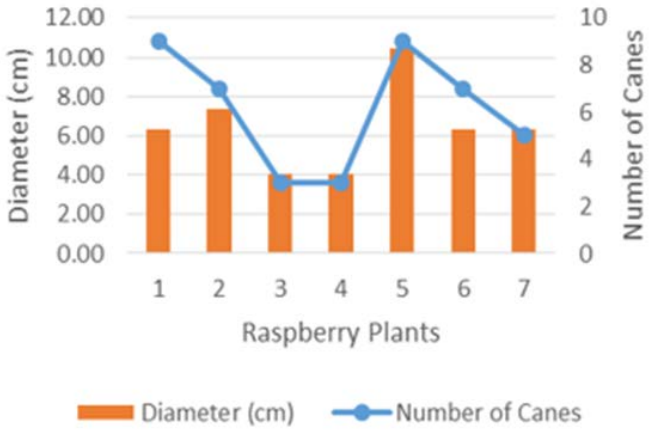


Fig. 3. Samples of bundle diameters for different numbers of red raspberry canes.

Engineering Study:

Novel mechanisms were designed and fabricated to work in field conditions in trellised red-raspberry production system for cane bundling and tying. Innovative methods were also developed for floricane detection. Details on these activities and results will be discussed below.

Cane Bundling: A hydraulically controlled cane gripping mechanism was designed, fabricated and evaluated in a red-raspberry plot. This mechanism has been designed with L-shaped arm whose closing action, controlled by chain and sprocket, brings scattered canes together as a bundle. A metal rod was added in front of the sprockets to prevent the canes moving into the sprockets and getting damaged. This mechanism was mounted on the three-point hitch of a John Deere tractor (Fig. 4) and controlled by the tractor hydraulics for field evaluation. Field evaluation in a test plot in Prosser, WA showed 97% bundling success (Table 3). As the plant was still young, there were only 5 to 10 canes in each plant after pruning.

Fig. 4: Field evaluation of a cane bundling mechanism

Table 3. Results of bundling mechanism test

S. No.	Number of Canes	Number of samples	Total number of canes missed	Average Bundle Diameter(cm)
1	4	5	0	5.0
2	5	8	2	5.6
3	6	3	1	7.6
4	7	4	0	7.3
Mean				6.1

Cane Tying: A circular gear-teeth end-effector was designed to wrap an adhesive tape around bundled canes (Fig. 5). Canes enter into the wrapper through an opening in the wrapper. The circular wrapper was motorized using a stepper motor connected on the top of one of the vertical shafts. A half-scale prototype was fabricated using a 3D printer. The tape tying end-effector prototype was evaluated in the field along with the bundling mechanism discussed before. The prototype accommodated cane bundles with a maximum of 7 canes. After this field test, the tying mechanism has been improved by adding a rack and pinion-based arm, which can cut the tape as well as grab and hold the tape for next plant to be bundled. With this mechanism, the tape wrapper goes around the bundled raspberry canes for several rounds (currently programmed for three rounds but no. of rounds can be adjusted as needed). Once the switch is on, wrapper will go around the bundled canes. Tape is released from the grabbing end during the first round of the wrapper. During the final round of the wrapper, the forward movement of the motor will extend rack, letting the tape pass between the cutting blade and the grabbing end. When the tape wrapper stops completely, the extended arm will close, cutting the tape from the end near the plant while the other end of the tape is being pulled and held by the cutter for next round of wrapping. The improved prototype was also fabricated using a 3D printer and was evaluated in the laboratory environment earlier this fall (Fall 2016).

Some features of this mechanism include:

- *This newly added tape cutting and grabbing mechanism is fully automated and is controlled by a single dc motor.*
- *The tape wrapper design has been improved by adding supports for guiding the tape for grabbing and cutting mechanism. Opening in the new tape wrapper has been increased to let up-to nine canes enter inside it.*
- *Special attention has been given to synchronize the movement of wrapping and cutting mechanisms.*

Fig. 5: A mechanism to tie adhesive tape around a bundle of canes; Left - Earlier version of the prototype being evaluated along with a bundling mechanism. Right – Improved version of the mechanism being evaluated in the lab.

Automated Detection of Floricanes: Automated pruning requires a sensing system for automated detection of Floricanes (two year old canes). During pruning season, it is not always easy to distinguish Floricanes and Primocanes (one year old canes). In this work, a hyperspectral camera was used to estimate spectral signature of different types of canes (Fig. 6). The hyperspectral imaging system used was a line scanner Hyperspec® VNIR 1003A-10143, with a spectral range of 350nm to 1006nm, divided into 881 channels with 0.72 nm interval between channels. Hyperspectral images of primocanes and floricanes were obtained in laboratory environment. The spectral signature for primocanes and floricanes showed some differences (Fig. 7), which was utilized in automatically detecting floricanes in the complex scene of primocanes, floricanes, and background surfaces such as ground and sky. K-means classification algorithm was used to detect floricanes using the spectral signatures, which resulted in an accuracy of 85%.

Feasibility of another approach of using color painting of canes during bundling was also explored. Food grade colors were used to paint floricanes in June, 2015 and were evaluated qualitatively over several months. Out of different colors painted, orange showed more promise for longevity and prominence compared to yellow, blue, or white.

Fig. 6: Enclosed laboratory setup - hyperspectral camera with a pan-tilt unit for taking images of red raspberry canes.

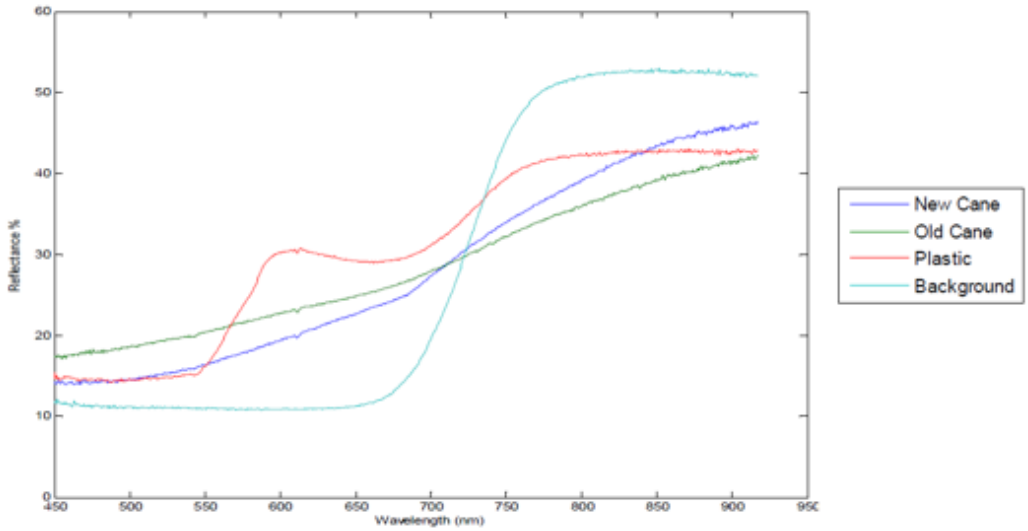


Fig. 7: Spectrum of new canes (dark blue), old canes (green), plastic tie (red), and background cloth (light blue) as observed from hyperspectral scanner.

Robotic Pruning: A robotic end-effector or a hand was designed and fabricated using a scissor mechanism (Fig. 8). The end-effector was then integrated with a robotic manipulator or arm and was automatically controlled to achieve a pruning cut in the laboratory environment.

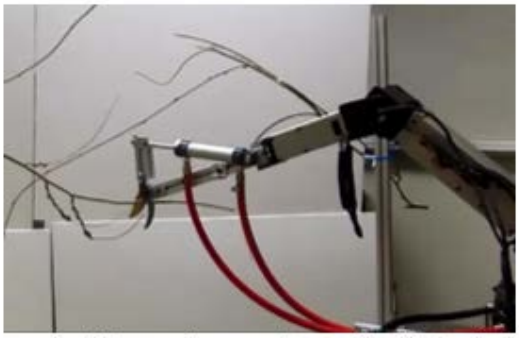


Fig. 8: A manipulator and a pruning end-effector in lab testing

WSU's Center for Precision and Automated Agricultural Systems and USDA/ARS conducted the research into establishing a red raspberry plot in WSU Prosser and development of a mechanical cane bundling and typing techniques as well as a machine vision system for facilitating automated pruning. The details on these activities are described in the Project Summary and Goals and Outcomes Achieved sections of this report.

This project does not benefit non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

The long term goal is to lower the cost of production across the entire WA industry that produces frozen red raspberries. Specifically, the target is to develop mechanization and automation solutions to reduce labor costs in pruning and cane tying by up to 30 to 50%, which currently stands at an estimated $600 to $800 per acre. Through design, fabrication and evaluation of machine prototypes, significant progress has been made in this project towards developing mechanized or automated cane tying machines. Progress has also been made in various components of automated pruning including detection of floricanes for pruning, and integration and evaluation of an end-effector (a cutting scissor) and a robotic manipulator (or arm) for cane cutting. Further research in improving the cane detection method and maneuvering of robotic hand to desired canes for pruning is essential for moving the technology forward to achieve the stated long term goals.

Proposed Activity/Goals	Actual Accomplishment	Status
Planting and management of red raspberry plot	• A red raspberry plot was planted in Prosser, WA in 2014 and maintained using commercial practices. • Weed control and cane burning have been completed every season • The irrigation system was improved and row end drip/puddling has been eliminated.	Planting and management goal achieved; Alternate year planting was not pursued as discussed in Lessons Learned portion of report
Collection of plant growth and productivity data	• During 2015 harvest season, yield data was collected weekly by variety based on different cane burning chemistries. • Weight of canes and laterals were also measured.	Achieved
Collection of pruning-related data	• Plant size was measured after pruning as a parameter for bundling and tying mechanism design.	Achieved
Analyzing field data	• Fruit from each harvest was composited by burn down material, for a single season fruit quality analysis for Brix, TA, and fruit color.	Achieved
Design cane bundling and tying machine	• Several alternative designs for cane bundling were conceptualized. • Three conceptual designs were created for tying mechanism. • 3D computer models of tying mechanisms were developed. • A few raspberry fields were visited in Lynden, WA in 2013 and 2015 to learn more about floricane growth, which helped optimize the designs.	Achieved
Develop and evaluate bundling and tying mechanism	• Two to three versions of bundling and tape tying prototypes were fabricated. • Prototypes were first evaluated in the lab, improved, and further evaluated in the field in 2016. • Based on the experience and knowledge from the field work, both bundling and tying mechanisms were further improved.	Achieved
Develop sensing system for floricane identification	• Hyperspectral camera images were used to distinguish floricanes and primocanes. • Floricanes were painted with food grade and water-based colors to investigate the potential of using color-camera for automated floricane identification. • Orange color showed more promise than other colors.	Goal achieved; The team also hypothesized that further improvement in detection accuracy may be achieved using a spectroradiometer with wider spectrum than the currently used hyperspectral camera.
Develop and evaluate pruning mechanism	• Pruning machine conceptual design was explored. • A scissor type end-effector was integrated with a robotic arm and evaluated in the lab.	Lab evaluation was completed; Because of additional focus in detecting floricanes with different methods and also change in the horticultural

		studies, field evaluation of pruning mechanism was not pursued.
Outreach activities	• Update to Small Fruit Conference in December 2013 and 2014. • A presentation was also given in WA Red Raspberry Commission Meeting in October, 2014. • Team participated in the Raspberry Research Roundtable held on Oct 8, 2014, November 4, 2015 and October 12, 2016. • Team members also presented their work in expos and meetings including Washington Hort Show (Yakima, 2015), precision farming expo (Kennewick, 2016) and WSU CPAAS open house (Prosser, 2015).	Achieved

As discussed before, novel engineering solutions for red-raspberry cane bundling, tying and floricane identification was developed and evaluated. As there have been limited effort in the past towards solving this important problem for red-raspberry industry, this outcome leads the industry much closer to meeting the long term target of reducing labor use in red raspberry pruning and tying by 30 to 50%.

BENEFICIARIES

There are approximately 130 red raspberry growers in WA State and another 50 in the larger growing region which includes Oregon and British Columbia. All red raspberry growers rely on hand pruning and tying. Increasing labor costs and availability are priority concerns for the future of this industry.

The output and outcome of the project including information on the yield and horticultural parameters on the new red raspberry plot in Prosser has benefited WA red raspberry growers in all production areas including south east and north west regions. When the output of this project including red-raspberry cane bundling and tying mechanisms are commercially adopted, the industry will further benefit from this work. Researchers working in red raspberry crops were also benefited by the availability of the replicated varietal plot at WSU research center that was available for other research projects. One of those projects carried out by other WSU researchers was on evaluation of different chemicals for cane burning.

As described in the Project Approach portion of this report, three red-raspberry varieties (Chemainus, Meeker and Wakefield) were tested in this work for effectiveness of chemical cane burning, which showed a significant difference in TA following the cane burning with Wakefield variety having the highest TA of 2.06%. Size of young two-year old plants was found to be varying from 4 to 11 cm in diameter (assuming a circular plant). The engineering studies carried out in the project showed that the success rate of the designed cane bundling mechanism was about 97% and the accuracy of floricane detection was found to be 85%. These results show a promise for further development and eventually commercial adoption of automated or robotic red raspberry pruning and bundling tasks.

LESSONS LEARNED

There has been only limited commercial production of red raspberry in the south east Washington area. Planting and maintaining a red raspberry plot with different varieties planted in a randomized way provided an excellent infrastructure for various types of research including engineering and automation solutions investigated by the team for red-raspberry bundling, tying and pruning. The plant canopies, though maintained following standard commercial practices, did not seem to grow as well as some of the commercial platting the investigators have visited in Mt. Vernon and Lynden, WA. It could be because of the difference in weather conditions between the two regions of the state. In 2014, some winter injury was observed in the top third of the canes, but with no particular pattern.

It was proposed to implement an in-row alternate year cropping system to physically separate primocanes (1 year old canes) and floricanes (2 year old canes) so that the pruning task could be simplified. After considering the growth pattern of canes in the test plot and the size of a smaller clip for the lower trellis wire (as proposed), it was decided that the

canes would be too compressed and the canopy too dense if alternate year cropping system was implemented. Thus the proposed alternate year training system was not pursued further.

Mechanization and automation technologies investigated for cane bundling and tying showed a great potential for developing practically adoptable solutions. For example, the bundling mechanism prototype developed in this work successfully bundled and tied red-raspberry plants with up to 7 canes. Further research to improve the speed of operation, and to evaluate the system in more diverse cropping systems and varieties would be important to further increase the potential for commercial success. The work also showed that color painting of canes (after pruning) could be a simple yet effective method to detect floricanes (for pruning) from the complex mix of primocanes and floricanes using a color camera. Orange food grade color painting remained highly noticeable to color cameras for more than 6 months. Hyperspectral imaging also showed a promise for differentiating primocanes and floricanes as can be seen by the spectral signature differences depicted in Fig.7. The accuracy achieved for floricane detection with hyperspectral sensing was more than 85%. To further improve the detection accuracy, it can be hypothesized that spectral measurement up to 2500 nm wavelength will be helpful as differences could be further enhanced in the spectrum range of 1000 nm to 2500 nm. The WSU team has plans to continue investigating the spectroscopic analysis beyond this project using a free-of-cost equipment loan that has already been awarded to Co-PI Karkee by ASD Inc. (Boulder, CO).

The next step after the detection of floricanes would be to actually cut those canes out of the canopies. In this project, a scissor type end-effector and a robotic manipulator (Fig. 8) was evaluated in a laboratory setting for its speed and effectiveness in cutting woods/canes. However, accessing floricanes in the mix of primocane and floricane remains an important challenge in the current cropping systems. It is important that both horticultural modifications and automation solutions are developed in collaborations so that a systematic solution can be developed for pruning. Irrespective of how pruning occurs as further studies are continued in the future beyond this project, 60% of the manual labor is involved in cane bundling and tying, for which the automation solution investigated in this project brings us much closer to having a practically adoptable solution.

No unexpected outcomes or results affected this project.

As discussed in above, in-row alternate year cropping system is a challenging horticultural problem and may require an innovative solution. A simpler solution to the proposed in-row alternative year cropping would be spatially separating crop for alternate years, such as alternate rows or even alternate plots used for alternate year cropping. Total yield and economic analysis of such a system are being evaluated by other scientists and one of the grower collaborators (Maberry Packing). It was also discussed above that use of a spectrometer that can provide spectral signature from 400 nm to 2500 nm could help improve the accuracy of floricane detection.

ADDITIONAL INFORMATION

COST CATEGORY	Grant Funds	Invoiced	Balance	Total Project Cost
Contractual	$169,926	$169,926	$0	$169,926
TOTAL	**$169,926**	**$169,926**	**$0**	**$169,926**
Matching Funds	WRRC, farm contributions	$382,101	$0	**$382,101**

All funds were contracted with Washington State University. WRRC contributed an additional $30,000 to the contract. WSU used the funds to partially or fully support salaries of one post-doc and two graduate students. WSU also used the funds to establish and maintain a red raspberry plot at WSU Prosser. Some part of the funds were also used to purchase materials and supplies to build and evaluate prototypes in red-raspberry fields. WRRC administration of the project was valued at $7,500 in in-kind match, two farms where the research took place contributed $102,000 in in-kind services supporting the project, and WSU added $72,675 in in-kind support.

***Publications and Posters*:**

Shrestha, A., Karkee, M. and Zhang, Q., 2016. Mechanism for Bundling and Tying of Red Raspberry Primocanes. IFAC-PapersOnLine, 49(16), pp.166-170.

Shrestha, A., M. Karkee and Q. Zhang, 2015 (Poster). Automation of Red Raspberry Bundling and Pruning. 2016 Precision Farming Expo, 6-7 January, 2016; Kennewick, WA.

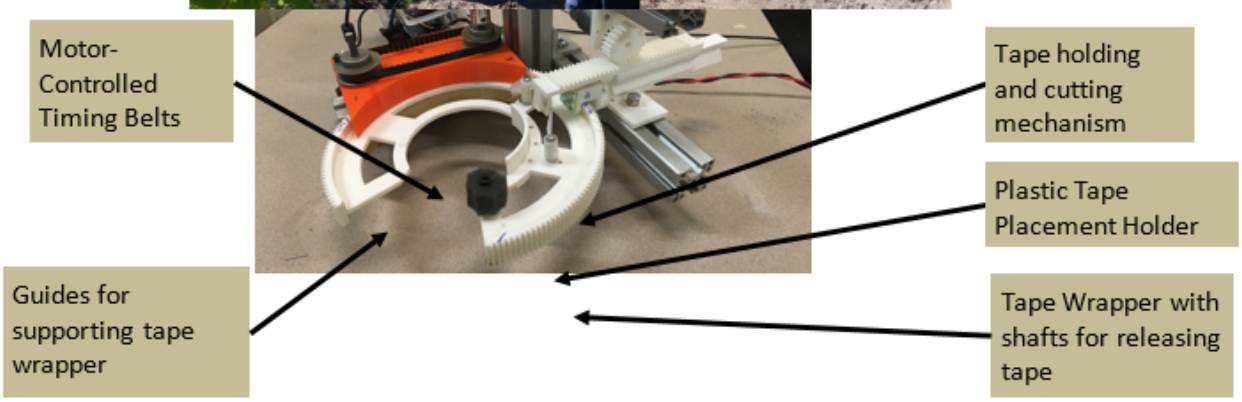
Shrestha, A., M. Karkee and Q. Zhang, 2015 (Poster). Efforts Toward Automation of Red Raspberry Bundling and Pruning. 2015 Washington State Tree Fruit Association Annual Meeting, 7-9 December, 2015; Yakima, WA.

Additional Pictures:

Co-PI Manoj Karkee (WSU Associate Professor) discussing about red raspberry pruning and bundling process with growers, and horticulturists.

Co-PI Manoj Associate graduate Shrestha raspberry WA with PI growers the middle),

Karkee (WSU Professor) and student Aadit visiting red fields in Lynden, Henry Bierlink, (Randy Honcoop in and horticulturists.



Final prototype with tape wrapping, tape cutting and tape grabbing mechanisms.

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WASHINGTON STATE DEPARTMENT OF AGRICULTURE
Final Report
AMS Agreement: 12-25-B-1704

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Original Submission:

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PART TWO

PROJECT #11

Project Title: Enhancing Sustainability of Pea Production in Washington

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

English/garden and edible pod peas are important processing and seed crops in Washington State with a combined production value of approximately $42,000,000 in 2012. Powdery mildew is serious disease threat to pea and is poorly controlled by the use of fungicides. There is no reasonable control option for organic growers. Development and utilization of genetic resistance to powdery mildew are considered an effective and sustainable strategy to manage this disease.

The project was motivated by feedback from growers, processors and breeders of English/garden and edible pod peas. According to a USDA SCRI-funded survey, powdery mildew is identified as the number one disease to pea that reduces crop qualities and results in yield loss up to 50%. Additionally, the spores produced by the fungus can cause allergic reactions and breathing problems for field crews during harvests. Developing powdery mildew resistant peas is essential for English/garden pea and edible pod pea production and is important for the health of field crews. Some edible pod pea varieties, which had previously been classified as resistant to powdery mildew, were observed to be susceptible to this disease in New Zealand and in Columbia and Walla Walla counties in Washington. It was suspected that the pathogen is either overcoming the traditional source of resistance or a new pathogen has been introduced into these regions. The ultimate goals of this project were to understand the pathogen and deploy additional sources of genetic resistance, which result in providing growers and processors with more stable and sustainable high yielding varieties of peas. By addressing the powdery mildew issues, the purposes of this project were to:

- Develop online breeding tools
- Conduct a comprehensive study to screen pea germplasm for additional sources of resistance
- Investigate changes in the genetic identify of the powdery mildew fungus
- Introgress new alleles into elite backgrounds
- Develop extension bulletins and online resources for powdery mildew management in pea.

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

PROJECT APPROACH

***Goal 1**: develop online breeding tools*

The resistance conferred by the er1 allele has been identified as a loss-of-function of PsMLO and er1 has been successfully cloned and sequenced. Eight breeder-friendly kompetitive allele specific PCR (KASPar) markers, KASPar-er1-1, KASPar-er1-3, KASPar-er1-4, KASPar-er1-5, KASPar-er1-6, KASPar-er1-7, KASPar-er1-8, and KASPar-er1-9, were designed from the PsMLO sequence, based on the mutation information of the er1 alleles. The information on the KASPar markers is available on the cool season food legume website (www.coolseasonfoodlegume.com).

***Goal 2**: identify additional germplasm with powdery mildew resistance*

The USDA pea single-plant (PSP) collection was used for a comprehensive evaluation for reaction to powdery mildew. The 246 accessions of the PSP were obtained from the USDA Western Regional Plant Introduction Station, Pullman, WA. The evaluation for reaction to powdery mildew was conducted in two ways, phenotypic evaluation and genotypic evaluation. For the phenotypic evaluation, the collection was planted in a disease nursery at the Oregon State University Horticulture Farm, Corvallis, OR in 2015 and the reaction to powdery mildew was evaluated through visual assessment according to the disease severity key with modifications of methods from the study of Falloon et al. (1995), where 1 = 0-20% of leaflets covered by the disease, 2 = 20-40%, 3 = 40-60%, 4 = 60-80%, 5 = 80-100%. For the genotypic evaluation, DNA was isolated from the leaf tissue using Qiagen DNeasy 96 Plant Kits. Then, the eight breeder-friendly KASPar markers and the corresponding gel-based markers were used to genotype the accessions. Additionally, in collaboration with pathologists and geneticists from John Innes Centre (UK), University of Bari (Italy), Chinese Academy of Agricultural Sciences (China), Universidade do Algarve (Portugal), and Centre for AgriBioscience (Australia), nine resistant, positive controls (JI 1559, JI 210, JI1951, ROI3/02, G0001778, DDR-11, F (er1-8), ps1771 and Yarrum) and one susceptible, negative control (JI 510) were also genotyped.

***Goal 3**: Investigate changes in the genetic identify of the powdery mildew fungus*
During the 2014-2015 growing season, 32 powdery mildew isolates were collected from seven regions in U.S.A. and one region in New Zealand. Ten were obtained from greenhouses and the rest were collected from fields. The collected isolates were derived from single pea plants and the collection sites in each region were at least 500 meters apart. Total DNA was extracted from the powdery mildew conidia and mycelia using Qiagen DNeasy Mini Plant Kit. To identify the species of each isolate, internal transcribed spacer (ITS) sequencing assay was used and the amplified fragments were sequenced using an ABI sequencer. Each isolate's species was determined based on the pairwise comparison with the BLAST algorithm in NCBI. To implement population diversity analysis of the collected isolates, thirty simple sequence repeat (SSR) markers were developed from the whole genome sequences of Erysiphe pisi using Msatcommander software. The genotypic data were analyzed by GenAlEx 6.5, Structure 2.3.4, and NTsys 2.1, respectively. GenAlEx was used to analyze number of alleles, allele frequency and Nei's genetic diversity; Structure was used to estimate the possible number of genetic population using Bayesian method; NTsys was used to perform principal component analysis (PCA).

***Goal 4**: introgress new alleles into elite backgrounds*
A third, dominant allele, Er3, for powdery mildew resistance was identified in one of pea's wild relatives – Pisum fulvum. This allele confers immunity to pea. Three germplasm lines containing Er3 were obtained from the Institute for Sustainable Agriculture, CSIC, Córdoba, Spain. Pisum fulvum has very small, darkly pigmented seeds. The plants are very tall, with very thin stems, small leaflets and pigmented flowers. A series of crosses was initiated using the P. fulvum accessions as male and garden peas as the female. These interspecific crosses were difficult to make and in the ensuing F1 and F2 generations, there was considerable male sterility. Two back crosses were made (eg. P. sativum x F1) to obtain BC2F2. Ten single plant derived progenies from this generation were evaluated for resistance to powdery mildew in 2016 in the field nursery at Oregon State University. Single plants that were resistant to powdery mildew were harvested. Because Er3 is dominant, it is necessary to progeny test the resistant lines to determine if they are heterozygous or homozygous. These lines are currently being grown for seed increase for progeny testing and the homozygous resistant lines will be released as germplasm in 2017.

***Goal 5**: develop extension bulletins and online resources for powdery mildew management in pea*
This goal/objective was discontinued as the objective was met through the development of disease diagnostic cards by the pulse working group (of which all PI's on this project are members). Resources allocated for this goal were not spent and were returned.

The significant contributions and roles of project partners are as follows:

- *Rebecca McGee, PI.* Dr. Rebecca McGee oversaw, directed and guided this project, reviewed the project timeline and activities, and prepared quarter, annual and final reports to WSDA. Additionally, she was in charge of introgressing er2 and Er3 alleles into elite backgrounds and evaluated the PSP collection for reaction to powdery mildew in the field.
- *Clare Coyne, Co-PI*. Dr. Clare Coyne oversaw the genotyping aspects of this project and the development of the KASPar markers. She provided the PSP collection for identification of additional germplasm with powdery mildew resistance.
- *Dorrie Main, Co-PI*. Dr. Dorrie Main oversaw the bioinformatics portions of this project. She was responsible for developing the Cool Season Food Legume website.
- *Carol Miles, Co-PI.* Dr. Miles was responsible for Goal 5, which was discontinued.
- *Jodi Humann.* Dr. Jodi Humann was the Laboratory Project Manager, who ensured that expenditures remain within the budget categories and the funds were spent appropriately.
- *Yu Ma.* Ms Yu Ma conducted the majority of the laboratory experiments during this project as part of the research requirements for a Ph.D. degree. She was responsible for development and validation of KASPar markers, identification of additional resistant germplasm using DNA markers, investigation of the genetic diversity of collected powdery mildew isolates and data analysis. She assisted in the preparation of the final report to WSDA.

This project did not benefit any non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

The activities to achieve the expected outcomes are included in the descriptions above. The performance goals of this project were closely met.

***Goal 1**: increase production potential for English/garden and edible pod peas*

This became a long term goal due to the unexpected difficulties encountered with male sterility in the interspecific crosses. Germplasm known to be homozygous for Er3, and therefore immune to powdery mildew will be released in 2017. The long term goal of introgressing multiple powdery resistant alleles into elite backgrounds is still in progress – the Er3 germplasm will continue to be improved for agronomic traits while retaining Er3. er1 will be combined with Er3 using the KASPar markers. Tools for breeders to use in improving the powdery mildew resistance in their breeding programs include the KASPar markers developed for er1 – er8. In approximately 3 years, introgression of er1 and Er3 into elite backgrounds will be complete and the increased production potential of the new cultivars carrying both genes for powdery mildew resistance can be measured.

***Goal 2**: develop online breeding tools*

The eight low-cost, breeder-friendly KASPar markers were developed from the mutation information of the er1 alleles to assist in pyramiding multiple and specific powdery mildew resistant alleles. The manuscript is currently in preparation and expected to be submitted to Molecular Breeding journal in December 2016. The KASPar markers will be freely available and disseminated immediately following publication of the results. The relevant information will be included on the CSFL website.

***Goal 3**: identify additional germplasm and varieties with powdery mildew resistance*

For the phenotypic evaluation of the PSP collection for reaction to powdery mildew, the results showed seventeen pea accessions were found to be highly resistant to powdery mildew with a disease score of 1. These lines included W6 17293, W6 39729, W6 39761, PI 102888, PI 116944, PI 142775, PI 179451, PI 183467, PI 207508, PI 220174, PI 220189, PI 222071, PI 222117, PI 273605, PI 274307, PI 307666, and PI 486131. Among these, 16 were P. sativum and one was P. sativum var. arvense (W6 17293).

For the genotypic evaluation, the results showed the KASPar markers developed in this study worked perfectly to detect powdery mildew resistance except KASPar-er1-9. The results can be easily visualized through Bio-Rad CFX Manger software. Figure 1 is an example of KASPar-er1-1 on 18 pea accessions from the PSP collection. Individuals clustered in the upper left (purple) are homozygous for HEX-labeled er1/er1 powdery mildew resistance. Individuals clustered in lower right (orange) are homozygous for FAM-labeled Er1/Er1 powdery mildew susceptibility. Individuals clustered in the lower right (black) are no template controls and samples failed to identify because of evaporation during PCR amplifications. To validate the genotypic results using the eight KASPar markers, the pea accessions were also genotyped using the corresponding functional markers. From the genotypic evaluation of the PSP collection, one accession, PI 142775, was found to carry the er1-1 allele and was resistant to powdery mildew. However, no accessions were found to carry the other er1 alleles, er1-3, er1-4, er1-5, er1-6, er1-7, and er1-8. Given the 2-bp insertion for er1-9 allele occurs in an intron of the PsMLO gene, it is difficult to conclude whether KASPar-er1-9 works perfectly.

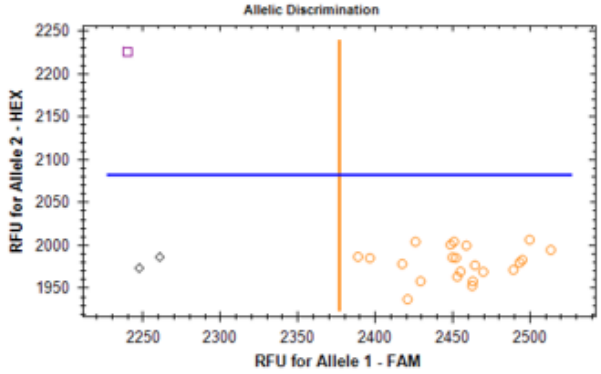

Figure 1. Result of genotyping with the marker KASPar-*er1-1* on 18 pea accessions

***Goal 3**.1: Investigate changes in the genetic identify of the powdery mildew fungus*

According to the ITS sequencing results, two isolates collected from a greenhouse in Washington State were found to be E. trifolii, while the rest of the isolates were E. pisi and none of collected isolates belonged to E. baeumleri (Figure 2). E. pisi is likely to be the main powdery mildew species in North America. However, it is still unknown if E. pisi is dominant in New Zealand due to limited numbers of samples (2 samples). More samples should be collected in this region in future study.

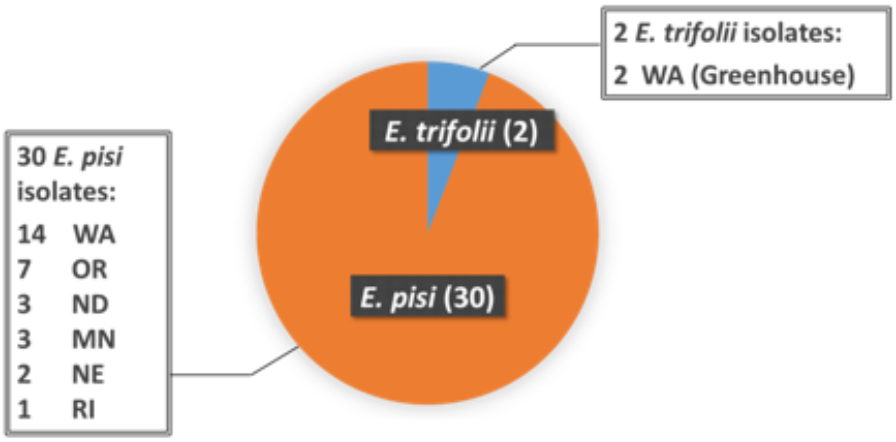

Figure 2. Pie chart of percentage of powdery mildew species from selected regions

The collection of powdery mildew isolates studied in this project was highly polymorphic, which was indicated by Nei's genetic diversity with values ranging from 0.1 to 0.6. The number of alleles per locus for SSR markers ranged from 2 to 7. Interestingly, two SSR markers can distinguish E. pisi from E. trifolii. The population structure of collected isolates was examined by PCA. Four distinct clusters differentiated by PC1, PC2 and PC3 were observed in Figure 3. E. trifolii was separated from E. pisi, while isolates from OR and ND were distinguished from the rest of regions. In agricultural ecosystems, environmental changes such as resistant varieties, applications of fungicides, irrigation, and crop rotation may cause population structure different from place to place. In OR, the sample-collected areas are disease nurseries where diverse pea varieties are planted. In ND, the sample-collected area has a humid climate with warm summers and no dry season. These factors may be the reason causing powdery mildew isolates in these areas different from others.

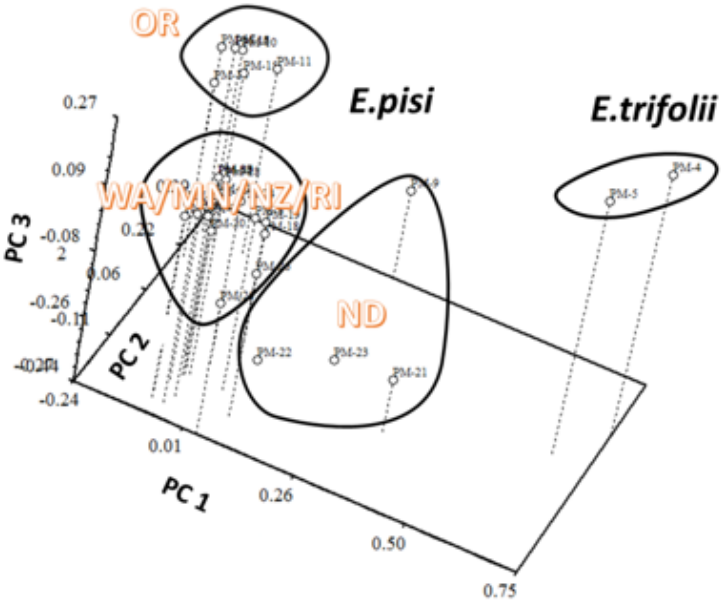

Figure 3. Principal component analysis of population structure among thirty-two powdery mildew isolates

Goal 3.2: *introgress new alleles into elite backgrounds.*
This goal has become a long term goal. There was an unexpected high level of male sterility associated with the interspecific crosses. This resulted in having to make much larger populations than initially anticipated in order to have a sufficient population to phenotype in the field. As a result, instead of being able to release finished varieties, only germplasm with Er3 introgressed will be released into adapted backgrounds. This part of the project will continue to be worked on. It is anticipated that within 3 years cultivars will be released with durable resistance to powdery mildew conferred by Er3 and er1.

Goal 4*: develop extension bulletins and online resources for powdery mildew management in pea.*
This goal was discontinued due to an extremely similar project completed by the Pulse Crop Working group. The project was to develop durable pocket reference cards for identification of common pea diseases.

Established activities and goals	**Actual accomplishments**
Goal 1: *Increase the production potential for English/garden and edible pod peas*	This goal was only partially met. The final development and deployment of pea cultivars with pyramided resistance (*er1* and *Er3*) to powdery mildew was not met because of the difficulties encountered in making the interspecific crosses between *P. sativum* and *P. fulvum* (source of *Er3*). The amount of male sterility encountered was not expected. Currently, elite lines have been identified that carry Er3, however until progeny testing is completed, it is not known if the lines are homozygous (*Er3Er3*) or heterogyzous (*Er3er3*). Following identification of the homozygous lines, seed will be increased and evaluated for increased production potential.
Goal 2*: develop online breeding tools* • Development and introduction of a breeders' toolbox on the Cool Season Food Legume. Upload phenotype and genotype data into breeders' toolbox and make data and cross-assistance tool publicly available • Development of low-cost, breeder-friendly markers.	Activities completed. Goal met. • KASPar markers have been uploaded into CSFL and will be made public immediately following publication of manuscript. • The eight low-cost, breeder-friendly KASPar markers were developed from the mutation information of the *er1* alleles to assist in pyramiding multiple and specific powdery mildew resistant alleles.
Goal 3 *develop new germplasm and varieties with improved levels of durable resistance to powdery mildew* • Identify resistant pea germplasm form the USDA collection by screening in controlled and field (irrigated) conditions	Activities completed. Goal met. • The 246 pea accessions from the USDA collection were evaluated for reaction to powdery mildew in the disease nursery in OR (2015). Seventeen pea accessions were found to be highly resistant to powdery mildew • The same pea accessions were evaluated using the KASPar markers developed in Goal 1 and the corresponding gel-based markers. One accession, PI 142775, was found to carry the *er1-1* allele and was resistant to powdery mildew.
• Determine pathogen species & pathotypes. In addition to cooperator provide samples, systematic sampling in WA. • Learn the nature of the diversity of the pathogen	• Thirty-two powdery mildew isolates were collected from seven regions in U.S.A. and one region in New Zealand during the 2014-2015 growing seasons. Two isolates collected from a greenhouse in Washington State were found to be *E. trifolii*, while the rest of the isolates were *E. pisi*. The collection of powdery mildew isolates

	studied in this project was highly polymorphic and population structure of the pathogen was discovered.
• Introgress Er3 from *Pisum fulvum* and er2 into elite sugar snap, snow and English pea backgrounds	• Er3 has been introgressed (initial cross and 2 back crosses) into adapted English pea backgrounds. Work is continuing on stacking the *er1* and *Er3* alleles. The resistance conferred by *er2* is weak and became a low priority.
Goal 4*: develop extension bulletins and online resources for powdery mildew management in pea* • Target: Two extension publications and on-line diagnostic decision tree	This goal was discontinued due to extremely similar work performed by the Pulse Working Group.

The first Expected Measurable Outcome was ***to increase the production potential for English/garden and edible pod peas***. During this project much effort was spent transferring the powdery mildew resistance conferred by Er3 from Pisum fulvum to Pisum sativum. The original intent was to transfer Er3 through a series of fast backcrosses, however the problems encountered with male sterility associated with the interspecific crosses really slowed this process down. Additionally, not having a biomarker for Er3 made progeny testing a necessity in order to identify lines that were homozygous dominant for Er3. In hindsight, a request to change or amend this EMO should have been requested. Although it was anticipated that EMO 1 would be met, as the project progressed that wasn't possible. A considerable amount of outreach was performed. During the three years of this project, information on the powdery mildew and the progress of this project was presented at one disease diagnostic clinic (50 participants); 15 field days at variety trials (total 345 participants); 4 field days at WSU Research Farms (705 total participants); 5 Grower Meetings (370 total participants). A considerable amount of knowledge was also gained regarding the population genetics of powdery mildew in Washington. In Washington there are two species of Erysiphe that cause powdery mildew on peas – E. pisi and E. trifoli. It was determined that E. pisi is the most common species in fields. Population genetics studies revealed that there are four distinct clusters of genotypes. Further research will determine if the four clusters have similar of different responses to the different er/Er genes and alleles.

The second outcome of this project was ***the development of online tools for breeders***. This includes the development and introduction of a breeder's toolbox on the Cool Season Food Legume website (www.coolseasonfoodlegume.org). KASPar markers have been developed and validated for the er1 alleles. Immediately following publication of the manuscript, these tools will be freely available on the CSFL website for all breeders to use.

The third outcome was the development ***of new germplasm and varieties with improved levels of durable resistance to powdery mildew***. Much was learned about the nature of the population genetics of powdery mildew in naturally infested fields in the state of Washington. Selected lines are currently being progeny tested to select lines that are homozygous dominant for Er3 seed will be increased in the summer of 2017 and germplasm will be released that carries immunity to powdery mildew conferred by Er3. Work in on-going to pyramid the resistance conferred by er1 and Er3 and cultivars and/or germplasm will be released in about 2019 that have extremely durable resistance due to the pyramiding of resistance alleles at both er1 and Er3.

BENEFICIARIES

Direct beneficiaries include pea breeders who now have a breeder friendly marker to use to help select for powdery mildew resistance in very early stages of their breeding programs. They also have access to a third source of resistance to powdery mildew, Er3. Er3 was successfully transferred from the wild relative, Pisum fulvum, into P. sativum and issues with male sterility were successfully overcome. Beneficiaries of future pea cultivars with the durable combination of er1 and Er3 or Er3 alone will include all growers and processors of garden and edible pod peas.

This project primarily impacts Washington growers and processors of peas. The growers and processors were impacted immediately by understanding the identity of the pathogen and learning the nature of the diversity. They will directly benefit from the resistant varieties developed in this research which increased yields and reduced costs of production (by eliminating use of fungicides). Also, they will benefit over time by accessing online tools that would assist them to efficiently manage varieties with durable resistance.

English/garden and edible pod peas had a combined production value of approximately $42,000,000 in 2012. The primary economic impact of this project is preventing yield losses and the secondary impact is reduced fungicide use. These economic impacts will be realized with the further development of pea cultivars carrying er1 and Er3 or Er3 alone.

LESSONS LEARNED

Interspecific crossing was unexpectedly difficult and the amount of male sterility encountered made it very hard to make the breeding progress initially anticipated.

It was not expected that only one accession from the PSP would have a known er1 allele. This leads to the hypothesis that there either are more than the nine previously published er1 alleles present in the PSP or that there are new, unidentified er alleles present. The hypothesis could be tested by making a series of crossing between the lines known to carry an er1 allele and the unknowns followed by progeny testing.

The number of powdery mildew isolates collected in the selected regions is much less than expected. Twenty pathologists/pea breeders were willing to help collect powdery mildew isolates in their regions. However, powdery mildew symptoms did not appear in most of their regions last year, which resulted in a small sample size with thirty-two isolates for genetic diversity analysis. The pathogen is prevalent in areas with a warm, humid climate, while the climate throughout US last year was relatively dry and powdery mildew symptoms were hardly observed under dry weather conditions with high temperature.

Another unexpected difficulty was the purification of collected isolates. The powdery mildew fungus is obligate, biotrophic pathogen, which indicates it can only grow in living hosts for growth and reproduction. It is more difficult to culture biotrophic fungus than necrotrophic fungus. The environmental condition of greenhouses is very important for the successful inoculation, such as temperature, humid, fungicide-free. However, the attempt of isolate purification failed because the application of sulfur fungicides was not noticed during the inoculation.

The goal of creating extension publications was not met –due to extremely similar work performed by the Pulse Working Group.

ADDITIONAL INFORMATION

Item	Year (s)	Value/year	Total Value
Laboratory Bench Space and misc. supplies (McGee)	2014, 2015, 2016	$500	$1500
Laboratory Bench Space and misc. supplies (Coyne)	2014, 2015, 2016	$500	$1500
Growth Chambers (2)	2014, 2015	$1440	$2880
Greenhouse supplies (McGee)	2014, 2016	$500	$1000
Greenhouse supplies (Coyne	2014, 2016	$500	$1000
Field Screening Nurseries (including labor, travel and land)	2014, 2015	$2000	$4000
Tuition Waiver (Yu Ma)	2014-2015	Approx. $15,400	
TOTAL			$27,280

Presentations related to this project were made at about 8 field days and 4 grower meetings per year.

Publications:
This project resulted in Chapter 4 of Yu Ma's Ph.D. thesis, "Enabling Marker-Assisted Breeding in Pea", 2016. Department of Horticulture, Washington State University, Pullman, WA.

Yu Ma, Clare J. Coyne, Dorrie Main, Stefano Pavan, Shimna Sudheesh, Sukhjiwan Kaur, John W. Foster, José Leitão, Suli Sun, Zhendong Zhu, Xuxiao Zong, and Rebecca J. McGee. Development and validation of breeder-friendly KASPar markers for er1, a powdery mildew resistance gene in pea (Pisum sativum L.). Molecular Breeding. (In preparation)

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PROJECT #12

Project Title: Effectiveness of ET-, Soil-, and Plant-Based Tools for Irrigation Strategies

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

The initial purpose of this project was to provide a scientific basis of and practical recommendations for enhanced irrigation management in support of the rapidly expanding wine industry in Washington State. The Washington wine industry is embarking on its next major expansion phase, yet many wine critics complain that the overall quality of white wines from this state lags behind red wine quality. Two varieties, Chardonnay and Riesling, account for 75% of all white wine made in Washington, yet virtually no research has been conducted to determine optimum irrigation strategies for these varieties.

Knowledge of irrigation management for white wine grapes is insufficient. Such research is important and timely, not only because these varieties continue to be a major component of the continued industry expansion, but also because most of these grapes are grown in arid eastern Washington, where highly efficient drip irrigation is the principal management tool to impact yield, quality, and sustainability of premium grape production. To address this issue, this study had three objectives:

- Evaluate the effectiveness of different decision-aid tools (ET-, soil-, and plant-based approaches) for irrigation scheduling, and determine the best approach for directing irrigation of white wine grapes;
- Investigate the influence of different irrigation regimes on white wine grape growth, physiology, yield, fruit composition, and wine quality, and optimize irrigation strategies for high-quality white wine grape production;
- Enhance practical recommendations for irrigation management of white wine grape varieties.

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

PROJECT APPROACH

Activities and accomplishments during the entire duration of this project (September 2013 – September 2016) are presented in chronological order as follows (when possible, repeated activities across years were combined):

- A Postdoctoral Research Associate was hired and began work on the project on October 1, 2013.
- The Work Plan indicates that project activities were to begin in January, 2014. However, using matching funds from the Washington State Wine Commission and in-kind contributions from the industry cooperator, the irrigation systems of two commercial vineyard blocks were modified and the proposed field trials established during the 2013 growing season. Soil samples were taken from both vineyards for soil moisture retention curve analysis to obtain accurate values of field capacity and permanent wilting point (beyond Work Plan).
- The Work Plan specifies six irrigation treatments (named T0 through T5; Table 1). One additional treatment (T6: partial rootzone drying, PRD) was added onto this project (beyond Work Plan). Consequently, seven irrigation treatments (Table 1) were implemented in two vineyard blocks (Chardonnay and Riesling).
- Data were collected during each of three growing seasons (April-September, 2014, 2015, and 2016). Data collection included weekly measurements of soil water status (volumetric soil water content, □v) an (midday stem water potential, Ψs), plant physiological and growth responses (leaf gas exchange, stomatal conductance, shoot growth, canopy density, fruit light exposure), and yield components and fruit composition (total soluble solids, pH, and titratable acidity). Wines from selected irrigation treatments harvested in each year were made by the cooperator at the WSU Wine Science Center in Richland (September-March). Pruning weights were measured and canes counted in February 2015 and 2016.
- Benchmark industry data for the beginning and the end of this project were compiled to evaluate the proposed target and to estimate measurable outcomes. Data were collected in cooperation with the Washington State Wine Commission and the Washington Association of Wine Grape Growers, in addition to data published by USDA-NASS.
- The PI hosted a visiting MS student from Geisenheim University, Germany, from May through November 2014, and a PhD student from the University of Milano, Italy, from July 2014 through February 2016. The students

worked with the Postdoctoral Research Associate to study effects of irrigation treatments and fruit exposure on vine physiological responses and on chemical components responsible for bitterness and astringency in white grapes (beyond Work Plan).

Significant results and conclusions (for tables see the "Additional Information" section below):

- A description of the seven irrigation treatments is provided in Table 1. Treatments T0, T1, and T2 were implemented to test three different approaches to irrigation scheduling. The weekly amount of irrigation water to be applied in T0 (ET-based approach) was based on replacing 100% of crop evapotranspiration. The goal for T1 (soil-based approach) was to maintain soil water content (stress levels (above non v l (plant-based approach) was to maintain stem water potential (Ψs) near or above non-stress levels (Ψs ≥ -0.7 MPa). Treatments T3 through T6 were designed to test method and timing of deficit irrigation. For T3, T4, and T5 the target for moderate stress was 12% < MPa 16% Ψs < -0.7 MPa. For PRD (T6), the drying side was irrigated when its v 12% to increase
- Comparison of three different irrigation decision-aid tools (T0, T1, and T2):
  - Chardonnay: As planned, little difference was found in v and was no difference in leaf gas exchange in all three years. Canopy growth and density of T0, T1, and T2 had different results among the three years (Table 4). In 2014, T0 vines generally had larger and denser canopies (more leaf layers, less light interception in the fruit zone, and more lateral leaves per shoot), compared with T1 and T2. Yet, no differences were found in 2015. Similarly in 2016, most measures of canopy growth and density showed no difference among these three treatments, except that T2 had more leaf layers than T0 and T1 at harvest. Minor differences in yield components were found among these treatments (Table 6). In 2014, T0 had higher yield than T2, and the highest berry weight of all three. In 2015 and 2016, T1 had higher yield than T0 and T2; T0 had lower cluster number than T1. In 2016, T0 also had lower cluster weight and fewer berries per cluster than T1. The inconsistencies in these results may be explained by the variation in irrigation amounts across the three years: in 2014, T0 received the highest amount of irrigation water, while it had the least irrigation in 2015 and 2016 (Table 8). In terms of fruit composition at harvest, little difference was found in all three years (Table 6).
  - Riesling: In general, T0 had higher s in and Ψs than T1 and T2, and there w T2 (Table 3). Little difference in leaf gas exchange was found among these treatments. Vines of T0 had larger and denser canopies (more leaf layers, less light interception in the fruit zone, and higher shoot vigor) than T1 and T2 across the three years (Table 5). Few differences were found between T1 and T2. In terms of yield components (Table 7), T0 had the highest yield in all three years, higher berry weight in 2014 and 2015, and higher cluster weight in 2015 and 2016. More irrigation in T0 may explain the higher vigor and productivity of these vines (Table 8). The relatively small differences in irrigation amounts between T1 and T2 (Table 8) were apparently insufficient to result in yield differences between these two treatments. Little difference was found in fruit composition in all three years (Table 7).
  - Among these three irrigation decision-aid tools, all the data inputs for irrigation decision-making of T0 (replacing 100% of crop evapotranspiration, ETc) were acquired from a nearby AgWeatherNet weather station. Therefore, this tool required no additional, vineyard-based measurements. However, the accuracy of ETc relies on the accuracy of reference evapotranspiration (ET0) and crop coefficient (Kc). If the local conditions of the weather station are rather different from those of the vineyard block, or if the estimate of Kc does not reflect the actual situation of the vineyard, unexpected results may occur when irrigation decisions are made solely based on ETc. For example, higher v and indicated that ETc was overestimated for the Riesling block. This led to a 71% greater irrigation water supply in T0 compared with the other decision-aid tools (Table 8). Scheduling irrigation based on (T1) or Ψs (T2) measured in the vineyard avoided this problem by providing data inputs for decision-making reflecting the local conditions. However, either approach required extra inputs of equipment and labor. This is especially true for T2, because Ψs only indicated whether or not irrigation was needed, an additional parameter (in this study v) wa by weather conditions, in particular temperature and humidity.
- Comparison of four deficit irrigation regimes (T3, T4, T5, and T6):

- Chardonnay: Compared with the no-water-stress treatments (T0, T1, and T2), the deficit irrigation treatments in general had lower □v and
  lower yield, lower berry and cluster weights, and lower titratable acidity (Tables 2 and 4). From veraison to harvest in all three years, T4 and T5 had higher □v and
  relieved as planned (Table 2). However, leaf gas exchange in T4 and T5 was only higher than T3 in 2015. In 2014, T6 had more leaf layers than the other three deficit treatments, and more vigor and less light interception in the fruit zone than T5. In 2015, T3 had fewer leaf layers and T6 had higher vigor than the other deficit treatments; T6 also had less light interception than T3 and T4. In 2016, T6 had more canopy growth and denser canopies than T3; T4 and T5 were either intermediate between, or no different from, T3 and T6. In terms of yield components (Table 4), T6 generally had higher yield and often the highest berry weight among the deficit treatments, even though the amount of irrigation water supplied in T6 was similar to the others deficit treatments (Table 8). Little difference was found in fruit composition among these deficit treatments in 2014 and 2015, but in 2016 grapes from T6 had higher acidity than those from T3 and T5 (Table 6). Importantly, berry skin phenolics (flavonols and monomeric, oligomeric, and polymeric flavan-3-ols) were not impacted by the irrigation regime per se, but sun exposure led to an eight-fold increase in flavonols, and a fourfold increase in flavan-3-ols compared with shaded berries (data not shown). This suggests that any potential irrigation effect on bitter or astringent wine phenolics likely occurs via its effect on canopy structure, and thus on light exposure of the fruit.
- Riesling: In general, the deficit irrigation treatments resulted in lower □v and
  shoot vigor, more open canopies, lower yield, and lower berry and cluster weights than in T0, and lower titratable acidity in 2014 and 2016 (Tables 3, 5, and 7). However, growth and yield components in these deficit treatments differed only occasionally from T1 or T2, despite lower irrigation water supply in the deficit treatments (Table 8). Among the deficit treatments, no consistent differences in canopy growth and density were found across the three years, except that T3 vines tended to have fewer leaf layers. From veraison to harvest in both 2015 and 2016, T4 and T5 had higher □v, Ψs
  which indicates that water stress was relieved as planned (Table 3). In terms of yield components and fruit composition, few or inconsistent differences were found, except that T6 often had higher berry weights than the other deficit treatments (Table 7), with similar amounts of irrigation water (Table 8). The results for fruit phenolic compounds were similar to those found in Chardonnay, with sun exposure resulting in a six-fold increase in flavonols, and a two- to three-fold increase in flavan-3-ols. Overall, Riesling produced much lower amounts of flavan-3-ols than Chardonnay, while flavonol levels were similar (data not shown).

Recommendations:

- It is feasible to schedule irrigation based on either ETc, □v, or
  in trade-offs between accuracy and labor/equipment demands, as described above. In order to improve the applicability of the ET-based approach, the current model for estimating Kc based on growing degree days may require adjustments to suit the local conditions of the vineyard. An alternative solution would be to adopt a different method that can estimate Kc locally. If using the ET-based approach, it would be advisable to at least employ either soil- or plant-based measurements to check whether intended irrigation goals are achieved under local conditions.
- Excessive water deficit should be avoided in white wine grape production. Overall, the T3 treatment that imposed moderate water stress throughout the growing season tended to produce the smallest canopies that were associated with high sun exposure of the fruit. Although water stress does not appear to directly impact grape phenolics that impart bitterness or astringency in wine, an increase in fruit exposure due to water deficit will nevertheless have a detrimental impact on these quality-relevant components. It should be noted that only moderate water stress was applied in the present experiments. More severe stress, which is known to result in leaf abscission in the fruit zone and in sunburn symptoms on the fruit, presumably would worsen the situation for wine phenolics.
- With similar or occasionally more canopy growth and little difference in fruit composition compared with conventional deficit irrigation regimes (T3, T4, and T5), partial rootzone drying (T6) may be beneficial considering its higher yielding with similar irrigation water usage. Also, the irrigation decision was easy to make based on □v
  of two separate rootzones: irrigation was initiated on the drying side and stopped on the wet side whenever □v of
  the drying side fell below 12% (v/v). This threshold could be adapted to different soil types for integration in automated irrigation decision-support tools.

Significant contributions and roles of project partners include:

- The PI (Dr. Markus Keller) provided overall project management, direction, and oversight and supervised the Postdoctoral Research Associate (Co-PI, Dr. Yun Zhang), a visiting PhD student (from University of Milan, Italy), a visiting MS student (from Geisenheim University, Germany), two technicians, and four student interns who assisted with trial establishment and data collection. The PI also collected benchmark data from industry stakeholder groups, submitted the progress reports to WSDA, and ensured that expenditures remained within budget categories and that funds were spent appropriately. In addition, the PI gave annual written and oral reports to the industry advisory committee and several oral presentations on irrigation management to industry stakeholders, as well as to the scientific community.
- The Postdoctoral Research Associate (Co-PI, Dr. Yun Zhang) co-supervised a visiting PhD student, a visiting MS student, and four student interns, and carried out most of the day-to-day activities and measurements in the experimental vineyards, and conducted the data analysis. Also, this Co-PI gave several oral presentations and poster presentations on irrigation management to industry stakeholders and to the scientific community, participated in a discussion panel at an industry meeting, coordinated work with all cooperators, and facilitated report preparation.
- The other Co-PI (Dr. Troy Peters) contributed to the design and modification of irrigation systems and the set-up of the field trials. Also this Co-PI facilitated the progress of this project through discussions, and gave several presentations on irrigation system design and management to industry stakeholders.
- The industry cooperator (Dr. Russell Smithyman) oversaw the collaborating company's in-kind commitment, ensured that standard viticultural practices were implemented at the field trial sites, and donated the fruit for harvest analysis and winemaking.
- The other cooperator (Dr. James Harbertson) supervised winemaking from the fruit harvested from the selected treatments.

This project does not benefit non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

The main goal of this project was to provide basic information to ultimately develop practical recommendations for irrigation decision-aid tools and irrigation strategy to enhance white wine grape production. Measurable outcomes include: expand acreage for white wine grapes; increase average crop yields of white wine grapes; and improve overall quality of white wine grapes, which will result in an increase in the price paid for grapes. To achieve these goals, outputs generated through this project have been shared with the state's more than 350 wine grape growers through various outlets. These completed activities include:

- In cooperation with the Washington State Wine Commission and the Washington Association of Wine Grape Growers, in addition to using published USDA-NASS data, benchmark data were compiled for 2013: total white wine grape tonnage (103,200 tons); average price of white wine grapes ($852/ton); total acreage of white wine grapes planted (18,851 acres; acreage data were available for 2011).
- The PI presented written and oral project progress reports to the industry advisory committee in Richland, WA (January/February 2014, 2015, 2016).
- The PI and the Postdoctoral Research Associate met several times with the industry cooperator in Prosser, WA, to discuss project progress and requirements, responsibilities, and activities for each growing and harvest season.
- The PI and Co-PIs gave a total of seven invited presentations about wine grape irrigation management at the Annual Meeting of the Washington Association of Wine Grape Growers in Kennewick, WA (February 2014, 2015, 2016).
- The PI gave two invited presentations on wine grape irrigation at the 10th Annual Sustainable Ag Expo in San Luis Obispo, CA (November 2014; beyond Work Plan).
- The Postdoctoral Research Associate presented on a discussion panel on "Early watering in wine grape production" at the Washington State Grape Society Meeting (Grandview, WA) in November 2014 (beyond Work Plan), and presented a poster of preliminary results from this project at the same meeting in November 2015.
- The Postdoctoral Research Associate gave a presentation on irrigation methods in wine grapes at the Grape Fieldmen's Breakfast in Prosser, WA (December 2014).

- The Co-PI gave an invited presentation at the Small Fruits Conference on irrigation management for small fruits in Lynden, WA (December 2014).
- The Co-PI presented a poster on irrigation water management at the Washington State Horticultural Convention in Kennewick, WA (December 2014).
- The PI gave an invited guest lecture on vineyard deficit irrigation at Cornell University, Ithaca, NY (April 2015; beyond Work Plan).
- The Postdoctoral Research Associate gave a poster presentation about this project at the 19th International GiESCO Symposium in Gruissan, France (June 2015; beyond Work Plan).
- The PI and the Postdoctoral Research Associate gave a total of three oral presentations on vineyard irrigation management and current results from this project at the American Society for Enology and Viticulture National Conference (June 2015, 2016).
- The PI and the Postdoctoral Research Associate led tours of the National Grape and Wine Initiative Board of Directors and a group of Argentinian viticulturists and winemakers to one of the trial blocks to showcase this project (July and August 2015; beyond Work Plan).
- The PI gave an invited presentation about fruit ripening and vineyard irrigation at the Southeastern United Grape and Wine Symposium in Dobson, NC (November 2015; beyond Work Plan).
- The PI gave an invited oral presentation about grape ripening and irrigation effects at the Oregon Wine Symposium in Portland, OR (February 2016; beyond Work Plan).
- The PI gave an invited oral presentation about vineyard irrigation at the annual technical retreat of Constellation Brands in Fish Camp, CA (May 2016; beyond Work Plan).
- The Postdoctoral Research Associate gave an oral presentation about grape berry water relations and ripening at the X International Symposium on Grapevine Physiology and Biotechnology in Verona, Italy (June 2016).
- The PI gave an invited oral presentation about WSU irrigation research at the 1st WAVE (Washington Advancements in Viticulture and Enology) event sponsored by the Washington State Wine Commission in Richland, WA (July 2016; beyond Work Plan).
- The PI was interviewed about this project by the following media: New York Times (May 2015), Cherry Creek Radio (January 2016), Western Fruit Grower (April 2016), Great Northwest Wine News (April 2016; beyond Work Plan)

Because changes in irrigation management require time for adoption by growers, the final targets of Expected Measurable Outcomes will be evaluated two years after the end of this project (September 2018). Therefore, besides all the completed activities listed above, future activities that will be performed beyond the Work Plan to achieve these targets include:

- The Postdoctoral Research Associate will present a poster of current results from this project at the annual meetings of the Washington Grape Society in Grandview, WA (November 2016) and the Washington Association of Wine Grape Growers in Kennewick, WA (February 2017).
- The PI will give an invited seminar and invited keynote presentation about grape ripening and irrigation at the University of Bordeaux, France, and the InnoVine Meeting in Toulouse, France (November 2016).
- The PI, Co-PI, and Postdoctoral Research Associate will give presentations of final project results at future meetings of the Washington Grape Society in Grandview, WA (November 2018) and the Washington Association of Wine Grape Growers in Kennewick, WA (February 2019).
- Novel scientific knowledge generated through this project will be published in appropriate peer-reviewed journals. Where applicable, such knowledge will also be integrated into online tools that are available to the public (e.g. irrigation.wsu.edu, weather.wsu.edu).
- Wines from selected irrigation treatments that have been and are being made by the cooperator will be evaluated; knowledge on the impact of irrigation regimes on wine quality will be disseminated to the industry.

Almost all of the activities proposed in the Work Plan have been completed. The two field experiments were completed by the end of the grant agreement. However, because grape harvest occurred in September 2016, wine making, data

compilation, and data analysis will continue beyond the end of the grant period. Therefore, conclusions and recommendations will be finalized after the end of this grant, including integration of the best irrigation strategies into online irrigation decision-aid tools. This additional work will be funded by the Washington State Wine Commission. The only activity in the Work Plan that was not accomplished was the proposed demonstration of the field trial sites during the WSU Viticulture and Enology field day in August 2016, because the organizers decided to focus field day activities in a different grape growing region. To compensate, project results and recommendations have been, and will continue to be, widely disseminated through presentations at the annual meetings of the Washington Association of Wine Grape Growers and the Washington State Grape Society, and through other avenues as described above.

Baseline data were gathered in cooperation with the Washington State Wine Commission and the Washington Association of Wine Grape Growers, and using publicly available data released by USDA-NASS. The initial baseline data for the three Expected Measurable Outcomes in the proposal were:

- White wine grape acreage in 2011: 18,851 acres (total wine grape acreage: 43,849 acres)
- Total white wine grape production in 2011: 78,300 tons (average crop yield: 4.15 tons/acre)
- Average price for white wine grapes in 2012: $844/ton

The measurable outcome targets for this project were to increase (1) acreage by more than 25%; (2) tonnage by 10%; and (3) average price by $50/ton by December 31, 2016. Additional baseline data reported at the beginning of this project were:

- Total white wine grape production in 2013: 103,200 tons
- Average price for white wine grapes in 2013: $852/ton

By the time this final report was due, the 2016 harvest data were not yet available; thus the 2015 production and price data were used here:

- Total white wine grape production in 2015: 109,200 tons
- Average price for white wine grapes in 2015: $844/ton

These benchmark data demonstrate that total white wine grape production (tonnage) increased by 39% from 2011 through 2015, and thus markedly exceeded the proposed target of 10% growth by 2016. The average price for white wine grapes was the same in 2015 as it was in 2012. Thus the targeted $50/ton increase did not materialize. This was mainly due to some oversupply, especially of Riesling and Chardonnay, due to rapid industry expansion. Unfortunately, the latest data on white wine grape acreage are available only for 2011. No data for either 2016 or 2015 are currently available. The USDA-NASS vineyard acreage report for Washington was expected to be published in 2016 (it has been on a 5-year cycle), but has not yet been released. However, industry figures indicate that the total wine grape acreage in 2016 has increased to approximately 55,000 acres, which would be a 25% increase over 2011, consistent with the proposed target.

BENEFICIARIES

The Washington state wine industry stakeholders (both wine grape growers and wine producers) have benefited from the completion of this project. As outlined in the Goals and Outcomes Achieved section of this report above, the outputs generated from this project have been shared widely with most grower and winery stakeholders, which will contribute to the long-term economic and environmental sustainability of the wine industry, and will enhance the industry's competitiveness in both domestic and global markets. Moreover, key findings from this project have already been integrated in the PI's classroom teaching materials in the Washington State University viticulture and enology program. This program currently has 113 enrolled undergraduate students, most of who will embark on careers in the wine industry upon graduation.

At the start of the project, the wine industry in the state of Washington comprised over 350 growers and more than 750 wineries. The number of growers has remained approximately constant or increased slightly, but the number of wineries has grown to more than 900 by 2016. White wine grapes account for about half of the total wine grape production in Washington. As explained in Goals and Outcomes Achieved section of this report, the total white wine grape production has increased by about 31,000 tons or 39% between 2011 (baseline data) and 2015 (one year prior to project completion). Since the average price for white wine grapes has remained constant ($844/ton), the increase in tonnage translates to an increase in farm-gate value of more than $26 million per year. Given that 1 ton of grapes on average produces 756 bottles of wine, and assuming a conservative average bottle price of $10, the increase in white wine grape production translates into additional winery income of over $234 million per year.

LESSONS LEARNED

On the positive side, almost all of the project activities and goals were achieved. The project confirmed the initial hypothesis, namely that applying principles of deficit irrigation developed for red wine grapes to white wine grape production may result in wines that can be overly astringent or even bitter. The solution to this potential problem is also a negative conclusion of the project: minimizing astringency and bitterness in white wines requires an increase in the amount of irrigation water, especially early in the growing season. However, the project also found that implementing the irrigation method of partial rootzone drying, rather than the industry standard of regulated deficit irrigation, might have the potential to achieve the desired fruit composition outcomes without an increase in irrigation water supply. Testing this method was not part of the original project Work Plan, and the results are preliminary. However, these results are encouraging enough to have met with considerable industry interest and to warrant further research.

No unexpected outcomes or results affected the implementation of this project.

All but one of the activities and all goals were achieved (see the Goals and Outcomes Achieved section of report). However, as anticipated at the start of this project, some industry data required to estimate the Expected Measurable Outcomes were not available by the time this final report was submitted. This is partly due to the predetermined grant dates, which do not coincide with the wine industry production cycle. Grape harvest was just winding down by the time this report was submitted. Moreover, the USDA-NASS vineyard acreage report that had been expected for 2016 has yet to be released.

ADDITIONAL INFORMATION

Cash match: $102,000

The Washington Wine Commission, through its Wine Advisory Committee (WAC), provided a cash match of $34,000 per year. These funds were used as follows: salary and benefits for two technicians (1 month/year: $6,500; and 4 months/year: $21,700) and for undergraduate student interns (2 days/week for 3 months/year: $2,360) to help with data collection and harvest; irrigation system maintenance and field and lab supplies ($2,500); travel to field sites (24 trips x 70 miles x $0.56/mile: $940).

In-kind match: $76,204

Ste. Michelle Wine Estates (SMWE) committed two production vineyard blocks to conduct the field trials associated with this project. To facilitate independent control of irrigation applications, SMouradapted their existing irrigation system and dug trenches to lay pipes to each of the two blocks and along the headland of each block. SMWE also donated approximately 0.5 tons of fruit from each block for experimental winemaking in 2014, 2015, and 2016. They estimate their total in-kind contribution to be valued at $39,840 and distributed as follows: irrigation system alteration ($2,500); viticultural management and supervision ($11,450); labor ($14,450); fuel ($640); pesticides ($2,100); fertilizer ($350); fruit value ($8,350).

Washington State University provided $36,364 (20%) of the total requested funds for the unrecovered F&A cost as a cost-share to this project.

Gohil H., M. Keller and M. Moyer. 2016: On-farm vineyard trials: A grower's guide. Washington State University Extension Manual EM098e, 23 pp.

Ruiz Mariño U. 2015: Decision tool comparison based on evapotranspiration, soil, and plant water content to determine vineyard water requirement and improve irrigation strategies for white winegrape production. MS thesis, Geisenheim University, Germany (co-advisor: M. Keller).

Rochi L. 2015: Physiological responses of white grape berries to sunlight exposure. PhD thesis, University of Milan, Italy (co-advisor: M. Keller).

Zhang Y. and M. Keller. 2015: Irrigation scheduling and management for white wine grape production. Proc. 19th International Symposium GiESCO, Gruissan, France. Publications et Actualités Vitivinicoles. pp. 154-158.

Table 1. Description of irrigation treatments implemented in 2014, 2015, and 2016.

Phenology		Before budbreak	Budbreak to fruit set	Fruit set to veraison	Veraison to harvest	After harvest
Treat-ment	T0	Replenish soil water content when necessary	Irrigate to replace 100% crop evapotranspiration (ET-based approach)			Replenish soil water content
	T1		Irrigate to maintain soil water content ≥16% (soil-based approach)			
	T2		Irrigate to maintain stem water potential ≥-0.7 MPa (plant-based approach)			
	T3		Moderate stress [a]	Moderate stress	Moderate stress	
	T4		Moderate stress	Moderate stress	No stress [b]	
	T5		No stress	Moderate stress	No stress	
	T6		Partial rootzone drying [c]			

[a] For moderate stress, soil water content was between 12% and 16% (v/v), and stem water potential was between -1 MPa and -0.7 MPa.
[b] For no stress, soil water content and stem water potential were equal to or higher than 16% and -0.7 MPa, respectively.
[c] Irrigation was alternated when soil water content of drying side was equal to or less than 12%.

Table 2. Soil water content (θ_v), stem water potential (Ψ_s), and leaf gas exchange (A, photosynthetic rate; g_s, stomatal conductance, E, transpiration rate) by treatment for Chardonnay in 2014, 2015, and 2016. Treatments are described in Table 1. Different letters within rows indicate significant differences by Fisher's LSD test ($P < 0.05$). Rows without letters indicate no significant difference.

Parameter	Irrigation treatment						
	T0	T1	T2	T3	T4	T5	T6
2014							
θ_v (% v/v) (before fruit set)	17.4	16.9	16.8	16.5	16.9	17.9	17.5
(fruit set – veraison)	16.6 a	13.9 b	12.8 c	11.5 d	11.0 d	11.6 d	12.9 c
(veraison – harvest)	16.6 a	15.3 a	12.5 b	11.3 b	15.3 a	15.8 a	12.1 b
Ψ_s (MPa) (fruit set – veraison)	-0.5 a	-0.8 b	-0.8 b	-1.1 c	-1.1 c	-1.2 c	-0.9 b
(veraison – harvest)	-0.4 a	-0.5 a	-0.7 b	-1.0 c	-0.6 b	-0.7 b	-0.9 c
Preveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	14.5 a	14.4 a	12.4 ab	8.8 d	9.7 cd	9.8 cd	11.6 bc
g_s (mmol $m^{-2}s^{-1}$)	187 a	185 a	108 b	103 b	95 b	95 b	110 b
E (mmol $m^{-2}s^{-1}$)	4.7 a	4.6 a	3.3 b	2.8 b	2.8 b	2.8 b	3.2 b
Postveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	9.2 b	10.1 ab	9.0 b	13.3 a	10.7 ab	10.7 ab	9.5 b
g_s (mmol $m^{-2}s^{-1}$)	170 ab	150 ab	158 ab	208 a	150 ab	147 ab	143 b
E (mmol $m^{-2}s^{-1}$)	3.2	2.9	2.9	3.5	2.9	2.7	2.9
2015							
θ_v (% v/v) (before fruit set)	16.6 a	16.5 a	16.6 a	15.3 b	15.3 b	17.1 a	16.9 a
(fruit set – veraison)	13.8 a	14.1 a	13.5 a	11.0 c	10.7 c	11.4 c	12.2 b
(veraison – harvest)	12.7 b	13.7 ab	13.3 ab	11.0 c	14.9 a	14.9 a	12.2 bc
Ψ_s (MPa) (fruit set – veraison)	-0.9 b	-0.8 a	-0.9 b	-1.2 d	-1.3 d	-1.2 d	-1.1 c
(veraison – harvest)	-0.9 a	-0.9 a	-0.9 a	-1.3 c	-1.0 a	-1.0 a	-1.2 b
Preveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	12.8 b	14.0 a	13.4 ab	10.1 d	10.8 cd	11.1 cd	11.4 c
g_s (mmol $m^{-2}s^{-1}$)	255 a	275 a	263 a	157 b	190 b	190 b	195 b
E (mmol $m^{-2}s^{-1}$)	6.8 a	6.8 a	6.8 a	4.9 c	5.7 bc	5.7 bc	6.0 ab
Postveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	16.6 a	15.3 ab	16.4 a	12.2 c	14.8 abc	13.4 bc	15.0 ab
g_s (mmol $m^{-2}s^{-1}$)	248 a	230 a	263 a	145 c	193 b	180 b	216 b

E (mmol $m^{-2}s^{-1}$)	6.6 a	6.4 a	7.0 a	5.1 c	5.7 b	5.6 b	6.2 ab
2016							
θ_v (% v/v) (before fruit set)	15.5 b	17.0 a	16.7 ab	14.9 c	15.0 c	16.7 a	17.6 a
(fruit set – veraison)	16.2 a	14.9 b	15.0 b	12.4 d	12.0 d	13.1 cd	13.8 c
(veraison – harvest)	16.6 a	13.9 b	14.1 b	12.3 c	15.2 ab	15.0 ab	13.9 b
Ψ_s (MPa) (fruit set – veraison)	-0.7 a	-0.7 a	-0.7 a	-0.9 c	-0.9 c	-0.9 c	-0.8 b
(veraison – harvest)	-0.4 a	-0.6 b	-0.7 b	-0.9 d	-0.6 b	-0.6 b	-0.8 c
Preveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	17.4 a	16.1 a	16.7 a	13.6 b	16.4 a	13.7 b	15.9 a
g_s (mmol $m^{-2}s^{-1}$)	294 a	268 ab	278 a	179 d	222 c	177 d	237 bc
E (mmol $m^{-2}s^{-1}$)	6.9 a	6.6 a	6.7 a	5.1 b	6.0 ab	5.1 b	6.0 ab
Postveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	14.6 ab	15.2 ab	16.3 a	12.4 b	14.1 ab	13.7 ab	14.5 ab
g_s (mmol $m^{-2}s^{-1}$)	288 a	263 ab	270 ab	193 c	230 bc	225 bc	238 abc
E (mmol $m^{-2}s^{-1}$)	10.7 a	9.9 ab	9.6 ab	9.0 b	9.3 ab	9.0 b	9.6 ab

Table 3. Soil water content (θ_v), stem water potential (Ψ_s), and leaf gas exchange (A, photosynthetic rate; g_s, stomatal conductance, E, transpiration rate) by treatment for Riesling in 2014, 2015, and 2016. Treatments are described in Table 1. Different letters within rows indicate significant differences by Fisher's LSD test ($P < 0.05$). Rows without letters indicate no significant difference.

Parameter	**Irrigation treatment**						
	T0	T1	T2	T3	T4	T5	T6
2014							
θ_v (% v/v) (before fruit set)	21.5 b	18.8 c	21.1 b	20.6 bc	20.0 bc	23.8 a	19.2 c
(fruit set – veraison)	23.3 a	16.3 b	14.8 bc	14.2 cd	12.8 d	13.2 d	14.7 c
(veraison – harvest)	20.3 a	16.6 b	14.0 cd	12.5 d	16.2 b	15.4 b	14.0 cd
Ψ_s (MPa) (fruit set – veraison)	-0.4 a	-0.7 b	-0.7 b	-0.7 b	-0.8 c	-0.9 c	-0.8 c
(veraison – harvest)	-0.4 a	-0.5 a	-0.7 b	-1.0 c	-0.7 b	-0.7 b	-0.8 b
Preveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	18.6 a	16.0 ab	15.7 ab	16.8 ab	14.3 b	15.5 ab	16.8 ab
g_s (mmol $m^{-2}s^{-1}$)	220 a	165 bc	170 bc	195 ab	138 c	170 bc	188 ab
E (mmol $m^{-2}s^{-1}$)	5.7	4.6	5.1	5.2	4.4	5.2	4.9
Postveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	16.8 a	17.0 a	17.9 a	16.7 a	15.5 ab	13.3 b	15.8 ab
g_s (mmol $m^{-2}s^{-1}$)	303 a	250 bc	270 ab	255 bc	200 d	190 d	228 cd
E (mmol $m^{-2}s^{-1}$)	4.3 a	3.9 ab	4.1 a	4.0 ab	3.7 ab	3.0 b	3.6 ab
2015							
θ_v (% v/v) (before fruit set)	18.9 a	18.0 b	18.2 ab	16.2 c	16.9 c	18.1 ab	18.0 b
(fruit set – veraison)	18.0 a	15.4 b	15.6 b	13.4 c	13.5 c	13.4 c	14.2 c
(veraison – harvest)	16.6 a	15.8 a	14.7 ab	12.2 c	15.4 ab	14.8 ab	13.7 bc
Ψ_s (MPa) (fruit set – veraison)	-0.5 a	-0.7 b	-0.7 b	-0.9 c	-1.0 c	-0.8 c	-0.9 c
(veraison – harvest)	-0.6 a	-0.6 ab	-0.7 b	-1.0 c	-0.7 b	-0.6 ab	-0.9 c
Preveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	21.9 a	19.6 ab	20.3 ab	17.5 b	19.0 ab	19.4 ab	14.7 c
g_s (mmol $m^{-2}s^{-1}$)	298 a	233 b	248 ab	173 c	195 bc	205 bc	123 d
E (mmol $m^{-2}s^{-1}$)	7.0 a	5.7 bc	6.0 ab	5.0 c	5.4 bc	5.4 bc	3.9 d
Postveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	13.1 ab	15.3 a	14.8 a	11.5 b	15.0 a	13.8 ab	14.0 ab
g_s (mmol $m^{-2}s^{-1}$)	157 b	220 a	187 ab	130 c	203 ab	190 ab	173 ab
E (mmol $m^{-2}s^{-1}$)	4.1 a	4.7 a	4.5 a	3.3 b	4.5 a	4.4 a	4.2 a
2016							
θ_v (% v/v) (before fruit set)	16.9	17.4	17.3	16.6	16.8	17.1	17.1
(fruit set – veraison)	18.1 a	16.4 b	16.1 b	14.2 d	14.0 d	13.7 d	14.8 c
(veraison – harvest)	20.1 a	15.9 b	16.0 b	13.1 c	16.0 b	15.8 b	14.0 c
Ψ_s (MPa) (fruit set – veraison)	-0.5 a	-0.6 b	-0.6 b	-0.7 c	-0.7 c	-0.7 c	-0.7 c
(veraison – harvest)	-0.5 a	-0.6 b	-0.6 b	-0.8 c	-0.6 b	-0.6 b	-0.8 c
Preveraison gas exchange							

A (µmol $m^{-2}s^{-1}$)	17.4 a	16.7 a	17.2 a	16.3 a	14.8 b	16.3 a	16.1 ab
g_s (mmol $m^{-2}s^{-1}$)	263 a	223 ab	223 ab	195 b	180 b	198 b	195 b
E (mmol $m^{-2}s^{-1}$)	8.4 a	7.5 ab	7.7 ab	7.2 b	7.0 b	7.2 b	7.1 b
Postveraison gas exchange							
A (µmol $m^{-2}s^{-1}$)	14.5 a	14.2 a	14.4 a	11.2 b	13.9 a	13.7 a	13.1 ab
g_s (mmol $m^{-2}s^{-1}$)	220 a	222 a	198 a	143 b	198 a	200 a	185 a
E (mmol $m^{-2}s^{-1}$)	10.0 a	10.1 a	9.6 a	7.7 b	9.8 a	9.5 a	9.2 ab

Table 4. Canopy growth and density by treatment for Chardonnay in 2014, 2015, and 2016. Treatments are described in Table 1. Different letters within rows indicate significant differences by Fisher's LSD test ($P < 0.05$). Rows without letters indicate no significant difference.

Parameter	Irrigation treatment						
	T0	T1	T2	T3	T4	T5	T6
2014							
Leaf layers (veraison)	4.2 a	3.3 b	3.2 b	2.1 d	1.9 d	1.7 d	2.7 c
(harvest)	5.1 a	4.3 b	4.5 b	3.2 d	3.3 d	3.0 d	3.8 c
Fruit zone light (veraison, % ambient)	24 d	29 cd	31 bc	32 bc	34 ab	38 a	33 bc
(harvest, % ambient)	22 c	28 b	26 bc	31 ab	30 ab	35 a	28 b
Vigor (fruit set – harvest, mm d^{-1})	1.5 a	1.5 a	1.0 ab	1.0 ab	1.0 ab	0.6 b	1.3 a
Internode length (harvest, cm)	4.5	4.5	4.3	4.4	4.6	4.2	4.5
Lateral leaves per shoot (harvest)	2.9 a	2.1 b	1.4 c	1.5 c	1.6 c	1.5 c	1.6 c
Brown nodes per shoot (harvest)	10.4 ab	11.7 a	9.7 abc	8.3 bc	9.6 abc	7.2 c	10.1 ab
2015							
Leaf layers (veraison)	4.4 a	4.2 a	4.6 a	2.6 c	3.2 b	3.2 b	3.4 b
(harvest)	4.7 a	4.6 a	4.6 a	3.3 d	4.0 b	3.7 b	4.0 b
Fruit zone light (veraison, % ambient)	38 c	32 d	36 cd	47 a	47 a	44 ab	40 bc
(harvest, % ambient)	36 cd	34 d	34 d	45 a	45 a	42 ab	39 bc
Vigor (fruit set – harvest, mm d^{-1})	0.5 a	0.3 a	0.4 a	0.0 b	0.0 b	0.0 b	0.4 a
Internode length (harvest, cm)	4.5	4.5	4.4	4.2	4.3	4.1	4.4
Lateral leaves per shoot (harvest)	2.0	2.0	2.0	1.9	2.0	2.0	2.1
Brown nodes per shoot (harvest)	14 a	14 a	15 a	11 c	11 c	11 c	13 bc
2016							
Leaf layers (veraison)	3.9 b	4.7 a	4.8 a	2.9 e	3.5 cd	3.4 d	3.8 bc
(harvest)	4.5 bc	4.8 b	5.4 a	3.6 e	3.8 d	3.8 d	4.3 c
Fruit zone light (veraison, % ambient)	31 cd	21 e	26 de	39 a	36 abc	38 ab	33 bc
(harvest, % ambient)	25 cd	20 d	24 cd	34 a	31 ab	34 a	28 bc
Vigor (fruit set – harvest, mm d^{-1})	2.1 ab	3.0 a	2.2 ab	0.7 c	0.9 c	1.4 bc	2.5 ab
Internode length (harvest, cm)	4.3	4.6	4.3	4.5	4.5	4.6	4.7
Lateral leaves per shoot (harvest)	2.05 ab	2.18 a	2.06 ab	1.69 b	1.83 ab	2.02 ab	1.90 ab
Brown nodes per shoot (harvest)	15.8 abc	17.2 a	16.7 ab	13.5 c	14.2 bc	16.2 ab	16.4 ab

Table 5. Canopy growth and density by treatment for Riesling in 2014, 2015, and 2016. Treatments are described in Table 1. Different letters within rows indicate significant differences by Fisher's LSD test ($P < 0.05$). Rows without letters indicate no significant difference.

Parameter	Irrigation treatment						
	T0	T1	T2	T3	T4	T5	T6
2014							
Leaf layers (veraison)	4.6 a	3.1 b	3.1 b	2.7 c	2.4 c	2.7 c	2.8 bc
(harvest)	3.8 a	2.8 b	3.3 ab	2.9 b	2.9 b	3.0 b	2.9 b
Fruit zone light (veraison, % ambient)	30 c	49 a	44 ab	43 b	48 a	45 ab	45 b
(harvest, % ambient)	21 b	42 a	37 a	38 a	41 a	37 a	42 a
Vigor (fruit set – harvest, mm d^{-1})	4.2 a	1.4 b	1.7 b	1.9 b	1.4 b	1.4 b	1.4 b
Internode length (harvest, cm)	3.9	4.0	4.0	3.8	4.1	3.7	3.9
Lateral leaves per shoot (harvest)	2.0 a	1.7 b	1.7 ab	1.8 ab	1.8 ab	1.6 b	1.7 ab
Brown nodes per shoot (harvest)	11.4	9.9	10.8	12	10.7	10.5	11
2015							
Leaf layers (veraison)	5.6 a	4.6 b	4.7 b	3.5 d	3.8 cd	3.7 cd	4.0 c
(harvest)	5.0 a	4.6 b	4.4 b	3.5 d	3.8 cd	4.0 c	3.8 cd
Fruit zone light (veraison, % ambient)	35 c	58 ab	53 b	62 a	57 ab	56 b	56 b
(harvest, % ambient)	32 b	50 a	45 a	46 a	50 a	50 a	49 a
Vigor (fruit set – harvest, mm d^{-1})	3.0 a	0.6 b	1.0 b	0.4 b	0.5 b	0.4 b	0.5 b
Internode length (harvest, cm)	3.8	3.6	3.7	3.6	3.8	3.7	3.9
Lateral leaves per shoot (harvest)	2.2 a	1.6 b	1.9 ab	1.6 b	1.5 b	1.6 b	2.0 a

Brown nodes per shoot (harvest)	15 a	11 b	11 b	10 b	11 b	11 b	12 b
2016							
Leaf layers (veraison)	5.2 a	4.6 b	4.4 b	3.4 d	3.7 cd	3.9 c	4.4 b
(harvest)	5.1 a	4.2 bc	4.4 b	3.4 d	4.0 c	4.0 c	4.0 c
Fruit zone light (veraison, % ambient)	32 d	41 bc	37 c	44 ab	41 bc	47 a	44 ab
(harvest, % ambient)	32 b	37 ab	33 b	41 a	42 a	42 a	42 a
Vigor (fruit set – harvest, mm d^{-1})	1.5 a	0.7 bcd	1.0 b	0.4 cd	0.2 d	0.3 cd	0.7 bc
Internode length (harvest, cm)	3.8	3.9	3.8	3.9	3.7	3.8	3.8
Lateral leaves per shoot (harvest)	2.4 a	2.1 abc	2.2 ab	1.9 bc	1.8 c	1.9 bc	2.1 abc
Brown nodes per shoot (harvest)	15	13	15	12	13	14	13

Table 6. Yield components and fruit composition at harvest by treatment for Chardonnay in 2014, 2015, and 2016. Treatments are described in Table 1. Different letters within rows indicate significant differences by Fisher's LSD test ($P < 0.05$). Rows without letters indicate no significant difference.

Parameter	**Irrigation treatment**						
	T0	T1	T2	T3	T4	T5	T6
2014							
Yield (tons/acre)	7.5 a	7.2 ab	6.4 b	5.1 c	5.1 c	4.8 c	6.5 b
Berry weight (g)	1.44 a	1.37 b	1.30 c	1.2 e	1.04 f	1.04 f	1.24 d
Cluster weight (g)	112 a	111 a	106 a	85 bc	79 cd	73 d	95 b
Clusters per vine	76 ab	73 ab	68 b	69 ab	74 ab	75 ab	80 a
Fruit composition (harvest)							
TSS (Brix)	22.1	22.1	22.6	22.8	22.5	23.2	22.5
pH	3.44 ab	3.45 ab	3.45 ab	3.50 a	3.39 b	3.43 ab	3.49 ab
TA (g/L)	5.78 ab	5.84 a	5.44 bc	4.73 d	5.06 cd	4.87 d	4.94 d
2015							
Yield (tons/acre)	3.0 bc	4.5 a	3.6 b	2.0 d	1.9 d	2.4 d	2.7 c
Berry weight (g)	1.5 a	1.5 a	1.4 a	1.0 d	1.1 c	1.2 b	1.2 b
Cluster weight (g)	132 a	140 a	126 a	86 d	95 cd	116 b	102 b
Clusters per vine	26 cd	37 a	32 ab	27 bcd	22 d	24 d	31 bc
Fruit composition (harvest)							
TSS (Brix)	24.0 ab	24.2 ab	23.8 b	24.3 ab	23.9 b	24.3 ab	24.8 a
pH	3.85 bc	3.78 cd	3.75 d	3.97 a	3.97 a	3.89 ab	3.94 ab
TA (g/L)	4.1 a	4.4 a	4.5 a	3.3 b	3.4 b	3.7 b	3.3 b
2016							
Yield (tons/acre)	8.2 b	10.5 a	9.2 b	5.7 d	6.8 cd	5.8 cd	6.9 c
Berry weight (g)	1.74 a	1.66 ab	1.66 ab	1.31 e	1.47 cd	1.37 de	1.53 bc
Cluster weight (g)	171 b	189 a	179 ab	137 c	141 c	139 c	133 c
Clusters per vine	55 bc	63 a	59 ab	47 c	54 bc	47 c	59 ab
Fruit composition (harvest)							
TSS (Brix)	21.7 c	21.7 c	21.8 bc	22.7 ab	22.4 abc	23.1 a	22.1 bc
pH	3.64 bc	3.58 c	3.60 c	3.79 a	3.70 ab	3.76 a	3.64 bc
TA (g/L)	5.4 a	5.1 a	5.3 a	4.1 c	4.4 bc	4.3 c	4.9 ab

Table 7. Yield components and fruit composition at harvest by treatment for Riesling in 2014, 2015, and 2016. Treatments are described in Table 1. Different letters within rows indicate significant differences by Fisher's LSD test ($P < 0.05$). Rows without letters indicate no significant difference.

Parameter	**Irrigation treatment**						
	T0	T1	T2	T3	T4	T5	T6
2014							
Yield (tons/acre)	8.7 a	6.6 b	6.9 b	6.6 b	6.7 b	6.8 b	7.2 b
Berry weight (g)	1.47 a	1.30 c	1.31 c	1.31 c	1.24 d	1.24 d	1.36 b
Cluster weight (g)	108 a	79 c	109 a	102 ab	92 b	93 b	92 b
Clusters per vine	83 ab	86 a	65 c	66 c	75 abc	74 bc	80 ab
Fruit composition (harvest)							

TSS (Brix)	19.8	20.8	20.4	20.6	19.9	19.7	20.4
pH	3.14 ab	3.15 a	3.06 d	3.14 ab	3.10 bcd	3.07 cd	3.12 abc
TA (g/L)	7.6 a	6.7 bcd	7.1 ab	6.6 bcd	6.4 cd	6.9 bc	6.3 d
2015							
Yield (tons/acre)	7.5 a	4.8 bc	5.4 b	4.9 bc	4.6 bc	5.2 b	4.1 c
Berry weight (g)	1.3 a	1.2 c	1.3 b	1.0 e	1.0 e	1.1 d	1.1 d
Cluster weight (g)	116 a	79 c	92 b	79 cd	69 d	80 c	77 cd
Clusters per vine	66 ab	62 abc	60 bc	64 abc	69 a	67 ab	55 c
Fruit composition (harvest)							
TSS (Brix)	20.2	20.8	20.7	20.5	20.6	20.7	20.3
pH	3.42 ab	3.37 ab	3.45 b	3.32 a	3.42 ab	3.44 ab	3.35 ab
TA (g/L)	4.6 a	4.5 ab	4.1 b	4.2 ab	4.2 ab	4.4 ab	4.3 ab
2016							
Yield (tons/acre)	9.5 a	8.1 b	8.0 b	6.9 c	6.2 c	6.1 c	7.4 b
Berry weight (g)	1.32 a	1.21 ab	1.29 a	1.05 c	1.05 c	1.12 bc	1.21 ab
Cluster weight (g)	124 a	103 bc	106 b	94 bcd	86 d	93 cd	97 bcd
Clusters per vine	82 a	78 a	76 a	76 a	75 ab	67 b	78 a
Fruit composition (harvest)							
TSS (Brix)	20.3 a	19.2 c	20.3 a	19.4 bc	19.8 abc	20.1 ab	19.1 c
pH	3.30 a	3.20 b	3.26 ab	3.29 a	3.27 ab	3.29 a	3.22 ab
TA (g/L)	6.3 a	5.9 ab	5.6 bc	5.6 bc	5.6 bc	5.2 c	5.7 bc

Table 8. Annual amounts of irrigation water applied by treatment for Chardonnay and Riesling in 2014, 2015, and 2016. Treatments are described in Table 1.

Cultivar	**Year**	**Irrigation water (mm)**						
		T0	T1	T2	T3	T4	T5	T6
Chardonnay	**2014**	396	347	293	208	205	181	169
	2015	383	425	414	255	268	282	243
	2016	451	473	496	294	324	320	346
Riesling	**2014**	381	196	159	124	146	147	129
	2015	341	238	201	161	166	215	185
	2016	381	270	254	193	203	247	223

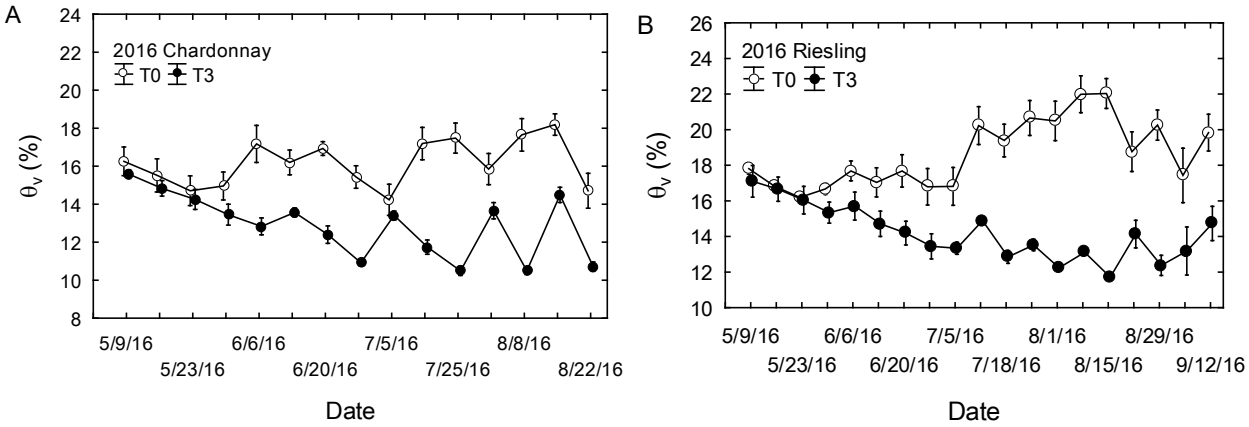

Figure 1. Examples of changes in soil moisture (θ_v) during the growing season for the two most extreme treatments (T0 and T3) in Chardonnay (A) and Riesling (B) in 2016.

CONTACT INFORMATION

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PROJECT #13

Project Title: Containing an Emerging Virus Disease Threatening Washington Vineyards

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

Virus diseases are recognized as one of the most serious impediments to the long-term sustainability of Washington's grape and wine industry (*Vinewise* [http://www.vinewise.org/] and *The Pest Management Strategic Plan for Washington State Wine Grape Production* [http://www.ipmcenters.org/pmsp/pdf/WA_WineGrape_PMSP_2014.pdf]). Viruses are known to induce a wide range of disorders, vine growth problems, graft incompatibility, reduced yield, delayed fruit maturity and poor quality of grapes. An industry-wide survey of stakeholders has identified management of viruses impacting fruit quality and vine health as one the highest research priorities for winemakers and wine grape growers (http://www.goodfruit.com/wine-grape-revelations/). A recent study (project #K952 funded by the SCBGP) on economic impacts of grapevine leafroll disease in a commercial Merlot vineyard, for example, indicated that a grower can lose up to $20,000 per acre over the 20-year period depending on the quantity of yield reduction and the scale of decline in fruit quality (*Is 'Grape Virus Tax' Hitting Your Pocketbook?* [http://www.goodfruit.com/is-grape-virus-tax-hitting-your-pocketbook/]).

A new graft-transmissible disease, designated as grapevine red blotch disease (GRBD), has been emerging as a serious threat to Washington's grape and wine industry (http://www.goodfruit.com/new-grape-disease-reduces-yields-quality/). A new virus with single-stranded DNA genome, designated as Grapevine red blotch-associated virus (GRBaV), was identified in grapevines (*Vitis vinifera* L.) showing red blotch symptoms. Previous studies have indicated significant negative impacts of GRBD on vine health, fruit yield and berry quality attributes in own-rooted wine grape cultivars Merlot and Cabernet Franc under commercial growing conditions. Preliminary surveys conducted during the 2013 season by Rayapati's team have shown that GRBD was present in other red-berried varieties, in addition to Merlot and Cabernet franc. However, the occurrence of GRBD and its effects on white grape varieties is unknown. Since symptoms of GRBD in red-berried cultivars overlap to a great extent under field conditions with those produced by grapevine leafroll disease (GLD), which is caused by grapevine leafroll-associated viruses that are distinct from GRBaV, growers had faced challenges in differentiating GRBD from GLD based on symptoms under field conditions. Thus, there is a critical need to generate science-based information about red blotch for practical applications in Washington vineyards.

Previous to the commencement of this project, no information was available on the prevalence of grapevine red blotch disease in Washington vineyards. Therefore, this project was initiated to (i) document the distribution of GRBD, relative to GLD, in Washington vineyards and (ii) measure impacts of the disease on fruit yield and berry quality in wine grape cultivars. In addition, the project was aimed at (i) disseminating science-based information through a variety of education and outreach programs for increased awareness of GRBD among growers and nurseries and (ii) strengthening grapevine clean plant and certification programs to facilitate the availability of virus-tested planting materials for growers. In the long term, the project outcomes are expected to foster sustainable growth of Washington's grape and wine industry that had an estimated $4.8 billion impact on Washington State's economy in 2013.

This project began in October 2013 and was not supported previously by the WSDA SCBGP. Activities of this project were carried out synergistically with research activities funded, in part, by other resources (the WSU Agricultural Research Center, the Wine Research Advisory Committee, the Washington Wine Commission, the Washington State Grape and Wine Research Program, WSDA Specialty Crop Block Grant Program, WSDA Grapevine Certification and Nursery Improvement Program, Washington State Commission on Pesticide Registration) for efficiency and effectiveness.

PROJECT APPROACH

The overall goal of the project was to document the distribution of GRBD in Washington using reliable diagnostic methods and assess impacts of the disease on fruit yield and berry quality in wine grape cultivars. Using the research-based knowledge generated during the project period, outreach and educational activities were conducted for increased awareness of GRBD among stakeholders and regulatory agencies to implement effective strategies for preventing the spread of this emerging disease.

- **Document the extent of distribution of grapevine red blotch disease in Washington vineyards.**

Activity: Test samples for the grapevine red blotch virus (geminivirus) and other grapevine viruses by high throughput molecular diagnostic methods.

During the project period covering 2014, 2015, and 2016 crop seasons, a total of 2,141 samples from 20 red- and 6 white-fruited wine grape (Vitis vinifera) cultivars were collected. These samples were collected in vineyard blocks planted in Yakima Valley, Horse Heaven Hills, Red Mountain and Walla Walla appellations. Names of appellations and grower vineyards were withheld from this report due to grower confidentiality. Leaf samples were collected from red-fruited cultivars exhibiting symptoms of GRBD and GLD symptoms and suspected for these two diseases. In the case of white-fruited cultivars, samples were collected randomly due to the lack of visible symptoms. In addition, growers have sent samples suspected for leaf roll or red blotch symptoms. These samples were extracted and tested by molecular diagnostic methods for the presence of Grapevine red blotch-associated virus (GRBaV) and grapevine leafroll-associated virus-3 (GLRaV-3). Virus-specific DNA fragments amplified in PCR assays from representative samples were cloned and nucleotide sequence determined. The sequences were analyzed using bioinformatics software programs to validate PCR results and confirm the presence of GRBaV and GLRaV-3 in grapevine samples.

Of the 2,141 samples tested, nearly 66.83% were positive for GLRaV-3 and 6% positive for GRBaV. Interestingly, about 8.73% of samples tested positive for both viruses. In contrast, nearly 18.4% were tested negative for both viruses. Some of these negative samples were tested positive for other grapevine viruses, such as GLRaV-4. It is likely that many of the samples tested negative could be showing 'symptoms' mimicking GRBD or GLD due to abiotic factors, such as nutrient deficiency, mechanical damage, mite feeding damage, etc. Nevertheless, the cumulative data over three seasons indicated that GLRaV-3 is the most predominant and wide spread compared to GRBaV. The results further indicated the presence of GLRaV-3 and GRBaV as mixed infections in some samples. The survey also revealed that symptoms of GLD and GRBD appear around véraison and are highly similar, though not identical, in red grape cultivars. Similar to GLD, white grape cultivars showed no apparent symptoms of GRBD. Consequently, symptoms of GRBD can easily be confused with GLD and virus-specific diagnostic assays are necessary for reliable diagnosis of these two disparate virus diseases under field conditions.

Activity: Conduct molecular analyses for confirmation of viruses associated with red blotch disease and improve sensitivity and specificity of diagnostic methods by real-time, quantitative PCR technology.

Multiplex detection of viruses: As stated above, visual diagnosis of GRBD and GLD in vineyards has become very difficult due to similar, though not identical, symptoms in many red-grape cultivars. Therefore, PCR-based diagnostic assays were used to test samples from individual vines to document whether a symptomatic vine is infected with GRBaV or GLRaV-3. Initially, individual samples were tested in separate molecular diagnostic assays for the presence of GRBaV (by PCR) and GLRaV-3 (by RT-PCR). To circumvent this time-consuming process, multiplex PCR assay, where samples from each symptomatic vine can be tested simultaneously for both viruses, was optimized to distinguish red blotch from leafroll. In 2016, this assay was further refined using 206 samples from seven red wine grape cultivars showing or suspected for GRBD and GLD symptoms. The results were compared with data from monoplex-PCR assay, where the same set of samples were tested for GLRaV-3 and GRBaV in separate assays. The data indicated 90.74 percent correlation between results obtained from monoplex- and multiplex-PCR assays. Additional studies are being pursued to further refine the multiplex-PCR assay (i.e. to achieve greater than 90% confidence levels) for detecting GLRaV-3 and GRBaV in single and co-infections. The multiplex PCR assay is expected to offer cheaper, faster, and reliable diagnostic services for nurseries to maintain virus-free vines in registered mother blocks and grape growers to establish new vineyards with 'clean' planting stock.

Genetic makeup of the virus associated with grapevine red blotch disease: Molecular analysis of the genome of GRBaV was carried out to gain a comprehensive understanding of the genetic makeup of the virus in Washington vineyards. Samples tested positive for GRBaV were selected from 15 wine grape cultivars and the entire genomic DNA of the virus was amplified by Rolling Circle Amplification and PCR. The DNA amplified from each cultivar was cloned separately and the nucleotide sequence determined. The derived nucleotide sequences were analyzed using bioinformatics software programs. The results indicated clustering of complete genome sequences of 36 virus isolates from Washington vineyards into two

distinct groups, independent of cultivar and geographic location. Of the 36 sequences, 31 sequences obtained from the majority of wine grape cultivars clustered into one group and the other 5 into a second group. Further analyses of GRBaV sequences is in progress to better understand their phylogenetic relationships with corresponding viral sequences from other grapevine-growing regions in the United States.

- **Document impacts of grapevine red blotch disease.**

During the project period covering 2014, 2015, and 2016 crop seasons, three red grape cultivars (Merlot, Syrah and Cabernet Sauvignon) planted in geographically separate grower vineyards were identified to assess impacts of GRBD on fruit yield and quality. For this purpose, grapevines with and without GRBD symptoms were tested for the presence of GRBaV and GLRaV-3 to ensure that vines with symptoms are positive for GRBaV and vines without symptoms are negative for both viruses. Subsequently, 15 to 20 vines with GRBD symptoms and equal number of disease-free vines were selected for each cultivar. To the extent possible, the same set of vines were used in all three seasons. Total fruit yield was collected from individual vines at the time of commercial harvest in September/October of 2014, 2015, and 2016. For measuring fruit quality, berries were collected randomly from five GRBD-affected and five disease-free vines and extracts used to measure total soluble solids (or sugars measured as °Brix), juice pH, titratable acidity and anthocyanin content of berries (a measure of berry color in red grape varieties). The data was analyzed by Student's t-test for significant differences between healthy and GRBD-affected vines.

A summary of the results are presented below:

- **Merlot**: In GRBD-affected vines, fruit yield per vine was reduced by 25.0%, 21.8%, and 9.53% in 2014, 2015, and 2016 seasons, respectively, compared to disease-free vines. Total soluble solids showed 11.90%, 10.03%, and 8.63% reduction in berries of GRBD-affected vines, respectively, in 2014, 2015, and 2016 seasons compared to berries from disease-free vines. There was no consistent difference in juice pH, titratable acidity and berry anthocyanins between GRBD-affected and disease-free vines across the three seasons.
- **Cabernet Sauvignon**: Fruit yield was reduced by 30.52% and 23.14% in GRBD-affected vines during 2015 and 2016 seasons, respectively, compared to disease-free vines (data was not collected during 2014 season). Total soluble solids showed 13.3% and 4.21% reduction in berries of GRBD-affected vines during 2015 and 2016 seasons, respectively, compared to disease-free vines. There was no consistent difference in juice pH, titratable acidity and berry anthocyanins between GRBD-affected and disease-free vines during the two seasons.
- **Syrah**: Fruit yield was reduced by 51.6%, 32.31%, and 52.9% during 2014, 2015, and 2016 seasons, respectively, in GRBD-affected vines compared to disease-free vines. Interestingly, no significant differences were observed in total soluble solids and berry anthocyanins between GRBD-affected and disease-free vines. In all three years, the pH of berry juice from GRBD-affected vines was higher by 3.58%, 8.86%, and 8.68% in 2014, 2015, and 2016 seasons, respectively, compared to pH of berry juice from disease-free vines.

The following conclusions were made based on the above results obtained during three consecutive seasons:

GRBD significantly affected fruit yield in all three red grape cultivars studied during this project period. However, the impact of GRBD on berry quality attributes was found to be variable between the three varieties. Total soluble solids were affected in berries of GRBD-affected Merlot and Cabernet Sauvignon vines. In contrast, no impact of GRBD was observed on total soluble solids in Syrah vines. The berry juice pH was higher in GRBD-affected Syrah vines, whereas no difference was observed in berry juice pH between GRBD-affected and disease-free Merlot and Cabernet Sauvignon vines. Berry skin anthocyanin content measured at the time of commercial harvest between GRBD-affected and disease-free vines showed no consistent pattern across the three seasons in Merlot, Cabernet Sauvignon and Syrah. These results suggest varying responses of red grape cultivars to infection with GRBD.

- **Conduct educational and outreach activities for increased awareness of grapevine red blotch disease among growers, nurseries, regulatory agencies and scientific community.**

The following presentations were made at grape and wine industry stakeholder meetings, workshops and professional scientific meetings to disseminate science-based information on viral diseases, with emphasis on grapevine red blotch disease:

Note: Naidu, R.A. and Naidu Rayapati are the same person, PI of this project.

2016:

i. Naidu, R.A. 2016. An overview of virus diseases in Washington vineyards. Washington State Grape Society annual meeting. November 10-11, 2016, Grandview, WA. (Oral).
ii. Adiputra, J., Swamy, P., Donda, B., Bagewadi, B., Natra, N. and Naidu, R.A. 2016. The prevalence of grapevine leafroll and red blotch diseases in Washington vineyards. Washington State Grape Society, November 10-11, 2016, Grandview, WA. (Poster).
iii. Naidu, R.A. 2016. It spread like…a virus: How leafroll spreads from old blocks to new plantings; What happens if I see something fishy and I want to test my vines? Industry Expansion Bottleneck: Where Will You Get Your Plants? October 27, 2016, The Clore Center, Prosser, WA. (Oral).
iv. Adiputra, J., Swamy, P., Donda, B., Bagewadi, B., Natra, N. and Naidu, R.A. 2016. The prevalence of grapevine leafroll and red blotch diseases in Washington vineyards. 2016 American Phytopathological Society Annual Meeting, June 30-August 3, 2016, Tampa, FL. (Poster).
v. Naidu, R.A. 2016. Managing viruses in Washington vineyards. WAVE 2016 Washington Advancements in Viticulture and Enology. WSU's Ste. Michelle Wine Estates Wine Science Center, Richland, WA. July 14, 2016. (Oral).
vi. Swamy, P. and Naidu, R.A. 2016. Impacts of grapevine leafroll and redblotch diseases in Washington vineyards. 67th American Society for Enology and Viticulture (ASEV) National Conference, June 27-30, 2016, Monterey, CA. (Oral).
vii. Adiputra, J., Swamy, P., Donda, B.P., Bagewadi, B., Natra, N., and Naidu, R.A. 2016. The relative distribution of leafroll and red blotch diseases in Washington vineyards. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
viii. Swamy, P. and Naidu, R.A. 2016. Impacts of grapevine leafroll and redblotch diseases in commercial vineyards. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
ix. Naidu, R.A. 2016. Grapevine virus diseases. Class lectures to WSU courses "HORT 421/521: Fruit Crops Management" in Spring 2016, "Hort 409: Seminar in Viticulture and Enology" in Fall 2016 and "PlP 300: Diseases of Fruit Crops" in Fall 2016.

2015:

i. Donda, B., Adiputra, J. and Naidu, R.A. 2015. Is it leafroll or red blotch? Washington Association of Wine Grape Growers 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA. (Poster).
ii. Swamy, P., Donda, B., Adiputra, J. and Naidu, R.A. 2015. Is grapevine red blotch disease a bad omen for Washington vineyards? 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA. (Poster).
iii. Adiputra, J., Donda, B. and Naidu, R.A. 2015. Grapevine leafroll and red blotch diseases in Washington vineyards. 66th American Society for Enology and Viticulture National Conference 2015, June 15-18, 2015, Portland, OR. (Poster).
iv. Swamy, P., Donda, B., Adiputra, J. and Naidu, R.A. 2015. Impact of grapevine red blotch disease in red-berried wine grape cultivars. 66th American Society for Enology and Viticulture National Conference 2015, June 15-18, 2015, Portland, OR. (Oral).
v. Naidu, R.A., Donda, B., and Adiputra, J. 2015. Grapevine leafroll and red blotch diseases in Washington State vineyards. Proceedings of the 18th Congress of the International Council for the Study of Virus and Virus-like Diseases of the Grapevine (ICVG), Ankara, Turkey, September 7-11, 2015, 38-39. (Oral).

2014:

i. Naidu, R. A. 2014. Grapevine Red blotch disease. G.S. Long Co., Inc. 2014 Grower Meeting, January 15, 2014, Yakima, WA. (Oral).
ii. Pack, J., Bagewadi, B. and Naidu, R.A. 2014. Studies on grapevine red blotch disease in Washington vineyards. Washington Association of Wine Grape Growers 2014 Annual Meeting, Convention and Trade Show, February 5-7, 2014, Kennewick, WA. (Poster).

iii. Naidu, R.A. 2014. An update on grapevine viruses in Washington vineyards. Washington Association of Wine Grape Growers 2014 Annual Meeting, Convention and Trade Show, February 5-7, 2014, Kennewick, WA. (Poster).
iv. Naidu, R. A. 2014. An update on grapevine viruses in Washington vineyards. WSU Academic Showcase, March 28, 2014, Pullman, WA. (Poster).
v. Pack, J., Bagewadi, B., and Naidu, R.A. 2014. Studies on grapevine red blotch disease in Washington vineyards. WSU Academic Showcase, March 28, 2014, Pullman, WA. (Poster).
vi. Richard Hoff (on behalf of Rayapati) 2014. Management strategies for red blotch virus. Ste. Michelle. Wine Estates Annual Grower meeting. May 20, 2014, Prosser, WA. (Oral).
vii. Naidu, R.A. 2014. Tasting – Red blotch & leafroll update. Ste. Michelle Wine Estates 2014 Winemaker Council Meeting. May 28, 2014, Prosser, WA. (Oral).
viii. Naidu, R.A. 2014. How to inspect a nursery and look for infected grape plants? WSDA Plant Science Program annual staff meeting. June 17, 2014, Prosser, WA. (Oral).
ix. Naidu, R.A. 2014. Grapevine virus diseases. WAWGG Summer Tour organized by the Washington Wine Industry Foundation. August 7, 2014, WSU-IAREC, Prosser, WA. (Oral).
x. Naidu, R.A. 2014. Grapevine virus diseases with emphasis on red blotch disease. WSU's professional certificate program in viticulture. September 14, 2014, Prosser, WA. (Oral).
xi. Naidu, R.A. 2014. Grapevine leafroll disease. Class lectures to WSU courses "HORT 421/521: Fruit Crops Management" in Spring 2014, "PlP 525: Field Plantt Pathology" in Summer 2014, "Hort 409: Seminar in Viticulture and Enology" in Fall 2014 and "PlP 300: Diseases of Fruit Crops" in Fall 2014.

Naidu Rayapati, PD of the project, performed overall management of the project and coordinated project activities, organized meetings with stakeholders, and submitted quarterly and annual progress reports. The technical personnel funded by the project, assisted by other members of Rayapati's program, conducted field and lab activities relevant for the project. Rayapati conducted outreach and educational activities disseminating project outcomes to grape and wine industry stakeholders and crop consultants, and students pursuing higher education at WSU. Both Rayapati and the project team presented results at professional scientific meetings.

This project is focused on wine grapes in Washington vineyards. Thus, potential benefits from this project are not anticipated to producers/processors of non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

As described in the Project Approach section of this report, nearly 2,150 Samples were collected during 2014, 2015, and 2016 seasons from 20 red- and 6 white-fruited wine grape (Vitis vinifera) cultivars in eight AVAs (appellations) across Washington State. Samples were tested by molecular diagnostic assays for the presence of grapevine red blotch-associated virus (GRBaV) and grapevine leafroll-associated virus 3 (GLRaV-3). The results indicated that GLRaV-3 is far more widespread than GRBaV. A multi-plex PCR assay was optimized for simultaneous detection of GRBaV and GLRaV-3 in grapevine samples. The multiplex PCR assay is expected to offer cheaper, faster, and reliable diagnostic services for nurseries to maintain virus-free vines in registered mother blocks and grape growers to establish new vineyards with 'clean' planting stock. Despite its low incidence, GRBaV can cause significant negative impacts on fruit yield and quality in three red grape cultivars studied during this project period. The research-based outcomes of this project was shared with growers and industry stakeholders at industry-sponsored grower meetings for increased awareness of GRBD and to encourage growers to adopt best management practices, including effective sanitation practices and planting new vineyards with certified planting stock, for healthy vineyards.

Based on the data generated from this project, it is anticipated that at least two research articles will be published in peer-reviewed scientific journals during 2017/2018. A portion of the project data will be included in the doctoral thesis of a graduate student to be submitted in 2017 to Washington State University. In addition, a fact sheet is being developed on red blotch disease with an anticipated publication in 2017. The fact sheet will be distributed widely among the industry stakeholders for implementing best practices to manage red blotch disease in grower vineyards.

Project Activity	Timeline (*month and year*)	Accomplishments
Sample collection from wine grape cultivars in vineyards from representative AVAs.	Oct 2013; Jun-Oct 2014 & 2015.	Completed.
Test samples for the geminivirus and other grapevine viruses by high throughput molecular diagnostic methods.	Oct 2013-Oct 2015	Completed.
Conduct molecular analyses for confirmation of viruses and improve sensitivity and specificity of diagnostic methods by real-time, quantitative PCR technology.	Oct 2013-Dec 2014	Completed.
Collect and analyze data on fruit yield, berry quality and pruning weights in at least one red wine grape cultivar from two seasons.	Sept-Oct 2014, 2015; Feb 2014, 2015 (for pruning wt.).	Completed. The data was collected from three wine grape cultivars.
Develop and distribute bilingual factsheets on GRD.	Jun 2014-Oct 2015.	Expected to complete by end of 2017.
Conduct field days and/or tail-gate meetings to disseminate knowledge.	Jun-Sept 2014, 2015.	Completed.
Present results at grape industry annual meetings for the benefit of stakeholders.	Feb and Nov 2014, 2015, 2016.	Completed.

Previous to the commencement of this project, no information was available on the status of grapevine red blotch disease in Washington vineyards. The data generated during this project provided reliable estimates of the distribution of this disease relative to other viral diseases, such as grapevine leafroll disease. The project also generated information on impacts of red blotch disease on fruit yield and quality in three wine grape cultivars and disseminated science-based information for practical applications in vineyards. The project outcomes have met the two goals "Document the extent of the distribution of GRD in Washington vineyards" and "Increased awareness of red blotch disease among growers, nurseries, and regulatory agencies" listed in the proposal.

BENEFICIARIES

i. The project outcomes have benefited the Departments of Agriculture in Washington, Oregon and Idaho in harmonizing grapevine nursery certification programs across the Pacific Northwest. Eight members from the Departments of Agriculture of the three states and ten members of wine industry stakeholders from three states learned about the status of red blotch in Washington and methods available for the detection of grapevine red blotch-associated virus.

ii. Nearly 50 members of the grape industry in Washington, Idaho and Oregon benefited with presentations at the workshop "Industry Expansion Bottleneck: Where Will You Get Your Plants?" held on October 27, 2016.

iii. Project results shared during a presentation at the first meeting "WAVE 2016 Washington Advancements in Viticulture and Enology" on July 14, 2016, benefited nearly 60 members of Washington's grape and wine industry.

iv. Oral and poster presentations at stakeholder meetings such as the Washington Association of Wine Grape Growers (WAWGG) Annual Meeting, Convention and Trade Show (February 5-7, 2014; February 10-13, 2015; February 9-11, 2016 at Kennewick, WA) and Ste. Michelle Wine Estates 2014 Winemaker Council Meeting (May 28, 2014, Prosser, WA) and Washington State Grape Society Annual Meeting & Trade Show (November 12-13, 2015 and November 10-11, 2016, Grandview, WA) provided excellent opportunity to share project results on distribution and impacts of grapevine red blotch disease. Approximately 250 members of grape and wine grape industry stakeholders (consisting of grape growers, wine makers, crop consultants, vineyard managers and farm workers) and about 30 research and extension faculty and research associates, graduate students and undergraduate students in Viticulture & Enology Program from Washington State University and community colleges benefited from these presentations.

v. Presentation at the WSDA Plant Science Program annual staff meeting (June 17, 2014, Prosser, WA) benefited 18 members of the WSDA Plant Science Program in gaining new knowledge about impacts of grapevine virus diseases and the importance of maintaining virus-tested grapevines in certified nurseries.

vi. Presentation at the WAWGG Summer Tour (August 7, 2014, WSU-IAREC, Prosser, WA) benefited about 50 Spanish speaking vineyard employees in better understanding negative impacts of virus diseases on grape and wine quality.

vii. During the project period, about 75 students enrolled in WSU's professional certificate program in viticulture and nearly 150 undergraduate students enrolled in WSU courses "PlP 300: Diseases of Fruit Crops" and "HORT 409: Seminar in Viticulture & Enology" learned various aspects of grapevine red blotch and its impacts on plant health and fruit and wine quality during the class room teaching and associated field visits to grower vineyards.

As listed above, outcomes of the project were used in education and outreach programs for an increased awareness of grapevine red blotch disease and encourage Washington growers to use virus-tested clean planting stock for new vineyards. In the long term, the project outcomes are strengthening the WSDA Grapevine Nursery Certification Program and expected to foster sustainable growth of Washington's grape and wine industry that had an estimated $4.8 billion impact on Washington State's economy in 2013. Outcomes of the project have directly contributed to the funding priority of the WSDA SCBGP "Controlling Pests and Diseases" for advancing sustainability of Washington's grape and wine industry.

LESSONS LEARNED

The project personnel have pursued participatory collaborative approaches with grape and wine industry stakeholders to generate new knowledge about grapevine red blotch disease and its impacts on fruit yield and quality. It is important to share the science-based knowledge with stakeholders in a time-sensitive manner through various dissemination pathways for increased awareness of viral diseases and implement disease mitigation strategies in vineyards. A working relationship with Washington State Department of Agriculture is important to provide science-based knowledge for strengthening grapevine quarantine and certification programs to ensure that alien viruses and vectors are not introduced into the state. Overall, it is vital to have strong research-regulatory agency-industry partnerships to address key constraints such as viral diseases for maintaining healthy vineyards and advancing sustainability of wine grape production, a key economically important agricultural sector of Washington State.

Grapevine cultivars exhibit seasonal variations due to Genotype (G)-by-Environment (E) interactions. Thus, elucidating cultivar-and clonal-specific responses to viral infections during several seasons could help making short-term adjustments and long-term adaptations to viticulture practices for implementing sustainable strategies to mitigate negative impacts of viral infections due to climate change.

Project activities have been conducted according to the timeline described in the project. This was made possible with excellent team work between project personnel and productive collaborations with wine grape growers.

ADDITIONAL INFORMATION

Cash match for this project totaled $94,062.06.

Two research publications in peer-reviewed scientific journals during 2017/2018 will be published based on the data generated from this project. A portion of the project data will be included in a doctoral thesis of a graduate student to be submitted in 2017 to Washington State University. A fact sheet is being developed on red blotch disease with an anticipated publication in 2017. Funding support from the SCBGP will be duly acknowledged.

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PROJECT #14

Project Title: Spotted Wing Drosophila Management in Sweet Cherries

Partner Organization: Washington State University Tree Fruit Research & Extension Center (WSU TFREC)

PROJECT SUMMARY

This project addressed the IPM challenges caused by the invasion of a new pest of sweet cherry, spotted wing drosophila (SWD). Because the pest was first detected in Washington in 2009, much was unknown about its biology, ecology, and control. Prior to its arrival, the sweet cherry IPM program was in a relatively stable state: the development and implementation of GF-120 bait sprays for the other key pest, cherry fruit fly, allowed a program that had fewer broad-spectrum canopy sprays, and less disruption of secondary pests such as spider mites and aphids. The appearance of a new, direct pest caused a reversion to cover sprays during the entire period of fruit maturation (straw color through harvest).

Washington's sweet cherry industry has experienced substantial growth in the past 20 years, increasing from 11,000 acres to 35,000 acres. Cherries are a high value crop, with average gross returns at full production estimated at $23,429/acre. The value of Washington's production in 2015 was $436,918,000 (NASS 2016, Non-Citrus Fruit and Nut Summary). Low levels of fruit infestation by SWD can reduce packouts, and high levels can cause entire loads to be rejected, or crops abandoned in the field, thus control of this pest is imperative. Conversely, prophylactic sprays (with limited numbers of active ingredients) set the stage for insecticide resistance. Re-establishment of an IPM program, using monitoring, thresholds, and insecticide rotation must be achieved as soon as possible.

This project built on the work of Project K750, which established the basic phenology and distribution of SWD in the State of Washington. It explored the relative efficacy of monitoring tools, then in a fairly early stage of development. The goal in the previous project was to develop a tool and system for large-scale monitoring; this work has continued, but with the goal of developing a tool for site-specific monitoring. The current project also continued the work on establishing insecticide efficacy and the timing of cherry fruit susceptibility.

PROJECT APPROACH

The statewide monitoring program for SWD concluded at the end of the 2014 season (and with it, the regional alert system), providing five years of phenological data for Washington. These data are being used in a manuscript that describes seasonal occurrence and abundance of this pest in the Okanagan and Columbia River Basins in Washington, Oregon, and British Columbia. The significant trends from this dataset indicate the absence of winter activity (with the exception of very mild winters), low levels during the spring and summer building to a peak in the late summer and autumn. Other important factors identified are year-to-year variation, pesticide treatments, and the number of days < 5 erC (41 □ months.

The advent of commercial traps and attractants has greatly changed the prospects for monitoring SWD. They bring a greater degree of standardization and ease of use compared to hand-made traps baited with apple cider vinegar. Four synthetic lures are available, which last at least 4 weeks in the field (although the drowning fluid still needs to be changed at each visit). Similarly, commercial traps are also available, designed for either liquid baits/drowning fluid or sticky cards. An ongoing problem with liquid-based traps is the large amount of by-catch (especially non-target Drosophila) and the amount of handling to process a sample; this characteristic has greatly impeded adoption of SWD monitoring after the conclusion of the statewide trapping program. An unexpected and exciting discovery was that the use of sticky cards (coupled with a synthetic lure) provides a more species-specific trap for SWD, while simultaneously biasing the capture to males, the sex most easily identified on the traps.

The unusually severe pest pressure during the 2015 season caused renewed concern among producers about SWD control. Because of this, determining the effective insecticides available for SWD control, along with their residual properties under Washington conditions, has been advanced considerably. Field and laboratory tests have identified the spinosyns and pyrethroids as the most residual materials, with carbaryl and malathion relatively short-lived. One athranilic diamide (Exirel) shows good activity against SWD. In preparation for a resistance management program, baseline sensitivities and preliminary screening of Washington populations has been accomplished for five SWD insecticides.

In the first year of the grant, the regional fieldmen (Wilbur-Ellis, Northwest Wholesale, GS Long, Cascade IPM, Northwest IPM, Columbia IPM, Quincy Farm Chemicals/McGregor and D&M consulting) provided substantial support in the form of trap sites in commercial orchards and weekly collection of the trap contents. The project was also supported by the WSDA commodity inspection service, which collected any Drosophila larvae found during cherry inspections. These were brought to either the WSDA office in Yakima or the TFREC in Wenatchee for identification. This program allowed an objective and industry-wide measurement of pest pressure and control program success. The Washington Tree Fruit Research Commission and the Washington Commission on Pesticide Registration continued their partnership in funding work on this pest throughout the life of the project.

The project does not benefit non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

Activity #1. Monitor SWD activity in eastern Washington cherry orchards.
This activity was completed in December of 2014, concluding a 5-year study of distribution and phenology of SWD in Washington State.

Activity #2. Use monitoring information from #1 to power an alert system.
The web-based regional alert system was conducted in 2014, based on the data collected in the statewide trapping program. The trapping results were uploaded to a database daily, and alerts distributed via a mailing list when populations or packinghouse finds warranted this. The website http://www.tfrec.wsu.edu/pages/swd has had a total of 16,737 page views since inception, but due to the loss of IT support, yearly totals are not available.

Activity #3. Determine optimal traps and lures.
Trap and lure studies were conducted during the field seasons of 2014-2016, and have allowed us to make recommendations on effectiveness, selectivity, and ease of use of 3 baits, 4 lures, and 6 trap types. The Scentry lure has consistently provided the highest capture rate of SWD at both low and high densities. When placed in a liquid-based trap, the level of by-catch can reach high levels; however, when used with a sticky card, the by-catch is considerably reduced.

Activity #4. Determine efficiency of SWD detection.
Several tests were conducted to determine the efficiency of the fruit crush/brown sugar flotation method to detect low levels of SWD larvae. Large larvae were fairly easy to detect, but smaller larvae were recovered at a much lower rate.

Activity #5. Determine pesticide efficacy and longevity.
The length of effective residues was determined for Sevin, Malathion, Entrust, Delegate, Warrior, Altacor, Exirel, Dimilin, Rimon and an unregistered diamide (Harvanta). The two spinosyns (Delegate and Entrust) provided 14-21 days of residual control; Warrior provided about 10-14 days. Exirel and Harvanta provided good levels of control through 21 days, but mortality was never as high as with the former products. Dimilin and Rimon caused little direct mortality, but the former appeared to either sterilize the females or prevent development of eggs or larvae when adult females were exposed to residues.

Activity #6. Screen new compounds for SWD control.
One unregistered pesticide (Harvanta) was screened for efficacy against SWD, and appears to be promising for control (see activity #5). Several repellents and oviposition deterrents have been tested including butyl and methyl anthranilate and horticultural (petroleum) oil; of the materials tested, oil had the greatest effect on oviposition deterrence, although this is likely to be of short duration.

Activity #7. Determine efficacy of bait sprays.
GF-120 was tested in small insect cages in the laboratory to determine if all dilutions listed on the label were effective against SWD. For both males and females there was a high level of mortality by 48 h, with no significant difference between the most and least concentrated dilutions. The longevity of the droplets in the field was tested, with high level of mortality after 15 days when applied either by the GF-120 sprayer or hand pipetted on to the leaves. Bait tests with caged whole cherry trees were conducted in 2015 and 2016; the 2015 results were compromised by the cage design, but the 2016 results

indicate that both spinosad applied airblast and GF-120 sprays provided lower damage levels than the unsprayed checks, although statistical differences were not detected.

Activity #8. Screen SWD populations for insecticide resistance.
Baseline bioassays were completed on five insecticides (Delegate, Entrust, Malathion, Sevin and Warrior) using a reference colony (OSU1) collected in 2009. The probit analysis of these bioassay data were used to develop a diagnostic dose (2x the LC99). To date, 13 populations from Washington cherry orchards have been screened for all five pesticides using the diagnostic dose, which is designed to kill 100% of the insects tested. Of the 65 screenings, only 2 populations have had survivors: a conventional orchard (Malathion, Warrior) and an organic orchard (Delegate), both in Douglas County. The number of surviving females was low in these cases, but indicates that resistance management must be a priority in the future.

Activity #9. Provide real-time information to producers and consultants.
The website was active during the field seasons of 2014-2016, but the most meaningful real-time measurement (the regional trapping results) was only available in 2014. Alerts were sent out in 2015 to warn growers that pest pressure was high, but low pest pressure in 2016 resulted in no alerts being sent.

Activity #10. Provide research updates to producers and consultants.
A total of 27 presentations were given to producers, consultants, and colleagues to update them on SWD phenology, occurrence, monitoring practices, pesticide efficacy, and resistance.

Activity #11. Work with WSDA Inspection Service to identify Drosophila larvae found in samples.
The number of packinghouse finds positively identified as SWD in the three years of the study were 1 (2014); 236 (2015); and 11 (2016). The number of positive identifications was enhanced by the use of PCR in 2015/2016 for larvae that were not successfully reared to the adult stage, but these trends are generally reflective of pest pressure during those years. The extremely high number of finds in 2015 appeared to be an abnormally mild winter and early spring, which likely enhanced survival and development of SWD.

Activity #12. Prepare, submit reports.
Quarterly and annual reports on the outputs of this grant have been conveyed to the WSDA in a timely fashion.

The Outcome of the website was achieved in 2014 as expected, but the most meaningful data powering this website was discontinued due to the high cost of state-wide monitoring. In retrospect, this type of information would have been a powerful indicator of the pest pressure/damage that occurred in 2015, but the cost of broad-scale monitoring is considerable, and cannot be sustained without industry input. Conversely, the goal of producing a crop free from SWD was not realized in 2015, although the 2014 (1 find) and 2016 (11 finds) packinghouse finds were closer to this goal. Part of the difference may be due to enhanced detection, but it is equally likely that the pest pressure and the ability to apply control measures in a timely fashion are also contributory.

For the most part, the activities were accomplished to the extent made possible by field pressure of SWD. Year-to-year variation has been identified as a major factor governing SWD pest pressure, but the understanding of the factors that underlie this variation are only understood at a rudimentary level. Warmer winters appear to enhance earliness of capture, and subsequent pest pressure/damage during the season. Rainfall events during the maturation period may impede the ability of producers to apply control measures in a timely fashion, regardless of the knowledge of what the most efficacious and appropriate measures are.

The ability to summarize population densities on an area wide basis was lost after 2014. The baseline data from 2013 was 41 packinghouse finds of SWD, and by this metric, 2014 (1) and 2016 (11) were an improvement. However, WSU failed to accurately forecast a high-pressure year (2015), because user-friendly monitoring measures were not available or used. Future projects must address this deficit if WSU is to improve the IPM of SWD.

The website http://www.tfrec.wsu.edu/pages/swd was created in the fall of 2010 had >6,000 page views since its inception. The goal was to have >1,500 page views per growing season. The website has had a total of 16,737 page views since inception, but due to the loss of IT support, yearly totals are not available.

BENEFICIARIES

The beneficiaries of this project are the sweet cherry growers of Washington; they have more confidence in when and where SWD will occur, and have more tools with which to control and monitor this pest.

The website http://www.tfrec.wsu.edu/pages/swd was created in the fall of 2010 had >6,000 page views since its inception. The goal was to have >1,500 page views per growing season. The website has had a total of 16,737 page views since inception, but due to the loss of IT support, yearly totals are not available.

LESSONS LEARNED

The lessons learned have to do primarily with benefits of cooperation for the mutual benefits of all: the area wide trapping program provided a reasonable indicator of regional pest pressure, which producers could have used to modify their pest control programs. Failure to work cooperatively allowed the high levels of infestation in 2015. It should be noted that a cooperative program (grower-funded) continues in Oregon in the major cherry producing districts.

Two outcomes were unexpected as the result of this project. First, that the year-to-year variation could be so dramatic, or more specifically, result in such high pest pressure (e.g., 2015). The understanding up until the 2015 season was that this pest was manageable with 2-3 sprays. The second unexpected outcome was that a trap, rather than a lure, could be highly selective both for species and sex. That this may greatly facilitate future monitoring and merits further exploration.

Producing a crop free from SWD infestation may not be a realistic goal given the current level of establishment, despite early indications from what are now seen as lower pressure years. Year-to year variation in overwintering success or ability to apply protective sprays may reduce the options of the producers.

ADDITIONAL INFORMATION

The Washington Tree Fruit Research Commission provided cash match in in 2014 in the amount of $50,000 from a grant on SWD management, listed on the grant proposal. However, this work was also supported by a WTFRC grant for work on insecticide resistance in SWD in the amount of $55,575 (2014-2016), although this was not used formally as match in the grant. The Washington State Commission on Pesticide Registration contributed $14,481 (2015) and $16,356 (2016) to the project. These projects funded technicians, travel, supplies and students.

The in-kind match from WSU provided unrecovered indirect cost for PI Beers (salary + benefits) for 3 years.

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PROJECT #15

Project Title: Full Season Management of Powdery Mildew on Sweet Cherries

Partner Organization: Washington State University

PROJECT SUMMARY

The fungus Podosphaera prunicola, incitant of cherry powdery mildew, survives winter as chasmothecia. These propagules are formed from June-September in Washington orchards and nurseries. They are produced in profusion after orchard fungicide applications are terminated at harvest. The rationale for the project was to extend the "spray" season and to effectively deploy various fungicide modes of action in order to reduce the amount of survival inoculum. Studies on other crops demonstrated that a reduction in overwintered inoculum translates to delayed disease onset and reduced disease severity during the growing season. The purpose of the project was to identify fungicide modes of action and application timings that could be utilized to prevent chasmothecia formation and the potential for fungicide programs to disrupt cherry IPM programs.

The disease is the most serious IPM issue related to the production of sweet cherries in the Pacific Northwest. The disease is intensively managed until harvest but not afterwards. However, survival structures of the causal fungus are produced on foliage in great profusion after harvest. The rationale was to develop spray regimens that provide effective disease control, reduce the amount of survival inoculum, while following fungicide resistance management guidelines and "fitting" in established cherry insect management programs. Therefore, this project focused upon the effectiveness of various fungicide modes of action on chasmothecia formation, appropriate application timings to reduce chasmothecia formation, and the benefits of full season (pre and post-harvest) disease management on foliage using a combination of synthetic (resistance prone) and non-synthetic (less resistance risk). The expansion of chemical management options from 2000-2010 presented the potential for full season management without increasing the risk of fungicide resistance.

This project does not build on a previous SCBGP project.

PROJECT APPROACH

Objective 1. An industry-wide survey was conducted at the beginning of the project. Obtained using Survey Monkey baseline information on current industry practices for cherry mildew control, cost and effectiveness from the perspective of growers, shipper/packers, and industry chemical consultants. As of September 30 there were 11 responses, all from industry opinion leaders. Ninety per cent indicated that management of powdery mildew of cherry was important to their business; the majority of growers also indicated that most fungicide recommendations originate from chemical distributors and their associated field support personnel.

Objective 2: Various full season fungicide programs were evaluated for efficacy, sustainability (i.e. conformity to FRAC resistance management guidelines) and cost. These studies were conducted in research orchards and also at commercial orchards and nurseries. Most full season programs consisted of synthetic fungicide applications/alternations up to harvest followed by postharvest applications of contact fungicides. All studies of this nature conformed to FRAC resistance management guidelines and in most cases single or sequential application of narrow-range petroleum oils.

Objective 3. Various fungicide modes of action (and combinations thereof) were evaluated for their effects on chasmothecia numbers in both the orchard and nurseries. Orchard studies focused on the application timing of quinoxyfen (quinolone class) and penthiopyrad (SDHI) while nursery studies focused on the efficacy of individual modes of action (DMI, quinoline, SDHI, QoI, oil, and biological fungicides).

Objective 4. Various quinoxyfen programs were evaluated for reducing chasmothecia populations. In orchard studies, single quinoxyfen applications were evaluated in a "sliding" format in overall quinoxyfen:penthiopyrad programs. In nursery studies, single quinoxyfen treatments were applied according to multiple degree-day thresholds after the initial appearance of disease signs.

Objective 5. Print (Goodfruit Grower, Phytopathology, and EB 0419) and social media venues (Facebook: https://www.facebook.com/search/top/?q=Cherry%20Powdery%20Mildew) were established for ongoing outreach activities.

Objective 2 Approach and Results

Approach 1: Post-harvest application of narrow-range petroleum oils in experimental (WSU-IAREC; Tables 4-7) and commercial orchards (Hayden Farms, Pasco, WA; Tables 1-3).

Experimental Design:
The plot design for the trial at the cooperator's orchard uses rows as replications to minimize the impact of the study on the cooperator and allow for standard orchard spray practices. There are 6 rows of trees in each of four treatment blocks. Trees 1 and 6 are boundary rows. The center 4 trees are designated as Reps 1-4. The trees are Bing scion on Mazzard rootstock 1997.

Postharvest Treatments:
Control: No postharvest treatment
Treatment 1: Stylet Oil (1-2%): one application
Treatment 2: Stylet Oil (1-2%): two applications, second one 14 days after first
Treatment 3: Stylet Oil (1-2%): three applications, third one 14 days after second

a) Powdery mildew evaluation. Powdery mildew disease incidence and severity (% or leaves and leaf area infected) was recorded two weeks after the final oil application (July 27, 2015 and August 12, 2016).
b) Chasmothecia evaluation. Representative leaf samples were taken (9-26-2014, 9-23-2015, 9-21-2016) to assess the total number of chasmothecia and the viability of the ascospores contained within the chasmothecia in each treatment.
c) Mite evaluation. Sampling was conducted just prior to each treatment in order for mite populations to rebound as much as possible. Four reps of 25 leaves were collected from each treatment. Leaves were collected randomly at a height of 3 to 6 feet from the orchard floor from each treatment area and placed in a paper bag. The bags were placed in a cooler (with ice) for transport to the Wenatchee lab where they were placed in a cold room (34° F). Within 24 hours, the mites were collected from the leaves using a leaf brushing machine (Leedom, Mi-Wuk Village, CA) onto a revolving glass plate coated with undiluted dishwashing liquid. The composite sample on the plate was counted using a stereoscopic microscope. All stages and species of phytophagous and predatory mites were recorded, including the eggs and motile stages of European red mite (ERM), Panonychus ulmi (Koch); two-spotted spider mite (TSM), Tetranychus urticae (Koch); apple rust mite (ARM), Aculus schlechtendali (Nalepa); McDaniel spider mite (MCD), Tetranychus mcdanieli (McGregor); and western predatory mite (TYPH), Typhlodromus occidentalis (Nesbitt). The mites were grouped into pest or predatory mites except for the apple rust mite which was reported separately. Pest mites include ERM, TSM, and MCD and counted together as

Tetrancychids. The predatory mite count includes only the TYPH. Sampling was terminated for the season when there were fewer than 5 mites/leaf counted.

Results and Discussion

a) Powdery mildew evaluation

In all years, significantly more disease was formed on the upper canopy than the lower canopy. In 2016, disease incidence in the upper portion of the trees in the treatment blocks ranged from 40 to 59% but only reached 15% in the untreated control. When lower and upper canopy ratings were combined, the untreated control had always significantly less powdery mildew than the oil treated trees. In general, an increase in oil applications resulted in an increase in powdery mildew disease incidence and severity. The same results were obtained in 2015 (22% disease incidence in the control versus 47%, 44% and 76% in Treatments 1, 2, and 3). In 2015 and 2016, disease severity was highest in the upper canopy of treatment block 3 (3x oil applications), with 4.7% in 2016 and 17% in 2015.

Table 1. Powdery mildew severity after final oil application in Pasco, WA

Powdery mildew Severity^ (%) 8-12-2016	Lower canopy		Upper canopy		Combined canopy	
Treatment 1 (1x oil)	0.21	A*	2.79	B	1.50	AB
Treatment 2 (2x oil)	0.98	A	3.52	AB	2.25	A
Treatment 3 (3x oil)	0.13	A	4.68	A	2.41	A
Control (No oil)	0.22	A	0.59	C	0.41	B

^ Severity = % leaf area infected by the fungus

*Values for a variable within a column followed by a common letter are not significantly different based on Tukey Kramer test (*P=0.05*)

b) Chasmothecia evaluation

Controlling the formation of chasmothecia, the overwintering structures of the powdery mildew fungus, is crucial for disease control. Moreover, reducing the viability of the ascospores contained within the chasmothecia can lead to a reduced amount of primary inoculum in the following season.

In 2016, neither the total amount of chasmothecia produced nor the ascospores viability was significantly increased or decreased by the application of post-harvest oil applications. No significant treatment differences were observed. In 2014 and 2015, Treatments 2 and 3 had the highest number of chasmothecia. In all three years, the untreated control had consistently the least amount of chasmothecia formed on leaves in the orchard, significantly less in 2014 (compared to Treatments 1 and 3) and 2015 (compared to Treatment 2) but not in 2016.

Table 2. Average number of chasmothecia formed on leaves and ascospore viability (%) – 2014 to 2016

2014	**Avg. Number of Chasmothecia**			**Ascospore Viability (%)**			
Treatment	**Lower canopy**	**Upper canopy**	**Combined canopy**	**Lower canopy**	**Upper canopy**	**Combined canopy**	
Treatment 1 (1x oil)	94.7	142.9	43.6 A	5.7	9.8	50.2	B
Treatment 2 (2x oil)	54.2	68.2	48.5 A	2.0	5.2	28.1	AB
Treatment 3 (3x oil)	17.0	231.9	38.7 A	1.5	11.9	9.3	B
Control (No oil)	37.6	88.4	45.3 A	4.5	8.4	21.0	AB

2015	**Avg. Number of Chasmothecia**	**Ascospore Viability (%)**

Treatment	Lower canopy	Upper canopy	Combined canopy		Lower canopy	Upper canopy	Combined canopy		*Values for a variable within a column followed by a common letter are not significantly different based on Tukey test (*P=0.05*)
Treatment 1 (1x oil)	11.4	44	27.7	AB*	0.7	4.4	2.5	A	
Treatment 2 (2x oil)	12.8	71.2	42	A	1.6	4.9	3.2	A	
Treatment 3 (3x oil)	12.1	46.3	29.2	AB	1.0	3.2	2.1	AB	
Control (No oil)	8.0	29.5	18.7	B	0.4	2.6	1.5	B	

*Values for a variable within a column followed by a common letter are not significantly different based on Tukey test (*P=0.05*)

2016	Avg. Number of Chasmothecia			Ascospore Viability (%)			
Treatment	**Lower canopy**	**Upper canopy**	**Combined canopy**	**Lower canopy**	**Upper canopy**	**Combined Canopy**	
Treatment 1 (1x oil)	26.8	60.4	43.6 A	3.3	5.4	4.3	A
Treatment 2 (2x oil)	44.8	52.3	52.3 AB	1.6	4.0	2.8	A
Treatment 3 (3x oil)	35.7	41.7	41.7 AB	2.5	2.9	2.7	A
Control (No oil)	19.1	71.6	19.1 B	3.6	2.4	3.0	A

*Values for a variable within a column followed by a common letter are not significantly different based on Tukey test (*P=0.05*)

c) Mite evaluation.

Mites/leaf values were calculated for each sampling date and analysis of variance (ANOVA) performed using SAS with confidence interval of 95% and means/Waller. Cumulative mite days (CMD) are calculated for treatment and both mites/leaf and CMD are presented graphically.

No rust mites were detected in the orchard. In 2015, the application of oil did significantly reduce the amount of Tetranychids (spider mites) per leaf during the peak season of the mites (mid to late August). The number of predatory mites never exceeded more than 1/ leaf and there was no significant difference between the treated and untreated blocks. In 2016, the untreated control had less Tetranychids and predatory mites/ leaf than the treated blocks, however, the difference was not significant.

Table 3.

2015: Pasco mites/ leaf

Tetranychids/ leaf

Treatment	11-Jun-15		9-Jul-15		23-Jul-15		6-Aug-15		20-Aug-15		3-Sep-15	
Control	0	A	0.07	A	0.18	A	4.56	A	8.18	A	0.22	A
1x oil	0	A	0.13	A	0.12	A	1.69	AB	0.75	B	0.17	A
2x oil	0.01	A	0.12	A	0.06	A	1.25	B	1.75	B	0.19	A
3x oil	0	A	0.01	A	0.04	A	0.79	B	2.24	B	0.5	A

Predatory mites/ leaf

Treatment	11-Jun-15	9-Jul-15	23-Jul-15	6-Aug-15	20-Aug-15	3-Sep-15

Control	0.01	B	0	A	0	A	0	A	0.98	A	0.2	A	
1x oil	0.04	A	0.02	A	0	A	0.03	A	0.87	A	0.58	A	
2x oil	0.04	A	0	A	0	A	0.04	A	0.64	A	0.61	A	
3x oil	0.02	AB	0	A	0	A	0	A	0.62	A	0.41	A	

*Values for a variable within a column followed by a common letter are not significantly different based on Waller test (*P=0.05*)

2016: Pasco mites/ leaf

Tetranychids/leaf

Treatment	22-Jun-16		7-Jul-16		21-Jul-16		4-Aug-16		18-Aug-16		1-Sep-16		15-Sep-16		29-Sep-16	
Control	0	a	0	a	0.08	a	0	a	8.1	a	16.47	a	0	b	0	a
1x oil	0	a	0	a	0.14	a	0.03	a	23.77	a	23.1	a	0.04	b	0	a
2x oil	0	a	0	a	0.03	a	0.01	a	44.18	a	20.04	a	0.19	b	0	a
3x oil	0	a	0.01	a	0.02	a	0	a	14.71	a	24.31	a	3.94	a	0	a

Predatory mites/leaf

Treatment	22-Jun-16		7-Jul-16		21-Jul-16		4-Aug-16		18-Aug-16		1-Sep-16		15-Sep-16		29-Sep-16	
Control	0	a	0	a	0	a	0	a	0.22	a	0.2	a	0.11	a	0.05	a
1x oil	0	a	0	a	0	a	0.01	a	0	a	0.55	a	0.5	a	0.03	a
2x oil	0	a	0	a	0	a	0.01	a	0.31	a	0.44	a	0.64	a	0.05	a
3x oil	0	a	0	a	0	a	0	a	0.05	a	0.63	a	0.44	a	0.02	a

*Values for a variable within a column followed by a common letter are not significantly different based on Waller test (*P=0.05*)

Approach 2. Experimental orchard in Prosser, WA. These experiments addressed objectives 2-4.
Experimental Design:
The Prosser D-39 plot uses a completely randomized design for both the Sliding Quintec fungicide trial and the post-harvest oil application trial. Pre-harvest fungicides for control of cherry powdery mildew were applied in 11 treatments (four single tree reps), starting at shuck fall and biweekly thereafter. Each 'Bing' tree was randomly assigned a treatment and replicate number in each year. Post-harvest Stylet oil was applied twice, 14 and 28 days after the last fungicide application.

Table 4: Fungicide rotation and post-harvest oil application schedule in the experimental orchard in Prosser, WA. Pristine (pyracostrobin + boscalid), Fontelis (penthiopyrad; SDHI), and Quintec (quinoxyfen; quinolone MOA) represent 4 fungicide modes-of-action).

Treatment	Shuck Fall	SF + 14	SF + 28	SF + 42	Post-Harvest 1	Post-Harvest 2
1	Quintec	Quintec	Fontelis	Fontelis	**Oil**	**Oil**
2	Fontelis	Quintec	Quintec	Fontelis	**Oil**	**Oil**
3	Fontelis	Fontelis	Quintec	Quintec	**Oil**	**Oil**
4	Fontelis	Fontelis	Fontelis	Quintec	**Oil**	**Oil**
5	Quintec	Quintec	Quintec	Quintec	**Oil**	**Oil**
6	Quintec	Quintec	Quintec	Quintec	Untreated	Untreated
Control: 7	Untreated	Untreated	Untreated	Untreated	Untreated	Untreated
8	Fontelis	Fontelis	Fontelis	Fontelis	**Oil**	**Oil**
9	Fontelis	Fontelis	Fontelis	Fontelis	Untreated	Untreated
10	Pristine	Pristine	Pristine	Pristine	**Oil**	**Oil**
11	Pristine	Pristine	Pristine	Pristine	Untreated	Untreated

Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree).

a) Powdery mildew evaluation. Powdery mildew disease incidence and severity (% leaf area infected) was recorded after the last fungicide application and was repeated after the final oil application (July 3, 2014; June 15 and August 1, 2015; June 15 and July 14, 2016).

Evaluation of *chasmothecia production in experimental orchards*. Representative leaf samples were taken (9-26-2014, 9-25-2015, 9-14-2016) to assess the total number of chasmothecia and the viability of the ascospores contained within the chasmothecia in each treatment.

Table 5. Average number of chasmothecia formed on leaves and ascospore viability (%) after fungicide rotations and post-harvest oil applications – 2014 to 2016

			Avg. Number of Chasmothecia			Ascospore Viability (%)		
2014 Fungicide rotation	**Post-harvest Oil**	**Treatment**	**Lower canopy**	**Upper canopy**	**Combined canopy**	**Lower canopy**	**Upper canopy**	**Combined canopy**
Q-Q-F-F	2x	1	112.8	315.0	214 B	4.3	21.5	13 A
F-Q-Q-F	2x	2	160.8	287.0	224 B	10.1	14.1	12 A
F-F-Q-Q	2x	3	121.8	189.0	155 C	12.2	14.0	13 A
F-F-F-Q	2x	4	36.8	158.5	98 C	3.3	13.3	8 A
Q-Q-Q-Q	2x	5	113.0	237.3	175 AB	10.6	8.5	10 A
Q-Q-Q-Q	none	6	337.0	337.3	337 A	19.0	16.5	18 A
none	none	7	213.3	296.8	255 B	31.9	24.5	28 A
F-F-F-F	2x	8	102.3	215.8	159 C	17.0	11.0	14 A
F-F-F-F	none	9	178.5	288.3	233 A	12.3	21.5	17 A
P-P-P-P	2x	10	108.8	143.0	126 D	16.3	17.4	17 A
P-P-P-P	none	11	52.0	111.3	82 D	10.5	7.0	9 A

*Values for a variable within a column followed by a common letter are not significantly different based on Tukey test (*P=0.05*). Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree).

2015		**Avg. Number of Chasmothecia**				**Ascospore Viability (%)**			
Fungicide rotation	**Post-harvest Oil**	**Treatment**	**Lower canopy**	**Upper canopy**	**Combined canopy**	**Lower canopy**	**Upper canopy**	**Combined canopy**	
Q-Q-F-F	2x	1	40.0	163.8	102 B*	4.8	5.0	5	A
F-Q-Q-F	2x	2	279.3	305.0	292 AB	7.4	8.8	8	A
F-F-Q-Q	2x	3	117.0	275.5	196 AB	3.5	7.8	6	A
F-F-F-Q	2x	4	110.0	272.3	191 AB	3.5	7.0	5	A
Q-Q-Q-Q	2x	5	97.0	181.0	139 AB	2.4	5.3	4	A
Q-Q-Q-Q	none	6	249.0	283.3	266 AB	4.8	8.3	7	A

Untreated Control	none	7	331.5	274.5	303	A B	8.3	5.8	7	A
F-F-F-F	2x	8	119.5	155.0	137	A	3.3	8.8	6	A
F-F-F-F	none	9	437.8	506.8	472	A B	7.5	9.5	9	A
P-P-P-P	2x	10	130.0	244.3	187	A B	3.5	8.5	6	A
P-P-P-P	none	11	161.8	374.8	268	A B	5.3	6.3	6	A

*Values for a variable within a column followed by a common letter are not significantly different based on Tukey test (*P=0.05*). Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree).

2016			**Avg. Number of Chasmothecia**				**Ascospore Viability (%)**			
Fungicide rotation	**Post-harvest Oil^**	**Treatment**	**Lower canopy**	**Upper canopy**	**Combined canopy**		**Lower canopy**	**Upper canopy**	**Combined canopy**	
Q-Q-F-F	2x	1	21.3	15.0	21.3	B*	2.2	0.5	11.7	AB
F-Q-Q-F	2x	2	9.0	34.8	9.0	AB	0.0	5.0	4.5	AB
F-F-Q-Q	2x	3	25.8	61.8	25.8	AB	1.5	3.8	13.6	AB
F-F-F-Q	2x	4	51.5	41.5	51.5	AB	1.8	3.3	26.6	AB
Q-Q-Q-Q	2x	5	65.0	60.0	65.0	AB	7.8	5.6	36.4	A
Q-Q-Q-Q	none	6	38.3	141.0	38.3	AB	1.7	4.8	20.0	AB
Untreated Control	none	7	99.0	234.3	99.0	A	3.2	5.8	51.1	AB
F-F-F-F	2x	8	7.5	10.5	7.5	B	0.0	0.6	3.8	B
F-F-F-F	none	9	10.0	17.3	10.0	B	1.0	3.0	5.5	AB
P-P-P-P	2x	10	18.3	52.3	18.3	AB	1.5	3.3	9.9	AB
P-P-P-P	none	11	33.0	79.8	33.0	AB	6.3	5.3	19.6	AB

*Values for a variable within a column followed by a common letter are not significantly different based on Tukey test (*P=0.05*). Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree).

c) Mite evaluation. Same as described for the commercial orchard in Pasco, WA.

Table 6. 2015: Experimental orchard Prosser, Mites/ leaf

2015		**Tetranychids/leaf**											
Treatment		**18-Jun**		**16-Jul**		**30-Jul**		**13-Aug**		**28-Aug**		**10-Sep**	
1		0.02	ab*	0.63	b	1.2	cd	10.63	abc	7.71	a	0.02	b
2		0	b	0.53	b	0.52	e	9.25	abc	7.7	a	0.05	ab
3		0	b	0.33	b	0.74	cde	6.12	c	9.73	a	0.08	ab
4		0.02	ab	0.71	b	0.78	cde	13.55	a	10.2	a	0.08	ab
5		0.07	a	0.56	b	0.96	cde	7.5	bc	10.19	a	0.15	a
6		0.01	b	0.77	b	0.81	cde	8.61	abc	13.82	a	0.02	b
Untreated 7	Control:	0.05	ab	0.43	b	1.32	bc	12.19	ab	7.55	a	0.02	b
8		0.02	ab	0.56	b	0.62	de	7.21	bc	8.7	a	0.01	b
9		0.01	b	1.19	ab	2.35	a	12.76	ab	11.62	a	0.01	b
10		0.04	ab	0.76	b	0.47	e	6.14	c	7.41	a	0	b
11		0	b	2.03	a	1.76	ab	11.08	abc	7.9	a	0	b
		Predatory mites/leaf											

Treatment	18-Jun		16-Jul		30-Jul		13-Aug		28-Aug		10-Sep	
1	0	a	0	a	0	a	0.11	a	0.01	a	0.04	b
2	0	a	0	a	0	a	0.02	a	0.05	a	0	ab
3	0	a	0	a	0	a	0.11	a	0.02	a	0.02	ab
4	0	a	0	a	0.01	a	0.02	a	0.05	a	0.03	ab
5	0	a	0	a	0.01	a	0.06	a	0.1	a	0.04	a
6	0	a	0	a	0.03	a	0.07	a	0.03	a	0.08	ab
Untreated Control: 7	0	a	0	a	0.02	a	0.01	a	0.02	a	0.06	ab
8	0	a	0	a	0.01	a	0.12	a	0	a	0.05	b
9	0	a	0	a	0.03	a	0.12	a	0.01	a	0.07	b
10	0.01	a	0	a	0.01	a	0.05	a	0.04	a	0.02	ab
11	0	a	0	a	0	a	0.13	a	0.04	a	0.05	ab
	Apple rust mites/leaf											
Treatment	**18-Jun**		**16-Jul**		**30-Jul**		**13-Aug**		**28-Aug**		**10-Sep**	
1	0	a	0	a	0	a	0	a	0	a	0	a
2	0	a	0	a	0	a	0	a	0	a	0	a
3	0	a	0	a	0	a	0	a	0	a	0	a
4	0	a	0	a	0.2	a	0	a	0	a	0	a
5	0	a	0	a	0	a	0	a	0	a	0	a
6	0	a	0	a	0	a	0	a	0	a	0	a
Untreated Control: 7	0	a	0	a	0	a	0	a	0	a	0	a
8	0	a	0	a	0	a	0	a	0	a	0	a
9	0	a	0	a	0	a	0	a	0	a	0	a
10	0	a	0	a	0	a	0	a	0	a	0	a
11	0	a	0	a	0	a	0	a	0	a	0	a

*Values for a variable within a column followed by a common letter are not significantly different based on Waller test (*P=0.05*). Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree).

Table 7, 2016: Experimental orchard Prosser, Mites/ leaf

	Tetranychids/leaf													
Treatment	**16-Jun**		**30-Jun**		**14-Jul**		**28-Jul**		**11-Aug**		**25-Aug**		**8-Sep**		**22-Sep**	
1	0	a	0	a	0	a	0	a	0.01	a	0.12	a	0	a	0	a
2	0	a	0	a	0	a	0	a	0	a	0.05	a	0.02	a	0	a
3	0	a	0	a	0	a	0	a	0.02	a	0.04	a	0.03	a	0	a
4	0	a	0	a	0	a	0	a	0	a	0.02	a	0.01	a	0	a
5	0	a	0	a	0	a	0	a	0.01	a	0.03	a	0	a	0	a
6	0	a	0	a	0	a	0	a	0	a	0.04	a	0.01	a	0	a
Untreated Control: 7	0	a	0	a	0	a	0	a	0	a	0.09	a	0	a	0	a
8	0	a	0	a	0	a	0	a	0.01	a	0.03	a	0	a	0	a
9	0	a	0	a	0	a	0	a	0.02	a	0.1	a	0	a	0	a
10	0	a	0	a	0	a	0	a	0	a	0.25	a	0.03	a	0	a
11	0	a	0	a	0	a	0	a	0	a	0.02	a	0.01	a	0	a
	Predatory mites/leaf													

Treatment	16-Jun		30-Jun		14-Jul		28-Jul		11-Aug		25-Aug		8-Sep		22-Sep	
1	0.01	a	0	a	0	a	0	a	0.02	a	0.3	abcd	0.57	a	0.13	a
2	0	a	0	a	0	a	0	a	0	a	0.06	d	0.37	a	0.21	a
3	0	a	0	a	0	a	0	a	0	a	0.07	cd	0.91	a	0.11	a
4	0	a	0	a	0	a	0	a	0.01	a	0.31	abc	0.4	a	0.15	a
5	0.02	a	0	a	0	a	0.01	a	0.09	a	0.24	bcd	0.49	a	0.05	a
6	0	a	0	a	0	a	0	a	0	a	0.1	cd	0.67	a	0.14	a
Untreated Control: 7	0	a	0	a	0	a	0	a	0.01	a	0.5	a	0.56	a	0.16	a
8	0	a	0	a	0	a	0	a	0	a	0.42	ab	1.26	a	0.13	a
9	0	a	0	a	0	a	0	a	0	a	0.37	ab	0.53	a	0.02	a
10	0	a	0	a	0	a	0	a	0.01	a	0.22	bcd	0.49	a	0.12	a
11	0	a	0	a	0	a	0	a	0.02	a	0.2	bcd	0.81	a	0.13	a

Apple rust mites/leaf

Treatment	16-Jun		30-Jun		14-Jul		28-Jul		11-Aug		25-Aug		8-Sep		22-Sep	
1	0.2	b	0	a	0	a	15.0	ab	117.8	ab	28.2	a	15.8	b	0	a
2	0.6	b	0	a	0	a	9.0	b	91.4	b	81.8	a	36.8	ab	0.4	a
3	0.6	b	0	a	0	a	13.2	ab	108.8	ab	77.2	a	66.2	a	0	a
4	0	b	0	a	0	a	12.6	ab	100.1	ab	73.6	a	10.2	b	0	a
5	2.4	ab	0	a	0	a	7.8	b	79.2	b	60.4	a	26.6	ab	1	a
6	4.8	a	0	a	0	a	21.6	ab	121.6	ab	59.2	a	15.0	b	0.8	a
Untreated Control: 7	0	b	0	a	0	a	47.6	a	150.0	ab	94.0	a	14.6	b	0	a
8	0.4	b	0.2	a	0	a	7.0	b	55.2	b	100.8	a	13.6	b	0	a
9	0	b	0	a	0.4	a	23.8	ab	201.1	a	120.8	a	13.0	b	0	a
10	0.2	b	0	a	0	a	19.6	ab	112.0	ab	106.2	a	12.2	b	0	a
11	0.8	b	0	a	0	a	38.4	ab	145.6	ab	45.4	a	4.0	b	0	a

Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree). *Values for a variable within a column followed by a common letter are not significantly different based on Waller test (*P=0.05*)

Approach 2: Pre-harvest fungicide rotations using Quintec (Tables 8-10)
A)Experimental orchard in Prosser, WA

Table 8, 2014: Effect of fungicide rotations on sweet cherry powdery mildew incidence and severity on leaves - 2014

2014 TMT #	Pre-harvest Fungicide rotation*	Powdery mildew Severity (%)** Upper canopy		Lower canopy		Combined	
1	Q-Q-F-F	65	AB	14	BC	40	AB
2	F-Q-Q-F	47	AB	13	C	30	B
3	F-F-Q-Q	55	AB	18	BC	37	AB
4	F-F-F-Q	40	B	15	B	28	B
5	Q-Q-Q-Q	44	AB	31	AB	38	AB
6	Q-Q-Q-Q	53	AB	27	ABC	40	AB
8	F-F-F-F	49	AB	20	BC	35	B
9	F-F-F-F	53	AB	27	ABC	40	AB

10	P-P-P-P	60	AB	26	ABC	43	AB
11	P-P-P-P	45	AB	11	C	28	B
7	None	68	A	40	A	54	A

*Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree). Fungicide application dates: 4-30, 5-14, 5-28, 6-10-2014.
** Disease evaluation date: 7/1/2014. Results are averages of four single tree replicates. Values for a variable within a column followed by a common letter are not significantly different based on Tukey's HSD test (*P=0.05*).

Table 9, 2015: Effect of fungicide rotations on sweet cherry powdery mildew and severity on foliage - 2015

2015 TMT #	**Pre-harvest Fungicide rotation ***	**Powdery mildew Severity (%) Upper canopy**		**Lower canopy**		**Combined**	
1	Q-Q-F-F	22	C	18	A	20	AB
2	F-Q-Q-F	21	C	10	A	15	B
3	F-F-Q-Q	21	C	5	A	13	B
4	F-F-F-Q	39	AB	8	A	23	AB
5	Q-Q-Q-Q	29	BC	10	A	19	AB
6	Q-Q-Q-Q	32	BC	6	A	19	AB
8	F-F-F-F	32	BC	4	A	18	B
9	F-F-F-F	24	BC	14	A	19	AB
10	P-P-P-P	19	C	12	A	16	B
11	P-P-P-P	22	C	8	A	15	B
7	None	50	A	14	A	32	A

*Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree). Fungicide application dates: 4/23/2015, 5/7/2015, 5/21/2015, 6/4/2015.
** Results are averages of four single tree replicates. Values for a variable within a column followed by a common letter are not significantly different based on Tukey's HSD test (*P=0.05*).

Table 10, 2016: Effect of fungicide rotations on sweet cherry powdery mildew incidence severity on leaves - 2016

2016 TMT #	Pre-harvest **Fungicide rotation***	Powdery mildew Severity (%) **Upper canopy**		**Lower canopy**		**Combined**	
1	Q-Q-F-F	19.2	A	7.4	AB	13.3	AB
2	F-Q-Q-F	13.6	A	1.4	B	7.5	B
3	F-F-Q-Q	16.8	A	4.6	B	10.7	AB
4	F-F-F-Q	10.6	A	3.8	B	7.2	B
5	Q-Q-Q-Q	20.4	A	4.3	B	12.4	AB
6	Q-Q-Q-Q	26.0	A	4.3	B	15.1	AB
8	F-F-F-F	11.6	A	2.1	B	6.8	B
9	F-F-F-F	12.1	A	2.5	B	7.3	B
10	P-P-P-P	16.2	A	2.9	B	9.5	AB
11	P-P-P-P	17.4	A	5.7	B	11.5	AB

7 None 21.4 A 15.2 A 18.3 A

*Q = Quintec 250SC, 7 fl oz/A, F = Fontelis, 20 oz/A, P = Pristine, 14.5 oz/A. Applied to run-off (400 gal/A = 1.5 gal per tree). Fungicide application dates: 4/21/2016, 5/5/2016, 5/20/2016, 6/2/2016.

** Results are averages of four single tree replicates. Values for a variable within a column followed by a common letter are not significantly different based on Tukey's HSD test (*P=0.05*).

Objective 3. Approach and Results. Various (FRAC Groups 3, 7, 11, and 13) fungicide modes of action were evaluated for their potential to reduce the amount of chasmothecia produced on infected foliage. All mode-of-action experiments were conducted in cherry nurseries in Central Washington (Tables 11-18).

Table 11. List of fungicides used in objective 3.

Fungicide – Trade name	**Common Name**	**FRAC Number**	**Chemical Class**	**Mode of action**
Quintec	quinoxyfen	13	aryloxyquinoline	Mechanism unknown
Fontelis	penthiopyrad	7	SDHI	Complex II: succinate dehydrogenase
Procure	triflumizole	3	DMI-imidazole	C14-demethylase in sterol biosynthesis (*erg11/cyp51*)
Serenade	*Bacillus subtilis*	44	microbial	Microbial disruptors of pathogen cell membranes
Luna Sensation	fluopyram/trifloxystrobin	11/7	Qol and SDHI	Complex III: cytochrome bc1 (ubiquinol oxidase) at Quinone outside site (*cyt b* gene)/ Complex II: succinate dehydrogenase
Luna Privilege	fluopyram	7	SDHI	Complex II: succinate dehydrogenase
GEM	triflloxystrobin	11	Qol	Complex III: cytochrome bc1 (ubiquinol oxidase) at Quinone outside site (*cyt b* gene)/

Products were applied at the following rates (sprayed to run-off = 400 gal/A): Quintec 250SC, 7 fl oz/A; Fontelis, 16 oz/A; Luna Sensation500C 5 oz/A; Serenade Optimum 16 oz/A; Procure480SC 16 oz/A; Luna Privilege 2.82 fl oz/A; GEM500SC 3.8 fl oz/A.

Table 12. Nursery Trial 1: Fungicide application schedule 2014 and 2015 (in Quincy, WA)

TMT #	**1st Application**	**2nd Application**	**3rd Application**	**4th Application**	**5th Application**
1	Quintec	Quintec	Quintec	Quintec	Quintec
2	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis
3	Procure	Procure	Procure	Procure	Procure
4	Serenade	Serenade	Serenade	Serenade	Serenade
5	Luna Sensation	Luna Sensation	Luna Sensation	Luna Sensation	Luna Sensation
6	Luna Sensation	Serenade	Luna Sensation	Serenade	Luna Sensation
7	Quintec	Quintec	Fontelis	Fontelis	Fontelis
8	Fontelis	Quintec	Quintec	Fontelis	Fontelis
9	Fontelis	Fontelis	Quintec	Quintec	Fontelis
10	Fontelis	Fontelis	Fontelis	Quintec	Quintec
11	Fontelis	Fontelis	Fontelis	Fontelis	Quintec

12	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis
13	Quintec	Procure	Quintec	Procure	Quintec
14	Untreated	Untreated	Untreated	Untreated	Untreated

Table 13. Fungicide application schedule **2016 (in Moses Lake, WA)** (Note: Treatment 2 and 4 were changed).

TMT #	**1st Application**	**2nd Application**	**3rd Application**	**4th Application**	**5th Application**
1	Quintec	Quintec	Quintec	Quintec	Quintec
2	GEM	GEM	GEM	GEM	GEM
3	Procure	Procure	Procure	Procure	Procure
4	Luna Privilege	Luna Privilege	Luna Privilege	Luna Privilege	Luna Privilege
5	Luna Sensation	Luna Sensation	Luna Sensation	Luna Sensation	Luna Sensation
6	Luna Sensation	Serenade	Luna Sensation	Serenade	Luna Sensation
7	Quintec	Quintec	Fontelis	Fontelis	Fontelis
8	Fontelis	Quintec	Quintec	Fontelis	Fontelis
9	Fontelis	Fontelis	Quintec	Quintec	Fontelis
10	Fontelis	Fontelis	Fontelis	Quintec	Quintec
11	Fontelis	Fontelis	Fontelis	Fontelis	Quintec
12	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis
13	Quintec	Procure	Quintec	Procure	Quintec
14	Untreated	Untreated	Untreated	Untreated	Untreated

Table 14. Powdery mildew severity in fungicide mode-of-action studies in Central WA nurseries 2014.

2014	**Powdery Mildew Disease Severity**			
Treatment	**Fungicide Rotation**	**8/18/2014**	**8/28/2014**	**9/7/2014**
1	Quintec only	0.0	0.3 A	2.6 A
2	Fontelis only	0.0	0.3 A	1.9 A
3	Procure only	0.0	0.2 A	2.3 A
4	Serenade only	0.0	0.2 A	2.1 A
5	Luna Sensation only	0.0	0.2 A	1.4 A
6	LunaS-S-LunaS-S-LunaS	0.0	0.2 A	2.0 A
7	Q-Q-F-F-F	0.0	0.4A	1.7 A
8	F-Q-Q-F-F	0.0	0.4 A	2.3 A
9	F-F-Q-Q-F	0.0	0.4 A	2.4 A
10	F-F-F-Q-Q	0.0	0.6 A	2.3 A
11	F-F-F-F-Q	0.0	0.5 A	2.2 A
12	F-F-F-F-F	0.1	1.3 B	1.8 A
13	Q-Pr-Q-Pr-Q	0.2	1.7 B	2.3 A
14	Untreated control	0.2	2.0 B	2.1 A

Table 15. Powdery mildew incidence and severity in fungicide mode-of-action studies in Central WA nurseries 2015.

2015

Treatment	Fungicide Rotation	6/27/2015		7/28/2015		8/14/2015	
1	Quintec only	0	A	54.255	AB	54.3	AB
2	Fontelis only	0	A	57.125	AB	57.1	A
3	Procure only	0	A	53.125	A	53.1	AB
4	Serenade only	0	A	53.87	AB	53.9	AB
5	LunaS only	0	A	48.5	B	48.5	B
6	LunaS-S-LunaS-S-LunaS	0	A	52.68	AB	52.7	AB
7	Q-Q-F-F-F	0	A	52.6	AB	52.6	AB
8	F-Q-Q-F-F	0	A	52.45	A	52.5	AB
9	F-F-Q-Q-F	0	A	52.55	AB	52.6	AB
10	F-F-F-Q-Q	0	A	54.425	AB	54.4	AB
11	F-F-F-F-Q	0	A	52.7	AB	52.7	AB
12	F-F-F-F-F	0	A	52.55	AB	52.6	AB
13	Q-Pr-Q-Pr-Q	0	A	54.74	AB	54.7	AB
14	Untreated control	0	A	52.87	AB	52.9	AB

Table 16. Powdery mildew incidence and severity in fungicide mode-of-action studies in Central WA nurseries 2016.

2016	Powdery Mildew Disease Severity								
Treatment	**Fungicide Rotation**	**8/8/2016**		**8/22/2016**		**8/31/2016**		**9/19/2016**	
1	Q-Q-Q-Q-Q	0.17	A	3.73	BCD	4.12	ABC	47.6	BCDE
2	Gem-Gem-Gem-Gem-Gem	0.07	A	1.89	CD	1.66	C	44.905	CDEF
3	Pr-Pr-Pr-Pr-Pr	0.19	A	2.61	BCD	4.785	ABC	56.64	A
4	LunaP-LunaP-LunaP-LunaP-LunaP	0.3	A	3.365	BCD	6.125	AB	53.68	BC
5	LunaS-LunaS-LunaS-LunaS-LunaS	0.01	A	1.23	D	3.045	BC	40.25	EF
6	LunaS-S-LunaS-S-LunaS	0.18	A	4.795	B	4.81625	ABC	56.48	AB
7	Q-Q-F-F-F	0.175	A	3.725	BCD	4.58	ABC	46.3	CDEF
8	F-Q-Q-F-F	0.1	A	4.355	BC	3.4425	BC	50.55	ABCD
9	F-F-Q-Q-F	0.12	A	3.5	BCD	2.995	BC	38.575	F
10	F-F-F-Q-Q	0.09	A	3.075	BCD	3.6	BC	52.8	ABC
11	F-F-F-F-Q	0.03	A	2.235	BCD	5.09	B	48.135	ABCDE
12	F-F-F-F-F	0.115	A	2.8	BCD	7.2	A	50.05	ABCD
13	Q-Pr-Q-Pr-Q	0.16	A	3.415	BCD	4.47	ABC	45.875	CDEF
14	Untreated control	0.09	A	7.6425	A	7.35	A	42.375	DEF

Table 17. Effect of fungicide program on chasmothecia production and ascospore viability in Central WA nurseries 2015 and 2016.

2015					
Treatment	Fungicide Rotation	Avg. Number of Chasmothecia		Ascospore Viability (%)	
1	Quintec only	1068.7	ABC	16.5	AB
2	Fontelis only	N/A		N/A	
3	Procure only	N/A		N/A	
4	Serenade only	1149.35	AB	18.25	AB

5	Luna Sensation only	295.2	C	10.25	B
6	LunaS-S-LunaS-S-LunaS	445.85	BC	10.75	AB
7	Q-Q-F-F-F	824.7	ABC	23	AB
8	F-Q-Q-F-F	951.2	ABC	13.5	AB
9	F-F-Q-Q-F	981	ABC	18	AB
10	F-F-F-Q-Q	1071.4	ABC	18.5	AB
11	F-F-F-F-Q	830.75	ABC	15.25	AB
12	F-F-F-F-F	877.15	ABC	19	AB
13	Q-Pr-Q-Pr-Q	1151.55	AB	17.75	AB
14	Untreated control	1427.95	B	26.25	A

2016					
Treatment	Fungicide Rotation	Avg. Number of Chasmothecia		Ascospore Viability (%)	
1	Quintec only	11.8	AB	4.6	A
2	Gem only	9.3	B	1.7	A
3	Procure only	71.0	AB	5.6	A
4	Luna Privilege only	25.0	AB	6.8	A
5	Luna Sensation only	7.8	B	5.8	A
6	LunaS-Serenade - LunaS-Serenade-LunaS	131.8	A	9.0	A
7	Q-Q-F-F-F	29.0	AB	7.9	A
8	F-Q-Q-F-F	63.3	AB	6.8	A
9	F-F-Q-Q-F	27.8	AB	4.5	A
10	F-F-F-Q-Q	36.3	AB	7.9	A
11	F-F-F-F-Q	22.8	AB	3.1	A
12	F-F-F-F-F	42.5	AB	4.5	A
13	Q-Luna Privlege-Q-Luna Privlege-Q	29.0	AB	2.8	A
14	Untreated control	92.8	AB	8.0	A

Table 18. Effect of Bacillus subtilis (Serenade), Bacillus pumilis (sonata), EO water, plant activator (Actigard) and SDHI on chasmothecia number in Quincy nursery 2015
1Sprays were applied at 14-day intervals beginning at the first signs of powdery mildew
2 Number of chasmothecia obtained from 1 gram of ground leaf tissue
3Means followed by the same letter are not significantly different according to GLM procedure LSD test at $p<0.05$

Treatment[1]	**Chasmothecia Number**[2]	**% Chasmothecia viable**
EO water	210b[3]	4.5c
Serenade	1149ab	18.25ab
Luna sensation	446b	10.75bc
Actigard	3789a	16abc
Sonata	1106 ab	24.25a
Luna sensation +Serenade	459b	10.25bc
Untreated	1428ab	28.25a

Objective 4 Approach and Results (Tables 19-22). Identification of critical spray timings for interruption of chasmothecia formation by quinoxyfen applications applied 100 through 1200 growing degree days after the first observance of powdery mildew signs. Fontelis (penthiopyrad) was applied at all other times in the spray regimes. *The timing of application of quinoxyfen did not significantly affect chasmothecia formation in 2015 and 2016 (Tables 21 and 22). Applications at 1200 cumulative degree days significantly reduced chasmothecia numbers in 2014 (Table 20).*

Table 19. Fungicide application schedule (moving quinoxyfen application). GDD = degree day thresholds (base 50) following identification of initial symptoms.

TMT #	First symptoms	100GGD	200GGD>	400 GGD	800 GGD	1200 GGD
15	Quintec	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis
16	Fontelis	Quintec	Fontelis	Fontelis	Fontelis	Fontelis
17	Fontelis	Fontelis	Quintec	Fontelis	Fontelis	Fontelis
18	Fontelis	Fontelis	Fontelis	Quintec	Fontelis	Fontelis
19	Fontelis	Fontelis	Fontelis	Fontelis	Quintec	Fontelis
20	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis	Quintec
21	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis
22	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis	Fontelis
23	Untreated	Untreated	Untreated	Untreated	Untreated	Untreated

Table 20. Effect of quinoxyfen application timing on chasmothecia production and ascospore viability in Central Washington nurseries, 2014. The initial quinoxyfen applications were made according to various cumulative degree day thresholds (base 50) between 100 and 1600 (after the initial appearance of powdery mildew signs).

Timing of Initial Quinoxyfen Application	Chasmothecia Production
Initial signs of powdery mildew	591.2 AB
100 CDD[1] > 50 F	594.5 AB
200 CDD > 50 F	826.2 A
400 CDD > 50 F	549.2 B
1200 CDD > 50 F	731 A
1600 CDD > 50 F	564.5 B
None (penthiopyrad only)	546 B
Untreated	600.8 A

[1] = cumulative degree days (base 50 F) from initial observance of symptoms.

Table 21. Effect of quinoxyfen application timing on chasmothecia production and ascospore viability in Central Washington nurseries, 2015.

2015					
Treatment	Fungicide Rotation	Avg. Number of Chasmothecia		Ascospore Viability (%)	
15	Q-F-F-F-F-F-F	1052.3	A	18.3	A
16	F-Q-F-F-F-F-F	1536.2	A	22.5	A
17	F-F-Q-F-F-F-F	1494.8	A	16.3	A
18	F-F-F-Q-F-F-F	1324.7	A	18.8	A
19	F-F-F-F-Q-F-F	1335.3	A	18.0	A
20	F-F-F-F-F-Q-F	1602.8	A	17.0	A

21	F-F-F-F-F-F-Q	1342.6	A	25.0	A
22	F-F-F-F-F-F-F	1389.2	A	18.0	A
23	Untreated Control	1489.6	A	14.7	A

Table 22. Effect of quinoxyfen application timing on chasmothecia production and ascospore viability in Central Washington nurseries, 2016.

2016					
Treatment	Fungicide Rotation	Avg. Number of Chasmothecia	Ascospore Viability (%)		
15	Q-F-F-F-F-F-F	11.8	A	3.4	A
16	F-Q-F-F-F-F-F	23.0	A	2.2	A
17	F-F-Q-F-F-F-F	10.5	A	2.5	A
18	F-F-F-Q-F-F-F	12.5	A	4.2	A
19	F-F-F-F-Q-F-F	38.0	A	3.8	A
20	F-F-F-F-F-Q-F	36.3	A	7.2	A
21	F-F-F-F-F-F-Q	29.0	A	4.3	A
22	F-F-F-F-F-F-F	21.5	A	2.4	A
23	Untreated Control	28.8	A	3.4	A

Van Well Nursery provided multiple plot locations during all years of the study. Nursery personnel conducted all IPM (other than fungicide applications) and horticultural support in the multiple plots. A total of 6 plot years were provided. Each plot was about 0.5 acre in area.

Tree Fruit Research and Extension Center. TFREC provided laboratory space connected with the insect aspects of the study.

Washington Tree Fruit Research Commission. Provided matching support for the project via projects "Factors Affecting the Fruit Phase of Powdery Mildew of Cherry".

Oregon Sweet Cherry Commission. Provided matching support for the project via projects "Factors Affecting the Fruit Phase of Powdery Mildew of Cherry".

JMS Flower Farms. Donated JMS Stylet oil for all aspects of the project.

Wilbur-Ellis Incorporated. Wilbur-Ellis assisted with the identification of commercial study orchards in Wenatchee and Pasco. Wilbur-Ellis personnel and associates assisted with fungicide applications during years 1 and 2 of the study.

Hayden Farms. Provided land, equipment, and labor and applied treatments to large multiple acreage plots during all years of the study. This aspect of the project focused on application of horticultural oils after harvest. Chasmothecia and mite data were collected by project personnel during all years of the study.

This project did not benefit non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

The primary outcome of this project was to demonstrate to the cherry industry that management of powdery mildew requires the management of two separate but related epidemics: management of the disease on fruit to ensure farm gate in any given year, and management of the foliar phase to reduce disease pressure in the following and subsequent year(s). Measurable outcomes included evolution in powdery mildew management practices and a framework for overall improvement in fungicide resistance management approaches (through deployment of specific fungicide modes of action at key

epidemiological times). A significant outcome was the demonstration that the use of narrow range petroleum oils did not disrupt or aggravate the overall IPM (e.g. mites) system.

Goal(s): Evaluation of timings of various fungicide modes of action for disruption of chasmothecia formation. Various phenological or weather based applications of quinoxyfen did not reveal a critical spray timing. The effects of applying the initial quinoxyfen spray according to various degree day thresholds (following the initial appearance of symptoms) were insignificant.

Goal: Determine the effect of various fungicide modes-of action on chasmothecia production. Only Luna Sensation (fluopyram + trifoloxystrobin) and Gem (trifloxystrobin) significantly reduced chasmothecia studies. Luna Privilege (fluopyram) did not, indicating that activity was due to the trifloxystrobin components. However four applications were needed, more than FRAC guidelines for managing resistance to QoI compounds. Alternations of QoI + biologicals (Serenade) did not inhibit chasmothecia formation.

The industry-wide change in management approaches is a long-term endeavor. Results of this project provided knowledge on the effectiveness of QoI fungicides for reducing chasmothecia formation, the relative ineffectiveness of full season programs (standard preharvest + postharvest oil applications) on the potential reduction of overwintering inoculum, and the potential disruption of the overall IPM system (mites) by those full season programs. The project demonstrated that some fungicide modes of action (e.g. QoI) were more effective in preventing chasmothecia formation than others but their adoption in orchards for use in this matter would be counter to current resistance management strategies. However, a positive outcome of the studies was that postharvest oil applications did not increase applications of deleterious mites.

Proposed Activity	**Accomplished Activity**	**Comments**
Industry survey	Survey complete 10/14	Poor survey response
Fungicide mode of action studies	Trials conducted 2014-2016	QoI and electrolyzed water class were identified as efficacious in reducing chasmothecia populations.
Fungicide timing studies	Trials conducted 2014-2016	Various timings of quinoxyfen applications in calendar and weather-driven programs were demonstrated as ineffective in reducing chasmothecia numbers.
Evaluation of full season synthetic/oil programs in reducing chasmothecia numbers	Trials conducted 2014-2016	Full season programs were inconsistent in reducing chasmothecia numbers but did not aggravate mite problems or disrupt the overall IPM system.
Economic analyses	End of project	Costs of full-season programs that conformed to FRAC guidelines were compared; non-compliant programs were considered unsustainable.

Survey results revealed a marginal understanding of disease biology and a potential conflict of interest vis a vis disease recommendations. The results of the experiments were encouraging in some respects but inconsistent in others. For example, experimental differences evident in experimental versus commercial orchards, and differences between lower and upper tree canopies, indicate that various application technologies should be evaluated. Furthermore, the performance of some key synthetic fungicides was mediocre in experimental orchard studies; a resistance survey is warranted. Efficacy data has been shared with industry. Positive results include the identification of QoI and electrolyzed as potential candidates for inhibiting chasmothecia formation in subsequent studies.

BENEFICIARIES

The utility of QoI and oil fungicides for reducing chasmothecia populations were demonstrated in some of the nursery studies. Furthermore, contrary to popular opinion postharvest oil treatments in orchards did not result in additional challenges with mites. In addition, the efficacy of QoI and electrolyzed water fungicide classes was confirmed during the course of the study and some rotational combinations provided reductions in disease severity and chasmothecia production. Cherry growers in the Western US will benefit because of the increased understanding of various fungicide modes of action and the incorporation of "soft" products (e.g. oils and electrolyzed water).

Adoption of additional chemistries will improve disease and fungicide resistance management. QoI fungicides are critical components of preharvest programs and due to resistance concerns additional applications postharvest would not conform to resistance management guidelines. Petroleum oils have far lower resistance risk and are therefore the most logical additions to full season programs. However, oil performance in the orchard studies was inconsistent (significant reductions in chasmothecia numbers on 2014, insignificant in 2015-16).

Nursery programs that included 3 late season oil applications significantly reduced late season disease incidence and severity and chasmothecia numbers. Oil regimens (using a generic narrow-range petroleum oil) of this sort would increase disease management costs from $200 to $224 per acre per season. The ability of such regimens to delay disease onset in orchards in spring needs to be demonstrated before the approach should be adopted as an industry-wide practice.

Chasmothecia numbers were not reduced by full-season orchard programs that conformed to resistance management guidelines. Furthermore, the inclusion of oils in such programs increased disease management costs from $200 to $224 per acre per season. QoI compounds were effective in reducing chasmothecia but their utilization in full season programs would not conform to resistance management guidelines and would therefore risk product availability over time and increase disease management costs to > $300 per acre season.

LESSONS LEARNED

WSU had originally attempted to demonstrate delayed disease onset in commercial settings. The experience proved that much larger commercial plot sizes were required and that growers were hesitant to include untreated controls in plots. Therefore, the epidemiological conclusions, hoped to demonstrate will require a (at least 5 acre) research orchard planted on dwarfing roostocks. Dwarf trees would help to reduce the variability in spray coverage.

In nursery plantings the effect of spray interval on chasmothecia formation and disease severity was critical. For example, electrolyzed water (one of the most promising treatments) was effective when applied at 7 day intervals and ineffective if applied biweekly.

The efficacy of electrolyzed water and the QoI components of Luna Sensation and QoI Gem for reducing chasmothecia numbers was an unexpected but a positive outcome.

It was also discovered that more chasmothecia were produced in the upper (rather than lower) portions of tree canopies. Several factors may account for this including light penetration, spray coverage, and other environmental factors.

Narrow-range petroleum oils did not consistently reduce chasmothecia numbers when used as the postharvest component of full-season management programs in orchards. However, the oil applications did not result in significant increases in deleterious mites at either sites over the three-year study.

The purpose of this project was to develop an economically viable and sustainable approach to temporally extend the disease management window to minimize mid to late-season chasmothecia formation (= overwintering structures which can discharge ascospores in the spring) and as a result lower disease pressure over time. Reducing the amount of chasmothecia and the viability of ascospores should consequently lead to a reduction in primary inoculum in the spring. However, full season fungicide programs need to be appropriately designed in order to be economically feasible and in a fashion that will not put increased resistance selection pressure on essential synthetic fungicides. The interest in post-harvest disease control has increased steadily in the past years and this study addresses questions frequently asked by growers in both Washington and Oregon State. By contrasting different management approaches (e.g. extended fungicide sprays or post-harvest oil

applications) efficacy of QoI and electrolyzed water fungicide and fungicide mixes to reduce chasmothecia production was demonstrated.

A thorough economic analysis of new program types was not completed due to the limited efficacy and biologically unsustainable nature of various programs.

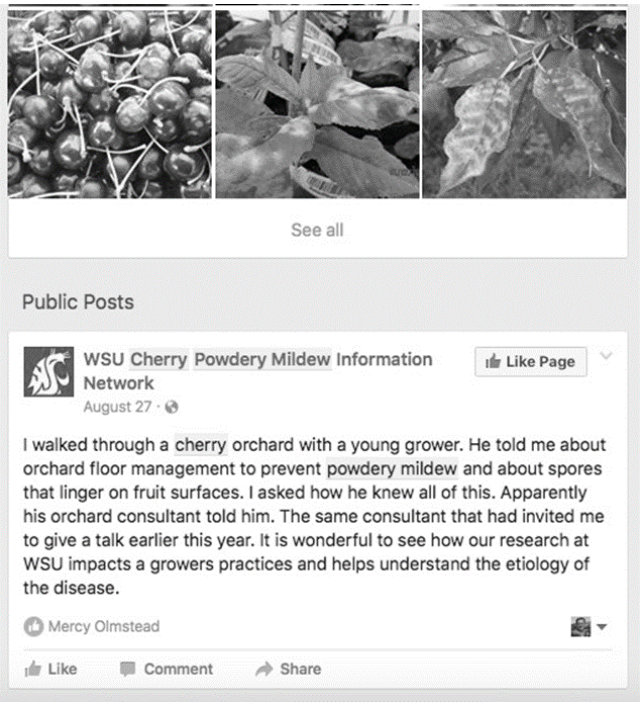
ADDITIONAL INFORMATION

Washington Tree Fruit Research and Oregon Sweet Cherry Commissions. These entities provided $191,415 for parallel studies under proposal "Factors Affecting the Fruit Phase of Cherry Mildew" and $140,000 for project "Podosphaera clandestina viability during post-harvest handling of sweet cherry fruit".

Van Well Nursery. Provided (in-kind) two, 1-acre plots during each year of the study and provided weed and insect control and water during the three years of the study.

Hayden Orchards. Provided (in-kind) 10 acre plots during all years of the study and covered all costs related to general horticulture and plant vigor, irrigation, insect management, and applied all postharvest fungicide applications.

A Facebook page on the disease was established in 2015 and will become the primary source of timely disease management information.



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Mildew threatens cherries all season. GoodFruit Grower Cherry Issue (Diseases) February 15th 2015 Issue.

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PROJECT #16

Project Title: Early maturing Dry Beans for Specialty Markets in Western Washington

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

For decades processing peas were a vital part of rotations in many western Washington counties. Today the industry and tens of thousands of acres of peas are gone. Farmers are looking for a legume to add to their rotations. Ideally this legume would require minimal, or no, processing and have value within local markets both economically and nutritionally. Dry beans fit this description very well. What is required to make them a success is identifying varieties that are early maturing, disease resistant and have excellent cooking and nutritional quality. This project's strategy is to utilize farmer knowledge to establish a collection of beans that have done well in western Washington to get a quick start on variety choice. This collection (which is at hand thanks to startup funding from the Port of Skagit and the Northwest Agricultural Research Foundation) will be combined with early maturing types that were sourced from germplasm collections and will be trialed in multiple locations so that recommendations can be made to growers on variety choice and planting date.

These needs are immediate. In 1990, 14,880 acres of peas were grown for processing in Skagit County alone (McMoran 2008), and today there are zero acres due to the loss of key processing facilities. The loss of peas is common up and down western WA, leaving a void in conventional and organic farming systems. Dry beans have the potential to fill a legume role in crop rotations, however, unlike processing peas, dry beans may be marketed directly to meet rapidly increasing demand for locally produced crops.

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

PROJECT APPROACH

Dry bean germplasm was obtained from 5 public breeding programs: University of California, Davis (n=6); Michigan State University (n=12), North Dakota State University (n=9), Oregon State University (n=2); and USDA breeding program in Prosser, WA (n=11). Early maturing varieties were specifically requested from within major commodity market classes. In addition, commercially available varieties were purchased (n=18) and seed of locally grown heirloom varieties was obtained (n=5). In total 61 entries (2014) and 55 entries (2015 and 2016) were evaluated in the Skagit observational trial and 10 commercially available varieties were grown in the replicated yield trial (2014, 2015, and 2016).

Five growers were contacted and confirmed that they were willing to host on-farm trials in Skagit, Whatcom, Thurston, San Juan, and Island Counties. These sites represent diverse production systems and climates within western Washington.

Modifications were made to a custom built cone planter in order to mechanically seed trial plots and an appropriately sized combine sieve was ordered to enable direct mechanical harvest of plots.

Planned field trials were planted all three years with 2 replicates of 10 entries in 4 on-farm trials as well as 2 replicates of 60 entries in Skagit County. Planting dates ranged from May 14th to June 9th. Trials at WSU Mount Vernon were machine planted using a modified Allis Chalmers planting tractor in rows on 24 in centers. On-farm trials were hand planted to accommodate variation in row width and field size. Percent emergence was noted in all trials. Farmer-collaborators managed soil fertility, assisted with weed control, and provided irrigation at on-farm trials.

Notes on height and maturity range were taken on all trials. Further notes were taken on plant architecture and general appearance of the plants and pods. All field trials were harvested within a one month period. Trials were harvested sequentially to account for different maturities. Skagit County trials were harvested using a Wintersteiger plot combine. On-farm trials were harvested by hand and then threshed using the plot. Weed seed was cleaned from samples using a wind machine. Samples were weighed and yield was calculated based on plot size and estimated on a per acre basis.

Differences between the highest and lowest yielding lines amounted to several thousand lbs. per acre, which can translate immediately into thousands of dollars per acre. Differences in days to maturity between the earliest and latest maturing lines

was as high as 34 days, which is significant for western WA where there are frequently early fall rains that can prevent a successful harvest. Project members are not comfortable making direct varietal recommendations, but instead present results from all trials for farmers to read and determine which varieties will perform best in their system. Preliminary data for the yield trial and observation trial are available at the end of this report in the Additional Information section.

Dr. Stephen Jones, director of the Bread Lab and professor at WSU-NWREC oversaw the project. Jeanne Burritt, the administrative manager at WSU-NWREC oversaw the budget. Dr. Brook Brouwer collected germplasm, developed the experimental design, and planted and maintained the first year of the trial for his PhD project. Brigid Meints conducted the experiments in the second and third year, and performed all data collection and analysis as part of her PhD project. Farmers in Skagit, San Juan, Island, Thurston, Whatcom, and Jefferson Counties allowed the use of their land for the trials.

This project does not benefit non-specialty crops.

GOALS AND OUTCOMES ACHIEVED

In May of each year, yield trials and observational trials were planted in multiple counties in western WA. The yield trials consisted of 10 commercially available varieties from several market classes in a randomized complete block design with two replicates at four or five counties (Skagit, Whatcom, Island, San Juan, Thurston, and Jefferson). The observational trial consisted of 55-61 lines (heirlooms, commercially available varieties, and breeding lines) planted in a randomized complete block design with two replicates in Skagit County. During the growing season, notes were taken on percent emergence, days to maturity, plant height, general appearance, and whether disease pressure was present. Lodging and amount of defoliation prior to harvest were also measured in 2016. The Skagit County trials were harvested directly using a combine. Trials in other counties were harvested by hand into gunny sacks and threshed using the same combine. After harvest was completed, yield, moisture, hundred bean weight, and the percentage of split and moldy beans was measured. Samples were sent to other labs for mineral and phytic acid analysis. These trials were the heart of this project and the valuable notes that were recorded on each line will serve to inform farmers on the quality of early-maturing varieties.

As a result of this project, an expected long term outcome was to increase the acreage of dry beans in productions in western Washington. However, as this is difficult to measure, it was not strictly quantified.

Each year, dry bean variety trial data was posted to the Bread Lab website (http://thebreadlab.wsu.edu/western-washington-variety-trials/) and shared with growers at annual field days in order to make progress towards this outcome.

The main goal of this project was to identify early maturing dry bean varieties suitable for direct marketing in western WA resulting in increased production. In order to accomplish this, activities included germplasm collection and field trials in five counties in western WA, with evaluation of agronomic and quality traits. This goal was successfully accomplished through the field trials and post-harvest analysis.

A survey of farms in western WA conducted in 2013 to collect information on bean types grown in the past 100 years that perform well in cool maritime climates, had over 90 respondents from 14 counties who indicated that they were currently growing or interested in growing dry beans. However, because of a lack of regional variety testing for dry beans, growers are at a loss when it comes to varietal choice. Choice of variety can affect yield, which can affect profit. This trial introduced a regional variety testing project over a number of representative counties in western WA in order to provide growers with an idea of which varieties or heirlooms perform best in their region. These data are published and available for anyone to view. A survey is currently ongoing to provide quantitative data on the number of growers who found this research useful.

BENEFICIARIES

The farmers who hosted the on-farm trials gained the greatest benefit from this trial. All farms included in this trial are practicing, or certified, organic. Because organic farming practices are so diverse, on-farm trials are the best way to determine which varieties will be most successful at that spot. Therefore, the farmers who hosted trials can look at the data and learn which varieties performed best on their farm. However, this project can benefit anyone interested in growing dry beans at any scale of production in western WA. The counties that hosted the trials ranged from the South Sound to the North Sound to the Islands, allowing farmers to extrapolate the results to their area based on whichever trial spot is most similar.

The quantitative results from this trial are summarized in the "Additional Information section" below. Differences between the highest and lowest yielding lines amounted to several thousand lbs. per acre, which can translate immediately into thousands of dollars per acre. Differences in days to maturity between the earliest and latest maturing lines was as high as 34 days, which is significant for western WA where there are frequently early fall rains that can prevent a successful harvest. Project members are not comfortable making direct varietal recommendations, but instead present results from all trials for farmers to read and determine which varieties will perform best in their system.

LESSONS LEARNED

Upon completion of the multi-county dry bean trials, project members were struck by the yield potential of dry beans in western WA. Although a maritime climate may not be the ideal location for growing dry beans due to cooler temperatures and early fall rains, the yields were comparable to dry beans grown in central WA, including the target early-maturing varieties.

In discussions with farmers about dry beans, project members realized that varietal choice is not the only issue holding back production. Many smaller farmers were interested in scaling up their production, but lacked appropriate infrastructure, including harvest and threshing equipment and drying facilities. These farmers are currently harvesting beans by hand and using primitive threshing methods that are not efficient for their system. While this research will provide useful varietal information, there remains a bottleneck for many farmers to increase production that will need to be solved before beans can become a widely grown crop in western WA.

Project members feel that despite some setbacks, this project was very successful in meeting the goal of identifying early-maturing varieties for western WA and are eager to begin using this information to begin breeding new varieties of dry beans.

Although dry beans are a primarily self-pollinating crop, there was a small percent of outcrossing between plots. These off-types were planted out and allowed to segregate. The next logical step in this project is to begin breeding new varieties of beans using early maturing types as parents in order to get other traits (disease resistance, seed coat color and pattern, growth habit, etc.) into an early maturing background to create more options for farmers in the future. With the outcrossing that occurred, the program was able to get a jumpstart on the breeding process when one of the parents of the off-types was identified as one of the early maturing heirlooms.

Another unexpected outcome was getting one of the beans trialed into a fine-dining restaurant in Seattle. One of the farmer partners began experimenting growing a few of the varieties on an acre each. The restaurant 'Canlis' is purchasing beans for their menu from this farmer. The bean dish was mentioned in a write-up by the Seattle Times: http://www.seattletimes.com/life/food-drink/timeless-yet-relevant-canlis-is-superb-under-new-chef/.

Each year of the project, project members had issues working with some of the farmer-collaborators. There were problems with on-farm management and poor communication that resulted in the loss of trials at some locations. Because of this, there are only results from 4 counties in year one and 3 counties in year two and three. On the other hand, several of the farmers were very easy to work with because they were invested in the research and supporting graduate students. Project members learned that for on-farm research it is very important to find farmers who are willing to work with researchers and understand the nature of research trials. Creating a bond between researcher and farmer was key to a successful trial. Another issue that came up when trying to complete the outlined activities was the timeline of the granting agency compared with the dry bean production timeline. The grant ended on September 29th, 2016. This project involved three growing seasons with post-harvest analysis in all three years. However, the final bean harvest was not completed until October 4th, 2016. Therefore, threshing, processing, and especially quality analysis were delayed until after the granting period ended. Because of this, the project members made the decision to postpone the final survey until after the year three data could be posted because they were not comfortable making variety recommendations until all data were available. This survey is now underway. Therefore, although the goal was met, the performance measure of how many farmers found the results useful has not yet been quantified.

ADDITIONAL INFORMATION

There were no cash donations contributed to this project. For In-Kind matches, WSU included in the proposal the following information on other resources available which are in support of similar research/activities undertaken by the Principal Investigator (PI). These resources are listed to identify other support for this research and are not included as a commitment of cost share by WSU. Unrecovered F&A from the PI's involvement is valued: Yr. 1—14,304, Yr. 2 – 14,725, Yr. 3 – 15,171.

Dry Bean Yield Trial across 4 counties in Western WA, 2014

Variety Name	Market Class	Yield (lb/A)	Clean yield (lb/A)	Plant height (cm)	Maturity rating (1-3)*	Emergence (%)	Hundred bean weight (g)
Island County							
Black coco	Black	612	587	32.5	1.0	80.6	53.8
CELRK	Kidney	808	805	37.5	2.0	76.4	59.6
Eclipse	Black	1493	1463	39.0	3.0	84.7	21.6
Etna	Cranberry	1600	1387	28.5	1.0	66.7	53.5
King of the early	Cranberry	1471	1399	39.5	1.0	83.3	60.2
Orca	Black and White	575	543	30.0	3.0	19.4	32.7
Silver cloud	White Kidney	629	569	41.5	3.0	55.6	57.2
Bright stone	Cranberry	1457	1421	32.0	1.5	80.6	41.2
Rockwell	Red and White	1396	1352	35.0	1.0	63.9	45.7
Whipolo	Cranberry	929	881	31.5	2.0	59.7	68.3
CV %		61.1	58.3	13.0	12.1	11.8	12.3
LSD (P=0.05)		1519	1372	10.2	0.5	17.7	13.7
Mean		1097	1040	34.7	1.9	66.7	49.4
Minimum		575	543	28.5	1.0	19.4	21.6
Maximum		1600	1462	41.5	3.0	84.7	68.3
San Juan County							
Black coco	Black	610	571	35.6	2.0	75.0	48.7
CELRK	Kidney	1270	1237	37.5	1.0	86.8	57.2
Eclipse	Black	53	52	36.2	3.0	81.9	16.9
Etna	Cranberry	1316	1043	37.5	1.0	84.0	46.9
King of the early	Cranberry	1149	1080	36.2	1.0	87.5	52.7
Orca	Black and White	29	26	36.8	3.0	89.6	31.0
Silver cloud	White Kidney	414	280	34.3	3.0	77.8	61.2
Franck kring	Cranberry	1158	1108	33.7	1.0	93.1	52.8
CV %		43.8	39.7	9.6	0.0	7.1	3.4
LSD (P=0.05)		777	634	8.2	0.0	14.2	3.7
Mean		750	675	36.0	1.9	84.5	46.9
Minimum		29	26	33.7	1.0	75.0	16.9
Maximum		1316	1237	37.5	3.0	93.1	61.2
Skagit County							
Black coco	Black	369	336	26.6	1.0	45.0	51.6
CELRK	Kidney	440	419	37.1	1.0	50.0	53.3
Eclipse	Black	991	985	31.6	2.0	87.5	22.1
Etna	Cranberry	961	877	26.9	1.0	77.5	57.3
King of the early	Cranberry	594	561	29.0	1.0	85.0	52.1
Orca	Black and White	340	273	36.3	3.0	12.8	32.8
Silver cloud	White Kidney	680	666	38.9	2.0	42.5	60.0
Baja chigaito	Small Red	1232	1222	40.8	2.0	72.5	22.9
CV %		48.8	50.7	14.3	0.0	22.6	3.5
LSD (P=0.05)		503	497	6.8	0.0	19.6	2.2
Mean		702	667	32.1	1.6	59.1	44.0
Minimum		340	273	26.6	1.0	12.8	22.1
Maximum		1232	1222	40.8	3.0	87.5	60.0
Thurston County							
Black coco	Black	3541	2687	53.5	1.0	78.5	59.9
CELRK	Kidney	4240	3759	58.5	1.0	91.0	64.8
Eclipse	Black	4123	3620	67.0	3.0	91.0	20.8
Etna	Cranberry	4439	2702	56.5	1.0	77.1	62.7
King of the early	Cranberry	4532	3851	59.5	1.0	91.7	62.9
Orca	Black and White	4857	4354	59.0	2.0	73.6	35.1
Silver cloud	White Kidney	4875	4299	70.5	2.0	92.4	74.4
Calypso	Black and White	3714	2964	54.5	1.0	87.5	55.5
CV %		32.2	37.3	10.1	0.0	7.9	5.7
LSD (P=0.05)		5263	5118	14.3	0.0	15.9	7.3
Mean		4288	3580	59.9	1.5	85.3	54.5
Minimum		3541	2687	53.5	1.0	73.6	20.8
Maximum		4875	4354	70.5	3.0	92.4	64.8

Dry Bean Yield Trial across 3 counties in Western WA, 2015

	Emergence (%)	Split (%)	Moldy (%)	Hundred Bean Weight (g)	Maturity (1-3 rating)	Height (in)	Moisture at harvest (%)	Yield (lb/A)
San Juan County								
Desert Song	25	34	11	26	2	13	20.8	318
Eclipse	45	15	9	15	2.5	13	32.6	240
Etna	50	32	16	48	2	11	35.0	253
Island	40	20	2	28	1	11	18.1	212
LRK	60	16	13	57	2.5	13	29.2	169
Orca	45	14	9	26	2	13	24.4	164
Rockwell	35	18	6	38	1.5	12	29.4	165
Rojo Chiquito	60	7	18	17	2	11	35.0	208
Sedona	30	27	6	27	2	12	26.2	203
King of the Early	50	21	18	51	2	14	35.0	125
CV (%)	**21.7**	**23.4**	**22.3**	**4.7**	**31.8**	**15.7**	**15.2**	**23.9**
LSD (p = 0.05)	**22**	--	--	--	**1.4**	**4**	**9.8**	**108**
Mean	**44**	**21**	**10**	**31**	**1.9**	**12**	**28.5**	**199**
Minimum	**25**	**7**	**2**	**15**	**1**	**11**	**18.1**	**52**
Maximum	**60**	**34**	**18**	**57**	**2.5**	**14**	**35.0**	**329**
Skagit County								
Desert Song	90	16	3	31	2	20	24.2	3644
Eclipse	93	2	2	21	3	21	24.6	3458
Etna	88	34	7	35	2	14	23.3	3961
Island	93	8	1	44	1	32	23.0	3218
LRK	90	23	3	60	1	18	21.2	2768
Orca	88	2	10	31	3	17	26.4	2142
Rockwell	95	12	2	49	1	18	21.0	2063
Rojo Chiquito	93	1	9	22	2.5	27	29.4	1965
Sedona	93	11	12	36	3	24	26.4	2555
King of the Early	90	11	6	54	1	18	24.2	3096
CV (%)	**4.8**	**33.8**	**57.6**	**4.5**	**11.5**	**15.9**	**13.9**	**26.2**
LSD (p = 0.05)	**10**	**9**	**12**	**4**	**0.5**	**9**	**7.6**	**1590**
Mean	**91**	**12**	**6**	**40**	**1.9**	**20**	**24.3**	**2469**
Minimum	**88**	**1**	**1**	**21**	**1**	**14**	**21.0**	**1063**
Maximum	**95**	**34**	**12**	**60**	**3**	**32**	**29.4**	**4358**
Thurston County								
Desert Song	90	28	13	33	1.5	20	22.6	3923
Eclipse	90	16	1	24	2	20	20.3	4466
Etna	93	63	5	69	3	16	16.6	4472
Island	90	23	16	43	1	35	22.6	4313
LRK	88	80	1	63	1.5	20	14.6	3149
Orca	85	5	31	37	3	22	35.0	3816
Rockwell	93	52	13	47	1	18	16.5	2948
Rojo Chiquito	98	4	6	24	2	27	27.5	4032
Sedona	95	49	2	40	3	34	17.6	3887
CV (%)	**5.4**	**34.9**	**80.9**	**7.1**	**15.6**	**7.3**	**18.9**	**17.2**
LSD (p = 0.05)	**11**	**29**	**18**	**7**	**0.7**	**4**	**8.4**	**1541**
Mean	**91**	**36**	**10**	**42**	**2**	**24**	**21.5**	**3890**
Minimum	**85**	**4**	**1**	**24**	**1**	**16**	**14.6**	**2204**
Maximum	**98**	**80**	**31**	**69**	**3**	**35**	**35.0**	**4890**

Dry Bean Yield Trial across 3 counties in Western WA, 2016

	Emergence (%)	Lodging (%)	Maturity (1-3 rating)	Height (in)	Moisture at harvest (%)	Yield (lb/A)	Split (%)	Moldy (%)	Hundred Bean Weight (g)
Jefferson County									
Desert Song	83	95	1.5	19	13	1414	37	2	22
Eclipse	88	10	3.0	20	14	802	10	1	16
Etna	90	60	1.5	19	16	1685	40	4	43
Island	83	75	1.0	31	14	1935	24	2	29
King of the Early	80	50	2.5	26	12	1338	46	6	47
LRK	68	98	1.5	25	14	1103	17	20	49
Orca	75	55	3.0	17	14	957	15	4	21
Rockwell	90	10	2.0	24	13	1123	32	1	38
Rojo Chiquito	60	28	2.5	20	15	637	9	2	17
Sedona	88	25	2.0	24	13	1371	37	3	25
CV (%)	**25.1**	**42.4**	**18.2**	**4.8**	**9.9**	**26.9**	**28.2**	**96.5**	**2.4**
LSD (p = 0.05)	**42**	**45**	**0.8**	**2**	**3**	**725**	**17**	**10**	**2**
Mean	**80**	**47**	**2.1**	**22**	**14**	**1192**	**27**	**4**	**31**
Minimum	**60**	**5**	**1.0**	**16**	**11**	**958**	**4**	**0**	**16**
Maximum	**95**	**95**	**3.0**	**32**	**17**	**2001**	**46**	**29**	**50**
Skagit County									
Desert Song	88	25	1.5	18	19	1180	4	1	33
Eclipse	90	10	3.0	23	20	2367	2	0	24
Etna	90	5	1.5	14	19	1680	7	1	60
Island	98	15	1.0	30	20	2260	1	1	40
King of the Early	80	10	1.0	18	20	1134	2	1	52
LRK	95	5	1.0	18	20	2586	2	0	58
Orca	80	25	3.0	18	19	1382	3	1	32
Rockwell	85	15	1.0	15	21	1301	2	1	45
Rojo Chiquito	90	8	3.0	22	20	3489	0	0	23
Sedona	95	20	2.5	23	18	3129	6	1	39
CV (%)	**6.0**	**47.6**	**18.5**	**7.7**	**2.6**	**21.9**	**85.8**	**97.2**	**3.6**
LSD (p = 0.05)	**12**	**15**	**0.8**	**3**	**1**	**1029**	**2**	**2**	**3**
Mean	**89**	**14**	**1.9**	**20**	**20**	**2081**	**3**	**1**	**41**
Minimum	**70**	**5**	**1.0**	**13**	**18**	**810**	**0**	**0**	**22**
Maximum	**95**	**80**	**3.0**	**32**	**22**	**4085**	**9**	**2**	**63**
Thurston County									
Desert Song	90	65	1.5	23	13	3042	36	2	31
Eclipse	93	48	2.5	25	11	1987	29	1	19
Etna	93	55	1.0	21	13	2304	42	1	48
Island	95	83	1.5	27	14	3406	9	2	40
King of the Early	88	63	1.5	18	14	1451	19	3	53
LRK	93	53	1.5	22	12	2042	32	3	55
Orca	88	65	3.0	19	10	1264	43	0	32
Rockwell	95	90	2.0	19	13	2220	37	2	47
Rojo Chiquito	95	48	2.5	20	15	2351	11	2	22
Sedona	93	70	2.0	29	13	3092	29	4	38
CV (%)	**3.1**	**47.2**	**38.4**	**13.2**	**9.9**	**37.1**	**33.3**	**76.5**	**7.0**
LSD (p = 0.05)	**7**	**68**	**1.7**	**7**	**3**	**1830**	**21**	**4**	**6**
Mean	**92**	**64**	**1.9**	**22**	**13**	**2297**	**26**	**2**	**38**
Minimum	**85**	**5**	**1.0**	**14**	**9**	**915**	**7**	**0**	**18**
Maximum	**95**	**90**	**3.0**	**30**	**16**	**4304**	**51**	**5**	**57**

Dry Bean Screening Trial at WSU-NWREC, 2014

Variety Name	Market Class	Yield (lb/A)	Clean yield (lb/A)	Days to maturity (days after planting)	Plant height (cm)	Hundred bean weight (g)	Emergence (%)
PI09-1	Pink	2410	2226	105	44	36.1	85
PI11-4-4	Pink	2131	2068	109	33	33.3	75
Stampede	Pinto	1938	1821	115	45	40.2	75
Rio Rojo	Small Red	1926	1865	112	36	29.5	80
Agate	Pinto	1893	1853	105	38	38.1	75
Rojo Chiquito	Small Red	1840	1822	117	43	22.4	75
Rosetta	Pink	1833	1514	125	49	37.3	60
Agassiz	Pinto	1740	1725	105	34	40.5	80
UCD9634	Pink	1725	1602	121	42	36.8	85
UI-239	Small Red	1696	1629	109	31	33.8	90
BL2725	Black	1653	1613	117	32	24.0	80
SR10-2-4[1]	Small Red	1646	1594	112	35	37.7	50
Eclipse	Black	1537	1529	117	46	22.1	80
Othello	Pinto	1525	1499	105	36	39.5	70
Island	Pinto	1512	1485	105	40	42.8	80
Victor	Pink	1503	1475	105	29	35.4	75
UI-537	Pink	1470	1440	105	38	38.8	90
BL2712	Black	1434	1257	121	40	21.8	85
PT12-31	Pinto	1386	1355	105	41	36.4	70
Sedona	Pink	1348	1211	117	46	41.2	75
C11144	Cranberry	1290	1210	105	31	48.0	75
Etna	Cranberry	1287	1177	105	32	59.4	70
FDM9623	Flor de Mayo	1255	1239	105	35	39.1	75
BK11-8	Black	1252	1251	111	40	22.5	70
M12466	Navy	1243	1160	121	43	17.0	55
PT8-15	Pinto	1219	1136	105	33	42.0	85
BL2724	Black	1213	1179	117	32	20.3	90
BL1806	Flor de Mayo	1192	1162	117	39	31.6	85
Francis king	Cranberry	1150	1101	109	34	55.7	80
BL1807	Flor de Mayo	1101	1049	105	34	33.5	85
Deckel	Cranberry	1099	1071	112	35	74.3	25
CELRK	Light Red Kidney	1097	1055	105	29	54.2	75
King of the early	Cranberry	1073	1045	105	33	53.1	80
GN10-1-1	Great Northern	1013	971	117	31	38.8	6
MDR1210	Dark Red Kidney	998	981	109	34	46.5	80
Matterhorn	Great Northern	985	910	117	38	38.6	15
Espresso	Black	979	940	105	24	21.2	50
M12467	Navy	977	934	121	37	17.8	45
MDR1106	Light Red Kidney	951	907	112	36	48.7	65
M11277	Navy	930	899	121	37	19.4	15
Krimson	Cranberry	869	806	105	28	54.1	55
Youngquist brown	Brown	814	563	125	36	48.5	55
GN10-1-7	Great Northern	769	752	115	30	39.6	10
Rockwell	Red and White	764	742	105	29	44.7	55
Marlax	Brown	701	668	105	28	36.4	60
Indi	Navy	683	662	125	40	18.8	10
Kennarly	Colored patterned	673	651	109	32	46.0	15
Black coco	Black	672	626	105	29	50.5	25
Avalanche	Navy	661	644	117	37	21.7	30
Merlot	Small Red	635	615	117	35	34.9	50
Vermont Cranberry	Cranberry	626	589	125	29	64.5	50
Silver cloud	White Kidney	612	586	112	37	58.8	10
Red Hawk	Dark Red Kidney	572	556	105	31	46.8	35
UC White Kidney	White Kidney	501	456	121	43	50.4	6
Calypso	Black and White	491	452	105	29	48.1	45
Snowdon	White Kidney	469	454	109	29	59.3	6
Canario 707	Yellow	433	382	125	29	47.6	15
Orca	Black and White	303	250	125	35	33.6	11
CV %		23.8	25.8	2.5	11.1	2.8	20.6
LSD (P=0.05)		552	530	6	8	2.2	23
Mean		1346	1110	112	35	38.8	57
Minimum		303	250	105	24	17.0	6
Maximum		2410	2226	125	49	74.3	90

Dry Bean Observational Trial in Skagit County, 2015

	Emergence (%)	Maturity (1-3 rating)	Height (in)	Moisture at harvest (%)	Moldy (%)	Split (%)	Hundred Bean Weight (g)	Yield (lb/A)
Black								
BL2712	88	1.0	18	20.9	0.9	1.8	18.9	1287
BL2721	90	1.0	18	34.9	3.5	2.3	23.5	2237
BL2724	85	1.0	16	20.6	0.4	4.8	17.4	1174
BK11-8	68	1.0	21	23.1	1.6	2.8	20.3	1893
Black coco	88	1.0	19	23.1	2.9	10.1	48.4	1448
Eclipse	73	2.0	22	23.2	1.4	1.4	23.6	1209
Espresso	95	1.0	15	21.9	0.8	5.2	21.7	1611
Zenith	85	1.0	22	16.6	0.1	26.8	18.2	1871
Black and White								
Calypso	90	1.5	13	23.7	2.2	14.1	50.4	1451
Orca	88	1.0	21	26.3	1.2	41.4	26.7	1256
Brown								
Marlax	95	1.0	19	23.6	0.7	10.3	37.7	1496
Cranberry								
C11286	98	1.0	16	22.2	3.2	14.8	47.2	1283
Etna	88	1.5	12	23.5	4.2	18.4	52.8	1093
King of the Early	90	1.0	14	21.7	1.3	11.8	53.3	1436
Krimson	93	1.3	18	23.7	5.8	22.8	55.3	1938
Vermont Cranberry	80	3.0	15	21.8	4.9	15.8	39.8	1857
Dark Red Kidney								
MDR1106	90	3.0	18	31.0	13.4	3.3	48.2	1429
MDR1218	95	2.0	18	25.3	2.8	4.5	46.1	2016
Red Hawk	80	2.0	19	24.7	2.2	2.5	47.3	1281
Flor de Junio								
Desert Song	85	1.0	24	21.6	1.1	8.1	29.6	2488
Flor de Mayo								
FDM9623	95	1.0	21	23.4	0.7	1.7	38.9	1764
Gypsy Rose	88	3.0	21	35.0	26.8	8.7	29.6	1331
Gold and white								
Jacobi's Gold	83	1.0	14	28.3	0.4	87.3	58.0	1109
Light Red Kidney								
CELRK	90	1.0	14	22.3	2.6	9.2	57.3	2217
LRK	65	3.0	16	29.4	5.6	5.9	54.1	1129
Navy								
Alpena	85	1.5	18	27.5	0.8	6.3	16.3	1728
Avalanche	85	1.5	23	23.4	3.3	1.8	21.4	1481
W1151	85	2.5	26	27.8	1.3	7.7	28.3	1913
W1438	95	2.5	22	30.0	1.2	5.9	15.6	1976
Pink								
PI11-4-4	90	1.0	18	33.0	0.8	2.2	38.9	1873
PI09-1	90	1.0	27	26.7	1.4	8.9	33.6	2531
Rosetta	90	3.0	24	37.3	9.7	48.7	27.6	1738
Sedona	85	2.0	20	26.7	9.3	5.8	34.7	1779
UCD9634	80	1.0	26	27.3	0.8	10.8	38.8	1866
UI-537	90	1.5	18	24.0	1.9	7.8	37.1	1581
Victor	90	3.0	17	34.6	2.7	2.2	33.8	1373
Pinto								
Agate	80	2.0	27	23.3	1.8	1.9	28.9	2687
Island	88	1.0	24	25.0	1.2	6.4	45.7	1680
Othello	68	1.5	18	34.9	2.2	4.6	37.5	1784
PT12-31	88	1.0	19	33.4	1.8	4.1	39.6	1874
PT8-15	88	1.0	28	28.9	1.1	17.7	41.6	1876
Quincy	80	2.0	23	27.9	9.7	15.3	48.3	858
Stampede	75	3.0	22	29.0	7.5	5.4	35.3	779
Red and White								
Jacobi's Cattle	75	1.0	18	27.9	0.7	79.3	51.0	794
Rockwell	90	1.0	13	23.1	2.2	5.2	49.3	1291
Small Red								
Merlot	80	3.0	25	30.3	18.2	4.6	34.2	1527
R12844	88	3.0	18	28.1	0.3	16.7	28.3	974
Rio Rojo	80	2.0	22	26.9	8.9	3.7	32.4	823
Rojo Chiquito	80	1.0	22	21.3	4.3	9.8	19.9	1648
SR10-2-4[1]	90	3.0	24	26.7	11.7	2.1	37.4	1981
UI-239	85	3.0	28	29.0	2.9	1.6	32.3	2196
Yellow								
Canario 707	73	2.0	22	21.0	6.7	9.8	29.7	1461
DRY28-1	70	2.5	14	21.7	5.1	21.1	48.2	813
DRY80-1	85	3.0	21	27.2	8.2	8.9	42.4	1488
Yellow eye								
Zenkeld	88	1.0	19	23.3	2.1	6.4	49.3	2231
CV (%)	**18.4**	**20.6**	**21.8**	**8.7**	**77.8**	**43.0**	**13.5**	**38.3**
LSD (p = 0.05)	**18**	**0.7**	**6**	**4.0**	**5.5**	**11.2**	**8.3**	**1202**
Mean	**85**	**1.7**	**19**	**22.8**	**3.5**	**10.0**	**35.9**	**1531**
Minimum	**68**	**1.0**	**12**	**16.1**	**0.1**	**0.0**	**14.4**	**786**
Maximum	**95**	**3.0**	**27**	**35.0**	**32.9**	**88.0**	**58.4**	**3745**

Dry Bean Observational Trial in Skagit County, 2016

	Emergence (%)	Lodging (%)	Defoliation (1-5 rating)	Maturity (d.a.p.)	Height (in)	Moisture at harvest (%)	Yield (lb/A)	Split (%)	Moldy (%)	Hundred Bean Weight (g)
Black										
812712	93	5	1	126	20	19	2888	3	1	21
812721	90	15	2	125	22	18	1809	5	0	25
812724	93	5	2	126	18	18	1794	5	2	22
DK11-8	90	10	2	125	23	19	2806	3	0	23
Black taco	95	0	4	114	10	17	1799	14	0	53
Eclipse	88	10	4	127	21	21	2767	2	2	25
Expresso	85	5	2	114	14	16	748	28	0	24
Zenith	90	5	3	125	21	16	1844	2	3	23
Black and White										
Calypso	75	10	4	114	16	17	591	18	0	53
Orca	60	10	4	108	16	22	683	1	2	34
Brown										
Matfax	88	5	4	114	14	17	1311	14	1	36
Cranberry										
C11356	88	0	4	114	14	17	1050	16	1	48
Bina	93	8	4	116	15	16	1269	18	1	58
King of the Early	75	10	4	114	18	18	1368	7	1	58
Krimson	73	20	3	116	17	16	915	18	0	56
Vermont Cranberry	90	15	3	125	20	19	1545	3	1	45
Dark Red Kidney										
ND0861230	88	10	4	114	16	17	1280	4	1	67
Red Hawk	78	5	4	114	15	18	972	7	1	69
Flor de Junio										
Desert Song	93	10	2	116	19	17	1815	11	3	54
Flor de Mayo										
FDM9618	78	18	3	114	24	19	1827	8	0	38
Gypsy Rose	93	40	2	125	18	18	2417	3	2	33
Gold and white										
Jacobs Gold	83	5	4	114	13	17	774	17	2	55
Light Red Kidney										
C818K	90	10	4	109	12	16	1234	12	1	61
ND0861106	85	5	4	123	19	22	2252	2	3	47
Navy										
Alpena	85	10	2	125	20	20	1825	0	1	20
Avalanche	73	15	2	126	17	21	1205	0	2	22
N11181	90	5	2	100	15	20	2231	0	0	22
N14280	78	5	2	105	19	22	2321	0	2	20
Pink										
PK11-4-4	90	20	2	118	20	18	1961	1	0	32
PKS-1	90	20	2	116	23	19	1920	5	3	38
Rosetta	80	8	2	135	24	19	2730	2	3	40
Sedona	90	8	1	126	23	17	2498	7	2	38
UI209604	93	8	4	100	20	20	2389	1	0	37
UI-537	75	35	3	114	25	17	864	4	1	35
Vietor	63	70	4	116	27	17	1054	1	1	35
Pinto										
Agate	88	45	3	118	22	19	2364	1	2	41
Island	90	15	3	109	33	17	1857	6	0	41
Othello	75	15	2	114	24	18	687	7	1	40
PT12-31	88	10	3	116	20	16	1534	2	0	35
PTB-15	85	45	2	117	24	20	1486	7	3	43
Quincy	85	70	3	116	29	17	1890	8	0	44
Stampede	60	10	3	126	25	19	1865	4	1	48
Red and White										
Jarrett's Cattle	83	5	4	109	14	17	1125	10	1	60
Rockwell	93	5	4	114	16	17	1339	10	1	67
Soldier	85	15	4	116	18	16	1371	5	2	64
Small Red										
Merlot	93	10	2	124	21	19	2873	0	1	26
R13044	93	5	1	116	11	18	1635	3	1	38
Pie Rojo	85	15	2	129	19	20	1182	1	1	38
Rojo Chiquito	90	5	3	123	20	19	2172	1	0	23
SR10-2-411	85	10	2	123	24	18	2810	3	0	41
UI-239	88	38	4	116	18	19	956	1	3	33
Yellow										
Canario 107	53	8	4	137	15	25	576	1	7	48
DBY19-1	83	55	4	134	25	21	2268	1	2	45
DBY68-1	88	18	4	134	14	22	1464	1	3	46
Yellow-eye										
Kenearly	90	15	4	114	19	17	1938	12	0	46
CV (%)	**8.9**	**46.9**	**16.9**	**2.2**	**14.6**	**6.7**	**24.2**	**60.6**	**186.8**	**4.1**
LSD (p = 0.05)	**13**	**15**	**1**	**5**	**6**	**3**	**836**	**7**	**3**	**3**
Mean	**84**	**16**	**3**	**120**	**19**	**19**	**1680**	**6**	**1**	**39**
Minimum	**25**	**0**	**1**	**101**	**10**	**15**	**536**	**0**	**0**	**19**
Maximum	**95**	**70**	**4**	**137**	**35**	**27**	**3097**	**28**	**12**	**65**

CONTACT INFORMATION

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PROJECT #17

Project Title: Management of an Emerging Adelgid Pest on Nordmann Fir Christmas Trees

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

In 2010, an unidentified adelgid was detected on 5% of the Nordmann fir trees in a 2004 Christmas tree planting of approximately 750 Nordmann (Abies nordmanniana) and Turkish fir (Abies bornmuelleriana), located at the Washington State University (WSU) Research and Extension Center in Puyallup, WA. By 2012, 61% of the trees in this planting were badly infested and 16% were unmarketable. Large numbers of crawlers had attacked the foliage, which led to discoloration and severe distortion of the needles on affected shoots (Figure 1). The planting was part of a multi-site, Pacific Northwest (PNW) regional genetic trial designed to identify seed sources with superior postharvest needle retention. Dr. Gary Chastagner, WSU's Professor of Ornamental Plant Pathology who had established the PNW trial because of strong grower interest in these two Abies species, suspected that the damage was caused by the silver fir woolly adelgid [Adelges (Dreyfusia) nordmannianae], a serious pest in Europe where Nordmann fir is widely grown for Christmas trees, but not known to be present in the PNW. Unlike the balsam woolly adelgid (Adelges picea), which is established in the PNW and slowly builds up on susceptible Abies species, the silver fir adelgid is known to spread rapidly once it appears in European plantations.

Christmas trees represent approximately $42 million in farm income and WA is the fifth largest producer of cut trees in the US. Growers range from small, choose-and-cut farms to large wholesale operations. During the past 10 to 15 years there has been an increased interest in growing Nordmann and Turkish firs as Christmas trees in the PNW. Previous research has shown that these species have excellent postharvest moisture and needle retention when displayed in water and are tolerant or have limited susceptibility to Phytophthora root rot, Annosus root rot, spider mites, and balsam woolly adelgid. Since 2004, an average of 500,000 Nordmann/Turkish firs have been planted each year in Oregon. Although data are not available, a similar increase has taken place in western Washington and the Inland Empire. Currently, these species are the third most widely-planted Christmas trees in the PNW. Most of the Nordmann and Turkish fir have been planted in areas where noble fir cannot be grown because of Phytophthora root rot. The limited susceptibility of these species to common diseases and pests has also allowed growers to produce them with little or no applications of fungicides and insecticides.

In 2010, the WSDA SCBGP awarded WSU Puyallup a three-year grant to identify superior sources of Nordmann and Turkish fir. The goal of that project was to identify sources that are adapted to local production conditions and identify potential trees that have superior postharvest needle retention. It was while working on that 2010 project that the adelgid was detected on Nordmann and Turkish fir trees in the 2004 planting. The adelgid crawlers were attacking the foliage during the early stages of shoot elongation, causing discoloration and severe distortion of the needles on infested shoots. Although the identity and origin of the adelgid was unclear, Dr. Chastagner recognized that the damage to trees in Puyallup was very similar to what had been reported for silver fir woolly adelgid in Europe.

Several adelgids are serious pests of conifers in North America. One is the balsam woolly adelgid that has spread throughout North America and been responsible for the mortality of Fraser fir throughout its natural range. It is also a serious pest in areas where Fraser fir is grown as a Christmas tree, including the PNW. Another adelgid that attacks hemlock has become a serious problem in eastern North America. Adelgids have complex life cycles. In its natural range in the Caucasus region (Russia, Georgia, and Turkey), the silver fir woolly adelgid alternates between Oriental spruce (Picea orientalis), where the sexual stage occurs, and various Abies species such as Nordmann fir which host the asexual stage. In areas outside its natural range, it persists as an asexual population that reproduces parthenogenetically. Depending on temperatures during the growing season, there may be 2 to 6 generations of this pest, making control difficult (Figure 2). To complicate matters, the identification of a specific species of adelgid is based on the hosts on which they occur, morphological characteristics, and mitochondrial and nuclear DNA sequence data.

There are about 15 acres of Christmas tree research plots at Puyallup. The balsam woolly adelgid has been present in these plantings on a number of other Abies species, but most commonly on Fraser fir. Nordmann and Turkish firs have been grown here for almost 20 years with no previous adelgid problems. The newly-infested planting was located in an area that

had previously only been used for forage production and close to residential areas, so the adelgid may have spread from infested landscape plants into the genetic planting. There is no indication that these pests can be carried on seed and all of the seedlings in this trial were grown from imported seed in a PNW nursery. Given the risk the unknown adelgid posed to plantings of Nordmann and Turkish fir that are being established in the PNW, Chastagner's lab at WSU Puyallup spent the past three years conducting studies to:

- Confirm the identity of the adelgid
- Determine the distribution of the adelgid in the PNW
- Determine the life cycle of the adelgid on Abies spp at WSU Puyallup
- Determine the growing degree days associated with emergence of the adelgid crawlers
- Determine the variation in susceptibility of commonly-grown Abies spp to the adelgid.
- Determine the effectiveness of commonly-available adelgid control products on Nordmann fir

In 2010, the WSDA SCBGP provided WSU Puyallup with a three-year grant to identify superior sources of Nordmann and Turkish fir. The goal of that project was to identify sources that are adapted to local production conditions and identify potential trees that had superior postharvest needle retention. The infestation of the trees in the 2004 Nordmann/Turkish fir genetic planting that was used in the 2010 project provided an unexpected opportunity to build on that by assessing the variation in resistance to the adelgids among the sources of Nordmann and Turkish fir.

PROJECT APPROACH

Activity. Sequence and use molecular markers to identify adelgid pest.

During spring 2013, various life stages of the adelgid were collected from Nordmann fir on the WSU Puyallup campus (Table 1). DNA was individually extracted from adults, eggs, and egg mass, and the cytochrome oxidase subunit I (COI) region of mitochondrial DNA was sequenced. The three samples sequenced were consistent with the Adelges piceae/nordmannianae/prelli group of adelgid species, a group within which species cannot currently be differentiated from each other by DNA sequence. In the summer and fall of 2013, additional samples were collected from a wider range of conifer hosts (Nordmann fir, Oriental spruce, spruce, and western hemlock (Tsuga heterophylla) in and nearby the WSU Puyallup campus (Table 1) to confirm that the adelgid on the Nordmann fir was unique compared to the adelgids on these other hosts. COI DNA analysis of the samples revealed a logical distribution of adelgid and host, and furthermore no adelgid from the Adelges nordmannianae and A. piceae complex were detected on any of the tested species other than Nordmann fir. The DNA sequences were aligned with sequences from known (voucher) adelgids in a phylogenetic tree (Figure 3), showing which adelgid species the WSU samples are most closely related to.

Dr. Nathan Havill at the USDA Forest Service Northern Research Station was contacted relating to issues associated with the molecular identification of the adelgid on Nordmann fir. Dr. Havill is an expert on adelgid identification and he indicated that the molecular technology is currently not available to distinguish between adelgids in the Adelges piceae/nordmannianae/prelli group. He indicated that within this group, host range is probably the most effective way of separating the species. Based on this, the results of the host susceptibility trials indicated that the adelgid is the silver fir woolly adelgid, [Adelges (Dreyfusia) nordmannianae].

Activity. Survey grower plantings of Nordmann and Turkish fir in WA and OR to determine distribution of adelgid pest.

The only locations where Chastagner's lab detected Nordmann fir infested with the adelgid were two sites located about 4 miles from the affected WSU Puyallup field plantings. His staff were unable to determine the source of both the infestations at WSU Puyallup and these sites. Following education and a request to growers at a regional Christmas tree meeting, samples were obtained from 25 growers in WA and OR. No evidence of adelgids was found on any of the samples. These data indicate that adelgids on Nordmann fir are either restricted to a relatively small number of sites in the Puyallup area or that common pest management treatments used by many growers in other areas are effectively controlling this pest.

Activity. Monitor changes in adelgid life stages on infested trees to obtain information on life cycle.

The silver fir woolly adelgid has a complex life cycle with the potential for multiple generations during each growing season (Figure 2). In addition, when it appears on Nordmann fir in Europe, it produces a winged form that colonizes Oriental spruce, the alternate host where the sexual stage of this pest occurs. Control treatments generally target the crawler stage, so it is important to understand when critical stages occur if growers are going to be able to effectively manage this pest. The life cycle of the adelgid was monitored on infested Nordmann fir trees at WSU Puyallup during 2013 through 2016.

Branches were collected on a regular schedule and examined under a dissecting scope to determine the development of adelgid life stages throughout the year. All potential life stages of the adelgid that occur on their Abies host were observed on the Nordmann fir trees at Puyallup (Figure 4). There was a consistent progression through the life stages and there were two generations per growing season (Table 2). Overwintering stem mother's started laying eggs in late March. Egg hatch and 1st generation crawlers began to emerge in early April, about 1 week prior to initial bud break. The winged form was only evident on trees during 2013 and 2014.

Activity. Correlate growing degree data with emergence of crawler.
For each of the life stages observed, the growing degree days (GDD base 41) were calculated from March 1st using the following formula: GDD = (Max Daily Temp + Min Daily Temp)/2 – 41. The initial appearance of the 1st generation crawlers ranged from 217 to 380 GDD (avg. 285) over the 4 years (Table 2). Following bud break, which corresponded to 354 to 437 GDD (avg. 380), the crawlers moved onto and fed on the newly emerging growth. This indicates that growers could utilize GDD to optimize their adelgid control treatments.

Activity. Determine the risk that the adelgid could be spread via the movement of infested Christmas trees and boughs
Adelgids are known to be spread via wind, human activity, birds and infested seedlings. Little is known about the risk of spreading adelgids form one location to another via the movement of infested cut Christmas trees or boughs. As a result, controlled studies were conducted during the 2013-14 and 2014-15 harvest seasons to determine the risk that adelgids could be spread from one location to another via the movement of infested cut Christmas trees or boughs. Three sets of branches, consisting of a branch from each of five heavily-infested Nordmann fir trees, were harvested on December 5, 2013 and December 2, 2014, respectively. One set was stored in ventilated plastic crates outdoors. The other two sets were displayed indoors at 20C until early January; one set with their bases in water and the other dry. Following the indoor display period, both sets of branches were placed in ventilated plastic crates and stored outdoors with the others. A baseline check consisted of branches that remained on the infested source trees and were observed regularly. The effect of the different display and storage conditions on adelgid survival was determined by periodically examining the branches to determine the adelgid's viability and life stages through early April.

No evidence of overwintering stem mother (SM) adelgid mortality was evident on any of the detached branches in early January, except for a few branches that were displayed dry in the 2013-14 test. Unlike 2013-14, in the 2014-15 test none of the adelgids produced eggs on any of the indoor-displayed branches or when the branches were displayed outdoors (Table 3). This may have been due to differences in the environmental conditions that occurred prior to harvest in 2013-14 and 2014-15. Stem mother adelgids on the check branches that were not removed from the source trees began laying eggs about 3 weeks prior to bud break in late March, 2014 and 2015 March 26 and 30, respectively and the first crawlers were evident 19 days later (April 9 and 13, respectively). None of the SM adelgids survived on the branches that were stored outdoors or displayed in water and then stored outdoors long enough to lay eggs in the spring when new growth was appearing in the field. The data from these two trials indicated that there was no risk that the adelgids on Nordmann fir would spread via the movement of cut Christmas trees or boughs under the test conditions.

Activity. Variation in susceptibility of Nordmann, Turkish, Trojan and North American firs to adelgids.
Chastagner's lab utilized a number of existing genetic plantings at WSU Puyallup and a diverse set of Abies spp. seedlings to obtain information on the variation in susceptibility of different Abies spp. to the adelgid under PNW production conditions. Data were generally collected on the extent of needle curling and/or damage on each trees/seedlings. Curling was rated on a scale of 0 to 5, with 0 = no curling or evidence of adelgids, 1 = the tips of a few needles bent throughout the branches, 2 = some needles beginning to curl, with bent needles evident throughout the branch, 3 = almost all needles bent, many beginning to curl with slight yellowing, 4 = almost all needles curling with a yellow discoloration and damage easily visible from the top of the branch, and 5 = most needles curled throughout the branch and many are yellow or brown. Overall damage on each tree was rated on a scale of 0 to 3, with 0 indicating no damage and 3 indicating an unmarketable tree.

2004 Nordmann/Turkish fir planting - The adelgid damage was originally observed in 2010 in a 2004 replicated common garden planting at Puyallup of Nordmann and Turkish fir seed sources from Denmark and Turkey. The planting included 12 sources of Nordmann fir and 3 sources of Turkish fir. Ten trees from each source were planted in each of five blocks. After the original adelgid observation, changes in the level of damage were evaluated yearly from 2014 through 2016. In

spring 2015, before the start of the growing season, approximately half of the trees were thinned out because of crowding in this plot. To determine if differences in severity of damage on different seed sources had stayed the same, the remaining trees were rated for adelgid damage at the end of the 2015 and 2016 growing seasons. The 2014 and 2015 ratings indicated that there were significant differences in susceptibility between sources of Nordmann fir, but only limited damage occurred on any of the Turkish fir (Table 4). The 2014 and 2015 data were subjected to Spearman Rank Order analysis to determine if relative susceptibility of sources was the same in both years. There was a highly significant correlation (P = 0.004) between the susceptibility rankings in 2014 and 2015. One of the most striking findings was the apparent natural collapse of the adelgid population and the limited damage that occurred on any of the trees in 2016 (Table 4). The reason is unclear, but additional studies might help to determine if this collapse was due to the buildup of natural predators.

2006 Republic of Georgia Nordmann fir planting – Another Nordmann fir field planting that was established in 2006 is located near the 2004 Nordmann/Turkish fir genetic trial plot. This plot consists of six different seed sources (numbered 33, 34, 35, 36, 37, and 38) from different elevations in the native range of the species in the Republic of Georgia. There are five trees from each source in each of 6 blocks (replications). Each tree was rated using the same damage scale described above. In 2014, 32% of the trees were affected, most with only a limited amount of damage. Analysis of the data showed no significant difference in the average damage to the different seed sources, which ranged from 0.23 to 0.56 within the plot. However, based on a visual representation of damage on the map that showed the spread of the adelgid within the plot, it appeared that the original infestation occurred in Rep 2 and was spreading through the other reps (Figure 5). During 2015, the number of trees (87.8%) and severity of adelgid damage increased (Figure 6). Even though the ratings were higher, analysis of the 2015 data, which ranged from 1.11 to 1.54, showed again that there was no significant difference in the average damage based on source (data not shown).

2014 Mixed *Abies* species trial - During 2013, 2014, and 2015, data were collected on the susceptibility of 13 different Abies species in a replicated, mixed demonstration planting located adjacent to the adelgid-infested 2004 Nordmann/Turkish fir genetic trial described above. In addition to adelgids that spread naturally from the adjacent 2004 planting, in spring 2013, small branches with overwintering adelgid stem mothers were harvested from infested trees and tied to a branch on each tree within this planting. The extent of needle curling and damage on each tree was then rated in the summer/fall of 2013, 2014, and 2015. Data in 2013 showed slight infestations on some species throughout the plot. Of the 13 species, the highest curling and damage ratings occurred on the Nordmann and European silver firs (Abies alba). Fraser (Abies fraseri), Canaan (Abies balsamea var. phanerolepis) balsam (Abies balsamea), Korean (Abies koreana), Nikko (Abies homolepis), and Turkish fir trees exhibited a very low level of curling at the site where the infested branch was secured to the tree in 2013 (Table 5). A year later, there was no evidence of adelgids on these trees, suggesting they were not able to overwinter and reproduce on any species in the planting other than the Nordmann and European silver firs (Table 5). Data in 2015 confirmed that collected in 2013 and 2014, with the exception of slight damage on Nikko and Turkish fir. Over the three year period, the highest level of damage occurred on the Nordmann and European silver firs. Since very little or no damage was observed on the other species, it would indicate that there is limited risk of this adelgid attacking species of Christmas trees grown in North America.

CoFirGE seedlings - The susceptibility of 1,420 seedlings from 71 sources, including Turkish fir, Trojan fir, and Nordmann fir that were obtained from a national CoFirGE project and representatives from other common North American Christmas tree species were evaluated for their susceptibility to adelgids in 2013 and 2014. In 2013, twenty seedlings of each species were placed in concrete bunkers underneath wire racks. Branches cut from infested Nordmann fir were placed on the racks to allow adelgid crawlers to fall onto the seedlings. A PVC hoop structure held shade cloth to protect the cut branches from direct sunlight (Figure 6). Branches were left for a two-week period and then replaced with fresh branches for another two weeks. A modified method was used to expose the same seedlings to adelgids in 2014. Instead of leaving branches above the seedlings on wire racks, infested branches were held above seedlings and clapped together. This was performed twice, on April 18th and April 30th. Sticky, 4 cm-square insect traps were placed among the seedlings to monitor the distribution of the adelgid crawlers that fell onto the seedlings during both years. In 2013, the average total number of crawlers captured on each 4 cm-square trap was 115 (23 crawlers per 0.8 cm squared), but there was a very uneven distribution throughout the different reps in the experiment (Figure 7). Results from the 2014 insect traps show that the modified method of infesting the seedlings was a less effective method. Though large numbers of eggs were found on the traps, the numbers of crawlers was much lower than in 2013 (Figure 8). The average total number of crawlers captured on each 4 cm-square trap was 20

(4 crawlers per 0.8 cm square). These differences are reflected in the different color gradient scales between Figure 7 and Figure 8 (0-60 vs 2-10).

Data was taken in July 2013 and July 2014 evaluating the seedlings for adelgid infestation using the 0-5 curling scale and a binary scale indicating the presence or absence of adelgids. As expect there was a pronounced difference between the two years. In 2013, when the trees received much higher levels of infestation, adelgids could be found on most all of the trees and some of the trees also exhibited some needle curling. In 2014, presence of adelgids and curling were both much reduced compared to 2013, which is most likely due to the fact that the seedlings were exposed to much lower numbers of crawlers. Although the Nordmann fir tended to have the highest levels of adelgids and curling damage ratings, the ANOVA on this data did not show a significant difference between them and other species (data not shown).

Activity. Evaluate the effectiveness and residual activity of conventional and new insecticides for control of the adelgid.
In 2014, a control trial was set up using trees in the infested 2004 Nordmann and Turkish fir genetic trial at WSU Puyallup. Five products (Table 6) were applied as foliar sprays, broadcast treatments to the soil, or direct applications to the basal bark on the stems of trees (Table 7). A single tree in each of 7 blocks was treated with each treatment. Checks consisted of a non-treated tree in each block. All treatment trees were separated from each other by at least 12 feet to prevent any effect from adjacent treatments due to overspray or runoff. Treatments were applied in April and trees were evaluated for adelgid damage as indicated in the susceptibility trials above in September. Results indicate that the foliar applications of OnyxPro and Ultor were the only treatments that significantly reduced the damage caused by the adelgids. Since adelgid treatments often provide more than one year of control, in 2015 trees that were treated in 2014 were reevaluated to determine if there was any residual activity of the treatments. The data showed that, there was no difference between the treatments (Table 8). Although the damage ratings were generally lower in 2015, this would indicate that there was no residual control from the 2014 treatments so growers would need to treat trees every year to control this pest.

Activity. Present updates to growers and collaborators at industry meetings.

- 2014 - Presentations were made to an estimated 400 growers attending the Wilbur Ellis U. Christmas Tree session in Auburn, WA (January) and the Pacific Northwest Christmas Tree Association Annual Short Course (March) and Tree Fair (September) in Portland, OR and 10 scientist at the annual NCERA 224 meeting in NC (September).
- 2015- Presentations were made to an estimated 450 growers attending the Pacific Northwest Christmas Tree Association (PNWCTA) Annual Short Course in Wilsonville, OR (March), PNWCTA Summer Tour in Rochester, WA (June), and the Puget Sound Christmas Tree Association Annual Meeting in Puyallup, WA (June); as well as 10 scientists at the annual NCERA 224 meeting in WY (September); and 60 Christmas tree scientists at the 12th IUFRO International Christmas Tree Research and Extension Conference in Honne, Norway (September).
- 2016 - Presentations were made to an estimated 400 growers attending either the Pacific Northwest Christmas Tree Association Annual Short Course in Wilsonville, OR (March), and/or the Tree Fair in Portland, OR. (September).

Activity. Analyze data, prepare project reports, articles for industry publications, and manuscripts for publication.
All of the progress reports for this project were submitted on time. Handouts with photos were provided to growers at the regional Christmas tree meetings and scientist at the NCERA 224 meetings listed above. An abstract from the 12th IUFRO International Christmas Tree Research and Extension Conference in Honne, Norway was posted on the IUFRO website NIBIO BOOK 1(1) 2015; p. 22. A manuscript reporting the results of this project is being prepared for submission the Scandinavian Journal of Forest Research.

Dr. Art Antonelli, Washington State University, provided assistance in setting up the life cycle studies; Dr. Ulrik Brauner Nielsen, University of Copenhagen, assisted with the design of the seedling susceptibility trials; Chal Landgren, Oregon State University, assisted with preliminary grower surveys; Dr. Richard Cowles, Connecticut Agricultural Experiment Station, assisted in designing the adelgid control trial; and Dr. Nathan Havill, USDA Forest Service Northern Research Station, provided assistance relating to attempts to identify the adelgid.

This adelgid only causes economically important damage on Nordmann fir, which is used for Christmas tree and bough production. No non-specialty crops are affected.

GOALS AND OUTCOMES ACHIEVED

A summary of the activities completed to achieve the following goals and Expected Measurable Outcomes is provided above.

Outcome 1 – See the life cycle and GDD activities above.
Goal: Determine when various life stages of the adelgid develop on Nordmann fir in the PNW.
Target: Share a timeline for the development of life stages of the adelgid on Nordmann fir with 200 growers by the end of the second year of the project.
Benchmark: No information is available.
Performance Measure: The number of growers will be measured by attendance at presentations at annual grower meetings.

Outcome 2 – See the life cycle, GDD, host susceptibility, postharvest spread, and control activities above.
Goal: This project will result in the development of best management practice (BMP) recommendations to control adelgids on Nordmann and Turkish firs.
Target: Information will be posted on the WSU-Puyallup Christmas Tree website and shared with more than 300 growers.
Benchmark: Progress on the development of the BMPs will be reported to growers throughout the project. Performance Measure: The number of growers who receive BMP information will be measured by downloads from the website and attendance at presentations at annual grower meetings.

This project did not have long term expected measurable outcomes.

All of the activities established for this project were completed. Due to the lack of genetic differences within the Adelges piceae/nordmannianae/prelli group, it was not possible to conclusively determine by DNA sequence which of those three species of adelgid are at hand. The Outcome 1 Goal to determine when various life stages of the adelgid develop on Nordmann fir in the PNW was completed. The Outcome 2 Goal to obtain sufficient data to develop best management practice (BMP) recommendations to control adelgids on Nordmann and Turkish firs was also completed. Information relating to this project was shared with an estimated 1,250 growers at educational grower meetings. The preparation of a best management fact sheet, which will be posted on the WSU Puyallup Plant Pathology Ornamental (PPO) website is in progress.

Prior to the start of this project, there was no information relating to the biology of the silver fir woolly adelgid, host susceptibility, and effectiveness of the products commonly used in the PNW to control this pest on Nordmann fir in the PNW. Below is a summary of the achievements made on the proposed targets.

Outcome 1:
Goal: Determine when various life stages of the adelgid develop on Nordmann fir in the PNW.
Target: Share a timeline for the development of life stages of the adelgid on Nordmann fir with 200 growers by the end of the second year of the project.

- Information on the life cycle and growing degree days associated with the appearance of crawlers was shared with an estimated 850 growers at regional meetings during the first two years of this project.

Outcome 2:
Goal: This project will result in the development of BMP recommendations to control adelgids on Nordmann and Turkish firs.
Target: Information will be posted on the WSU-Puyallup Christmas Tree website and shared with more than 300 growers.

- BMP recommendations were made to 400 growers during the final year of this project.

BENEFICIARIES

Data collected indicate that the adelgid only causes economically-important damage to Nordmann fir, which is used for Christmas tree and bough production. This project will benefit the state's approximately 250 Christmas tree growers involved in producing this specialty crop.

Information from this project was presented to approximately 1,250 growers at regional meetings.

LESSONS LEARNED

Although DNA sequencing was able to narrow the identification of the adelgid to the Adelges piceae/nordmannianae/prelli group, a lack of genetic differences limited further identification. However, the combination of this information with that from the host susceptibility trials yielded a confident identification of the silver fir woolly adelgid [Adelges (Dreyfusia) nordmannianae].

The methods employed to infest the 1,400 CoFirGE seedlings were unsuccessful due to the low number of crawlers that were transferred from the infested branches to the seedlings and the uneven distribution through the different reps in the experiment. A subset of these seedlings have been transplanted to a field plot in an effort to expose them to natural spread of the adelgid. The seedlings will be monitored during the next couple of years.

The apparently natural collapse of the adelgid population and limited damage that occurred on any of the trees in the 2004 plot in 2016 was unexpected. It is unclear if this is an indication that this adelgid is not well adapted to conditions in the PNW or if populations of natural predators developed and controlled the adelgid.

Although DNA sequencing was able to narrow the identification of the adelgid to the Adelges piceae/nordmannianae/prelli group, a lack of genetic differences prevented further identification. Efforts to determine a region of DNA that would differentiate within this group is recommended. Meanwhile, researchers are advised to combine molecular identification techniques with host susceptibility trials and morphological information.

ADDITIONAL INFORMATION

The Pacific Northwest Christmas Tree Association provided a total of $15,000 in support of this project. In lieu of funds from the Puget Sound Christmas Tree Association, the Washington State Department of Agriculture Christmas tree licensing program also provided a total of $20,000 in support of this research. These funds were used to help cover a portion of the costs for temporary help, supplies, and WSU land use fees. In-kind support included a total of 1,420 seedlings from a national CoFirGE project, worth an estimated $8775, and Bob Moore, a local Christmas tree grower, donated approximately 120 hours of assistance in culturing trees in research plots at Puyallup.

Tables, Figures and Pictures

Figure 1. Nordmann fir growth exhibiting severe needle curling associated with adelgid infestation.

Figure 2. Illustration of Adelges nordmannianae life cycle.

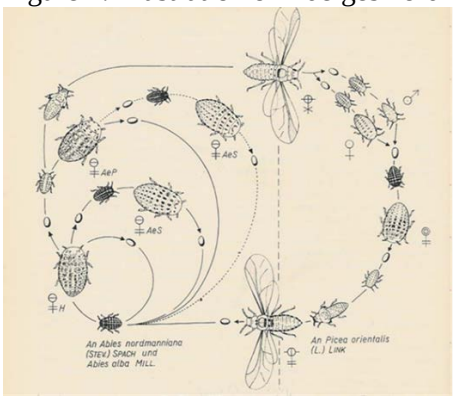

Figure 3. Neighbor joining tree showing the genetic relationship between adelgid samples collected in this study and sequences of known adelgid (voucher) species. Adelgid voucher sample names are preceded by an EF followed by the species and the word voucher, while this study's samples are identified by species, area of host, collection site, and collection date. Branch length is proportional to the numbers of nucleotide substitutions as measured by the scale bar.

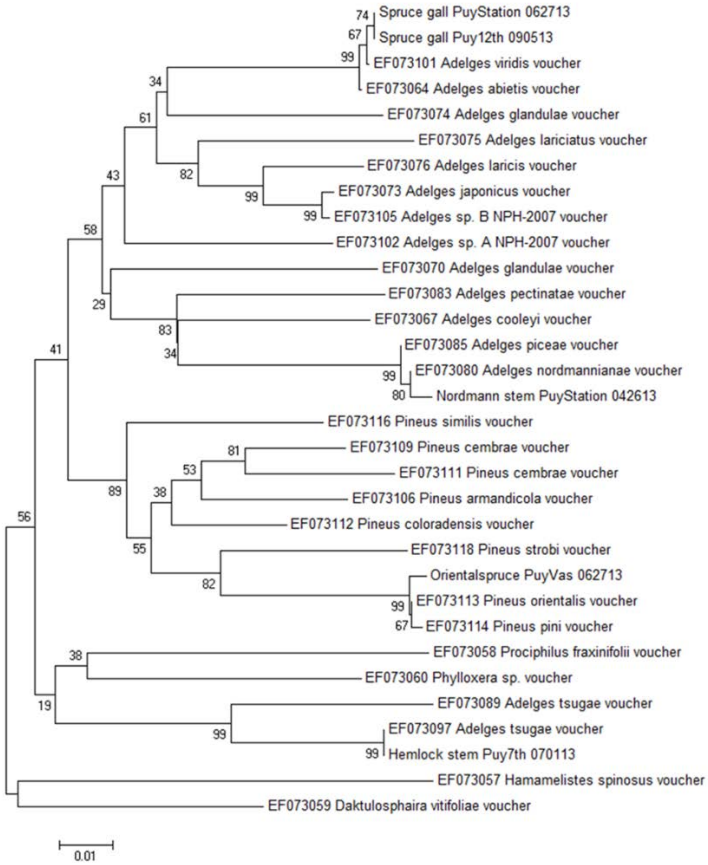

Figure 4. Life stages of adelgids observed on trees at WSU Puyallup. Overwintered stem mothers with eggs (left), crawlers (center), winged form with summer stem mother (right).

Figure 5. Plot map showing the distribution of adelgid damage on trees in the Nordmann fir elevation plot in 2014 (no fill color = no adelgid damage, gray fill = no tree, yellow fill = slight damage, orange fill = moderate damage, and red fill = severe damage).

Rep 6						**Rep 5**						**Rep 4**					
36	**35**	**38**	**33**	**37**	**34**	**36**	**34**	**35**	**38**	**33**	**37**	**35**	**38**	**33**	**37**	**36**	**34**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
34	**37**	**36**	**35**	**38**	**33**	**33**	**35**	**37**	**34**	**36**	**38**	**37**	**33**	**38**	**36**	**34**	**35**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Rep 3 **Rep 2** **Rep 1**

Figure 5. Plot map showing the distribution of adelgid damage on trees in the Nordmann fir elevation plot in 2015 (no fill color = no adelgid damage, gray fill = no tree, yellow fill = slight damage, orange fill = moderate damage, and red fill = severe damage).

Rep 6 **Rep 5** **Rep 4**

36	**35**	**38**	**33**	**37**	**34**	**36**	**34**	**35**	**38**	**33**	**37**	**35**	**38**	**33**	**37**	**36**	**34**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
34	**37**	**36**	**35**	**38**	**33**	**33**	**35**	**37**	**34**	**36**	**38**	**37**	**33**	**38**	**36**	**34**	**35**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Rep 3 **Rep 2** **Rep 1**

Figure 6. Setup showing shade cloth covering branches that were suspended over seedlings

Figure 7. 2013 contour plot showing density of crawlers captured per 0.8 cm sq.

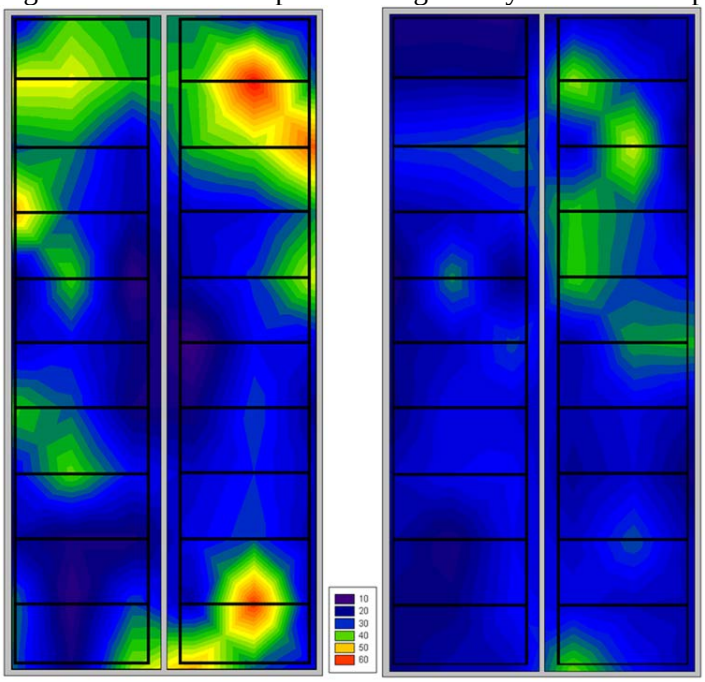

Figure 8. 2014 contour plot showing density of crawlers captured per 0.8 cm sq.

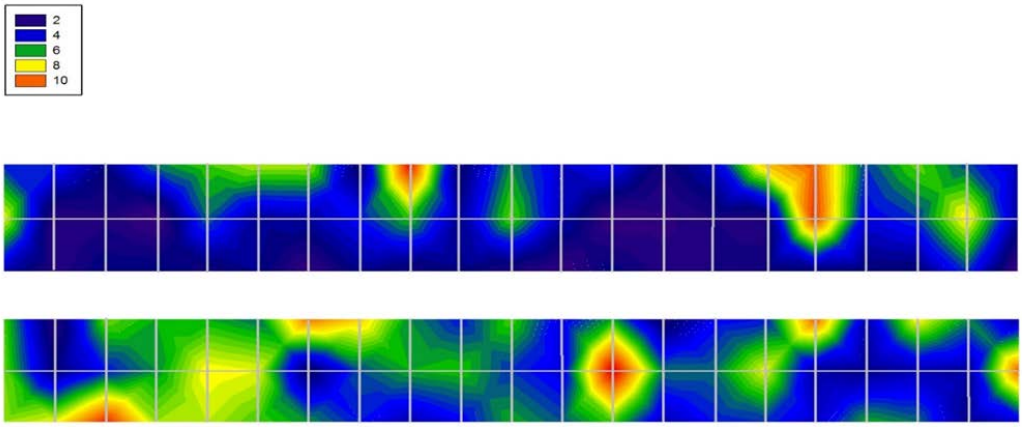

Table 1. Various stages of adelgid were collected from conifer on and nearby the WSU Puyallup campus and identified by DNA sequencing of the cytochrome oxidase I (COI) region.

Collected	Stage	Host	Area of host	Storage	Quantity	Location	Species ID by COI DNA sequence
4/26/2013	adults	Nordmann	stem	dry	~12 in one tube	WSU Puy	Adelges nordmannianae/piceae
4/26/2013	eggs	Nordmann	stem	dry	~12 in one tube	WSU Puy	Adelges nordmannianae/piceae
4/26/2013	crawlers	Nordmann	stem	alcohol	~12 in one tube	WSU Puy	Not analyzed
4/26/2013	crawlers	Nordmann	stem	alcohol	~12 in one tube	WSU Puy	Not analyzed
4/26/2013	egg mass	Nordmann	stem	dry	a mass	WSU Puy	Adelges nordmannianae/piceae
4/26/2013	adults	Nordmann	stem	alcohol	~12 in one tube	WSU Puy	Not analyzed

4/26/2013	eggs	Nordmann	stem	alcohol	~12 in one tube	WSU Puy	Not analyzed
6/24/2013	crawlers	Nordmann	unspecified	dry	14 in single tubes	Martenson	No result
6/27/2013	unspecified	Oriental spruce	unspecified	dry	14 in single tubes	Vassey Nursery	Pineus orientalis/pini
6/27/2013	unspecified	Spruce	gall	dry	14 in single tubes	WSU Puy	Adelges abietis/viridis
7/1/2013	unspecified	Hemlock	stem	dry	14 in single tubes	Puy 7th Ave	Adelges tsugae
9/5/2013	unspecified	Spruce	gall	dry	14 in single tubes	Puy 12th Ave	Adelges abietis/viridis

Table 2. Adelgid lift cycle timeline on Nordmann fir at Puyallup

	2013		2014		2015		2016	
Life Stage	Date	GDD	Date	GDD	Date	GDD	Date	GDD
1st generation eggs	26 Mar	77	26 Mar	116	30 Mar	211	28-Mar	179.8
First crawlers	3 Apr	243	9 Apr	221	13 Apr	297	14 Apr.	380
Bud break	30 Apr	371	1 May	437	20 Apr	361	11 Apr	354
2nd gen. eggs	7 June	996	30 May	914	7 May	543	16 May	913
2nd gen. crawler	13 June	1103	30 May	914	-	-	13 June	1447
Winged form	21 May	724	30 May	914	n/a		n/a	

Table 3. Effect of postharvest treatments on the viability of adelgids on cut Nordmann fir branches.

Treatment[1]	Mot.[2]	Eggs	Craw.	Mot.	Eggs	Craw.	Mot.	Eggs	Craw.	Mot.	Eggs	Craw.
2013-14	9-Jan.			19-Feb.			26-Mar.			9-Apr.		
1	+	-	-	+	-	-	+	+	-	+	+	+
2	+	-	-	+	-	+	+	-	-	-	-	-
3	+	+	+	+	+	+	+	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
2014-15	2-Jan.			15-Feb.			25.Mar.			13-Apr.		
1	+	-	-	+	-	-	+	-	-	+	+	+
2	+	-	-	+	-	-	-	-	-	-	-	-
3	+	-	-	+	-	-	-	-	-	-	-	-
4	+/-	-	-	-	-	-	-	-	-	-	-	-

[1]Treatment 1 = Branch on tree, 2 = branch harvested and stored outdoors, 3 = branch harvested and displayed in water for one month and then stored outdoors, and 4 = branch harvested and displayed dry for one month and then stored outdoors.
[2]Codes: Mot. = stem mother adelgid, Craw. = adelgid crawler, "+" = live life stage present, "-" = life stage absent or dead.

Table 4. Average Damage Ratings by Seed Source, 2004 Genetic Planting.

		Average Damage[1]					
Number	Source	2014		2015		2016	
8	Nordmann Fir, Denmark Statsskovenes Planteavlsstation	2.55	a	**2.00**	**a**	0.19	a
14	Nordmann Fir, Denmark Klon Hedeselskabet Forest Seed Center	2.38	a	1.13	abc	0.00	a

13	Nordmann Fir, Denmark Klon Hedeselskabet Forest Seed Center	2.26	a	0.60	cde	0.10	a
22	Nordmann Fir, Denmark Statsskovenes Planteavlsstation	2.22	a	1.12	bcd	0.13	a
17	Nordmann Fir, Denmark Klon Hedeselskabet Forest Seed Center	2.16	ab	1.90	ab	0.05	a
10	Nordmann Fir, Denmark Statsskovenes Planteavlsstation	2.15	ab	0.80	cde	0.00	a
18	Nordmann Fir, Denmark Klon Hedeselskabet Forest Seed Center	2.03	abc	0.93	cd	0.00	a
15	Nordmann Fir, Denmark Klon Hedeselskabet Forest Seed Center	1.91	abcd	1.43	abc	0.00	a
7	Nordmann Fir, Denmark Statsskovenes Planteavlsstation	1.80	abcd	1.46	abc	0.00	a
5	Nordmann Fir, Artvin, Yayla	1.30	bcd	1.00	cd	0.04	a
12	Nordmann Fir, Denmark Statsskovenes Planteavlsstation	1.19	cd	0.93	cd	0.00	a
16	Nordmann Fir, Denmark Klon Hedeselskabet Forest Seed Center	1.09	de	0.54	de	0.13	a
4	Turkish Fir, Adapazan, Akyazi	0.26	ef	0.33	de	0.00	a
3	Turkish Fir, Adapazan, Hendek	0.23	ef	0.44	de	0.00	a
1	Turkish Fir, Bursa, Komursu	0.11	f	0.00	e	0.00	a

[1] Overall damage was rated on a scale of 0 to 3, with 0 indicating no damage and 3 indicating an unmarketable tree. Numbers with the same letter are not significantly different, $P<0.05$, Tukey's Studentized Range (HSD) Test.

Table 5. Average damage ratings of 13 Abies species in a replicated demonstration planting.

	2013		2014		2015	
Species	Curling	Damage	Curling	Damage	Curling	Damage
California Red Fir	0	0	0	0	0	0
Noble Fir	0	0	0	0	0	0
Grand Fir	0	0	0	0	0	0
Fraser Fir	0.1	0	0	0	0	0
Shasta Fir	0	0	0	0	0	0
White Fir	0	0	0	0	0	0
Canaan Fir	0.1	0.1	0	0	0	0
Balsam Fir	0.9	0.2	0	0	0	0
Korean Fir	0.1	0	0	0	0	0
Nikko Fir	0.1	0	0	0	0	0.1
Turkish Fir #4	0.3	0.1	0	0	0	0.2
European Silver Fir	0.8	0.7	0.3	0.5	0.4	1.5
Nordmann Fir #13	1.4	1.0	1.8	1.6	1.4	1.5

[1]Curling was rated on a scale of 0 to 5, with 0 = no curling or evidence of adelgids and 5 = most needles are curled throughout the branch and many of the needles have a yellow or brown color. Overall damage was rated on a scale of 0 to 3, with 0 indicating no damage and 3 indicating an unmarketable tree.

Table 6. Products used in adelgid control trial.

Products	% active ingredient	Source
Ultor	14.4% spirotetramat	Bayer
Safari 20SC	20% dintefuran	Valent
OnyxPro	23.4% bifenthrin	FMC
Admire Pro	41.8% imidacloprid	Bayer
Syl-Tac	organosilicone surfactant	Wilbur-Ellis
Preference	NIS surfactant	Winfield

Table 7. Treatments rates, application sites, and application timing.

Treatments[1]	Rate	Type[2]	Timing[3]
Admire Pro + Syl-Tac	4 fl oz/A	Foliar	1
OnyxPro	6 fl oz/A	Foliar	1
Ultor + Preference NIS	16 fl oz/A	Foliar	1 &2
Admire Pro	12.8 fl oz/A	Broadcast	1
Admire Pro	25.6 fl oz/A	Broadcast	1
Safari 20SG	0.75 lb/A	Basal bark	1
Check	-	-	-

[1]Syl-Tac @ 4 fl.oz. and Preference NIS @ 0.25% v/v
[2]Sprays applied in 47.3 gal/A (foliar) or 11.9 gal/A (broadcast)
[3]Timing: 1 = April 8-11, 2014 and 2 = April 25, 2014

Table 8. Effect of adelgid treatments on 2014 needle curling and damage ratings on Nordmann fir trees[1].

			2014 Data		2015 Residual Control	
Treatments	Application site	Rate/A	Curling	Damage	Curling	Damage
Check	-	-	4.4a[2]	3.0a	1.3a	1.5a
Admire Pro+Syl-Tac	Foliar	4 fl.oz.	4.0ab	3.0a	0.8a	1.0a
Admire Pro	Broadcast	12.8 fl.oz.	4.0ab	3.0a	0.7a	0.7a
Safari	Basal bark	0.75 lb	3.0abc	2.4ab	1.0a	1.1a
Admire Pro	Broadcast	25.6 fl.oz.	2.8abc	2.8a	1.7a	1.6a
Ultor	Foliar	16 fl.oz	2.0bc	1.8bc	2.1a	1.9a
OnyxPro	Foliar	6 fl.oz.	1.4c	1.2c	1.0a	1.3a

[1]Curling was rated on a scale of 0 to 5, with 0 = no curling or evidence of adelgids and 5 = most needles are curled throughout the branch and many of the needles have a yellow or brown color. Overall damage was rated on a scale of 0 to 3, with 0 indicating no damage and 3 indicating an unmarketable tree.
[2]Columns with the same letter are not significantly different, $P<0.05$, Tukey's Studentized Range (HSD) Test.

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PROJECT #18

Project Title: The Snohomish County Agricultural Compost Research and Outreach Project

Partner Organization: Washington State University

PROJECT SUMMARY

The Snohomish County Agricultural Compost Research and Outreach Project (SCACROP) sought to increase the longevity and production of specialty crop farms through research, education, outreach and demonstration trials utilizing commercially produced compost as an experimental input on local specialty crops. Declining soil quality in intensive specialty crop rotations is threatening the long term productivity of the local farms. Western Washington specialty crop farmers are under considerable economic pressure to maintain intensive cash crop rotations in order to retain the farm businesses. Due to local consumer demands, these farmers wanted to reduce detrimental effects to soil and water quality, soil erosion, soil compaction, and contribution to greenhouse gases, all of which are caused by mining, rather than building, soil resources. This comprehensive, integrated project had a long term goal of increasing farmer economic and environmental sustainability in western Washington through the soil quality improvement practice of incorporating local, commercially produced compost into specialty crop production.

High annual rainfall, soil saturation, and fragile waterways pose particular challenges for specialty crop farmers in western Washington. In a region with high annual rainfall growers deal with compacted soils, saturated soil and drainage issues, (Backlund, 1995), erosion (Faucette, 2004), and nutrient runoff contributing to pollution in local waterways (Carpenter, 1998). While compost has the potential to alleviate these problems, the economic connection between local compost producers and specialty crop farmers had yet to be established. There was a lack of information on cost/benefit analysis of compost and minimal training available on the use of compost in specialty crop production. SCACROP was needed to address the disconnect between western Washington farmers and readily available commercial compost. SCACROP helped close the local nutrient cycle and returned food and yard waste nutrients to local specialty crop farmland in a time when local municipal compost companies are only selling approximately 5% of their product volume to the western Washington agricultural market.

SCACROP built upon a previous compost program that was funded from 2011-2013. SCACROP continued the previous program's work by facilitating on-farm side by side crop demonstration trials with municipal compost. SCACROP was able to increase program participants by adding additional certified organic farmers and increasing outreach and education regarding agricultural use of municipal compost. SCACROP continued to conduct farmer surveys and was able to verify barriers to compost use that were hypothesized during the previous compost program (2011-2013). Furthermore, SCACROP was able to expand the list of project partners to include Lenz Earthworks (the second largest compost producer in the county), Bailey Compost, as well as Snohomish County's Surface Water Management Division and Economic Development Team.

PROJECT APPROACH

SCACROP recruited two farmers in 2015 and 2016 for on-farm research trial collaboration. The two research trials utilized a more complex design than in previous years, going beyond the scope of the grant and providing valuable and interesting research results. SCACROP also conducted 59 demonstration trials with local specialty crop farmers and organized the distribution of 2,950 cu/yards of compost. As per the work plan, farms were visited regularly. Each trial site was visited three to five times throughout the season to collect photos and feedback and monitor trial progress. Demonstration crops included mixed vegetables, tomatoes, radishes, pumpkins, sweet corn, Christmas trees, berries, cut flowers, salad greens, herbs, squash, and more. Compost delivery timing proved to be challenging (mostly due to erratic weather patterns) but ultimately was successful. Farmers in the demonstration trials did side by side comparisons with compost vs. no compost in the same field and with the same crop. The aim was to let each farmer see for themselves how the compost would impact their crops in their fields. Surveys of the participants were conducted each year and in the WSU Social and Economic Sciences Research Center (SESRC) 2016 survey 73% claimed that compost either greatly or somewhat improved their farms profitability, 19% indicated that compost greatly or somewhat reduced the use of chemical fertilizers on their farm, and 84% of respondents may continue to incorporate compost in the future as part of their regular land management practices.

Outreach activities during the full grant period were numerous and have been detailed in previous annual performance reports. However, for perspective, prior to SCACROP there were limited western Washington specific field guides and resources available for western Washington farmers to understand how to use compost in their farming system and very little government or educational effort being allocated to discuss compost use with Snohomish County farmers. As a direct result of SCACROP there are now compost tools available for local farmers (Compost use field guide, Best Management Practices, instructional videos etc.). Furthermore, SCACROP hosted meetings and feedback sessions to improve communication between farmers and compost producers as well as farm planners and landowners who are interested in agricultural compost use. SCACROP considers these steps as evidence of progress towards increasing farmer knowledge of compost in specialty crop production.

SCACROP had 9 partners contributing to the success of this project.

- Cedar Grove, Lenz Earthworks and Bailey Compost all contributed the in-kind resource of compost to the program.
- Snohomish County Surface Water Management provided the funding to pay for the testing of soil and tissue samples gathered during the research trials.
- Snohomish County Ag. Director provided feedback on the program and free outreach space at the local Focus on Farming event each year.
- Snohomish County Office of Energy and Sustainability provided assistance in research on compost spreading equipment, document review and attendance at the annual partner meeting.
- The Snohomish County Solid Waste Division contributed in kind contributions of technical support and program promotion at conferences.
- Snohomish Conservation District provided valuable assistance in research days, program advising and demonstration trial monitoring.
- The US Composting Council Research and Education Foundation provided collaboration and guidance to the SCACROP program staff.

Project staff met with all farmers every season before they received compost and discussed with them the type of crops they planned on growing with compost. All farmers were instructed to use the compost on specialty crops. The farmers were visited a minimum of two other times throughout the growing season to insure that the compost was only used on specialty crops. This allowed for farmers to see for themselves the benefits of compost on specialty crops.

GOALS AND OUTCOMES ACHIEVED

SCACROP outlined three expected measurable outcomes in the grant project. Some of these outcomes have more than one specific benchmark and some are more focused on long term goals. The following paragraphs will outline each measurable outcome, and the activities taken to meet that outcome.

Outcome 1: Increase the number of famers in Snohomish County using compost on specialty crops. SCACROP visited more than 200 farms in Snohomish and King Counties and encouraged them to participate in the compost trials. Every farm that participated in the program had signs displaying to the public their participation in the demonstration trials. Outreach was conducted at local community events, like the Evergreen State Fair and Focus on Farming to encourage more farmers to use compost on their specialty crops. SCACROP created educational compost videos that are featured on a Washington State University Snohomish County Extension website (http://extension.wsu.edu/snohomish/agriculture/compost/watch-our-youtube-films/). This combined outreach effort helped increase farmer knowledge of compost utilization in specialty crop production.

Outcome 2: Increase specialty crop production in Washington through the use of commercially-produced compost. SCACROP addressed this outcome by providing farmers with commercially produced food and yard waste compost that was then used on specialty crops. SCACROP arranged for the delivery of the commercial compost to program participants at no cost to those participating farmers. The compost was offered in conventional and organic blends to meet the needs of a wider audience of farmers. In addition, SCACROP was responsive to initial farmer feedback and began providing double screened compost to help reduce contaminants and larger woody material. SCACROP also created a Best Management

Practices handout that was provided to farmers to aid them with compost application rates, methods, and timing for incorporating compost on specialty crops. Finally SCACROP helped develop and distribute a field guild entitled "Fertilizing with Manure and other Organic Amendments," shown below in the "Additional Information" section.

Outcome 3: Increase resilience of local specialty crop farmland through enhanced soil quality, increased water infiltration rates and reduced run-off.

Two farmers were recruited to collaborate in on-farm research trials in 2015 and 2016 using sweet corn as a crop. These four research trials utilized a more complex design than in previous years; a split block design was used to analyze compost by fertilizer interactions. In addition to compost and no compost treatments, nitrogen fertilizer was applied at staggered rates including 0x the recommended rate, 1/2x, 3/4x, and 1x the recommended fertilizer rate (based on soil tests). Planning meetings were held with each farmer and experimental sites were chosen for each trial. Plot marking, soil samples, and compost application for each trial took place in 2015 and 2016. Data collection included: pre-plant, mid-season, and post-harvest soil nitrate testing; corn biomass, ear weight, ear quality, and nitrogen content; and soil bulk density and infiltration testing. Data analyses are still underway, but the research design should indicate whether any yield increases due to compost were provided by an increase in nitrogen availability alone or if general enhancement of soil quality provided a synergistic effect.

Increasing the resilience of local specialty crop farmland through enhanced soil quality, water infiltration rates and reduced run-off are considered a long-term expected measurable outcome. It may take years of continual compost application to a field in order to observe these benefits. SCACROP believes that by providing farmers with compost and inspiring them to continue to use compost after the program is over, that farmers will increase the resilience of their farmland.

Project Activity	**Responsible Party**	**Timeline (*month and year*)**	**Actual Accomplishment**
Develop participant list, outreach plan and materials for recruitment of new and revisiting existing specialty crop participants. Begin outreach. Integrate compost education and outreach programs with volunteer outreach efforts, including developing, updating, printing/uploading and distributing outreach materials.	WSU Extension (WSUE) and Snohomish Conservation District (SCD)	Oct. – Nov. 2013	Completed
Farmer recruitment for 2014 season, create timeline, plan educational workshops, outreach at conferences and community events.	WSUE, Snohomish County (SC) and SCD	Dec. 2013- Feb. 2014	Completed
Farm visits, compost deliveries and application, begin research and demonstration trials.	WSUE, Farmers, Compost Producers and SCD	Feb.- May 2014	Completed
Monitoring and data collection for demonstration and research trials, host workshops, video/photo testimonials and documentation.	WSUE and SCD	June- Aug. 2014	Completed
Season wrap up & survey, research site data collection, report, website, create short video from testimonial and documentation footage.	WSUE and SCD	Aug. – Nov. 2014	Completed
Recruitment for 2015 season, refine timeline, plan educational workshops, outreach at conferences and community events.	WSUE, SC and SCD	Dec. 2014- Feb. 2015	Completed
Farm visits, compost deliveries and application, begin research and demonstration trials.	WSUE, Farmers, Compost Producers and SCD	Feb.- May 2015	Completed

Monitoring and data collection for demonstration and research trials, host field days and workshops, video/photo testimonials and documentation.	WSUE, SC and SCD	June- Aug. 2015	Completed
Season wrap up & survey, research site data collection, report, website development.	WSUE and SCD	Aug. – Nov. 2015	Completed
Recruit for 2016 growing season, refine timeline, plan educational workshops, outreach at conferences and community events.	WSUE, SC and SCD	Dec. 2015- Feb. 2016	Completed
Farm visits, compost deliveries and application, begin research and demonstration trials. Begin development of Compost Field Guide.	WSUE, Farmers, Compost Producers and SCD	Feb.- May 2016	Completed
Monitoring and cumulative data collection for demonstration and research trials, host field days/workshops, video/photo testimonials and documentation, begin drafting peer-reviewed article and continue Compost Field Guide.	WSUE, SC and SCD	June- Aug. 2016	Completed
Project wrap up & survey, research site data collection, create cohesive report for three years of trials, website, short film on findings for three years of trials, complete and distribute Compost Field Guide, and prepare manuscript submission to peer-review journal.	WSU and all partners	Aug. – Sept. 2016	Partially-Completed

Outcome 1: Increase the number of famers in Snohomish County using compost on specialty crops.
The original metric was an achievement of 60 specialty crop growers participating in the three year program.
Rather than 60 individual farms participating in the trials, at least 60 trials or 'site years' was achieved. Some of the completed trials took place on the same farm site over multiple years to encourage repeat compost applications and ongoing involvement in the program. As has previously been reported in the annual performance reports the Compost Trials Program has an additional funding source, the Coordinated Prevention Grant, administered through Snohomish County. This funding in conjunction with the SCBGP funding enabled SCACROP to work with a total of sixty-five individual farm participants over the course of 3 years. In 2013 only 20% of program respondents indicated that they had used food and yard waste prior to their participation in the SCACROP program. The original metric was a target of 80% of respondents plan to utilize compost in their operation after SCACROP. In the final survey of program participants (SESRC 2016) (see "Additional Information" section below), 84% of responding participants indicated that they may continue to incorporate compost as a part of their future land management practices.

Outcome 2: Increase specialty crop production in Washington through the use of commercially-produced compost.
The original metric benchmark for increasing specialty crop production was a 20% crop yield increase for pumpkins and 70% of program participants seeing increases in yield. SCACROP research with compost application results are as follows:

2014 research: Compost applications to cucumbers were tested and found that with an addition of 27.5 dry tons of compost per acre an additional 0.82 tons of cucumbers per acre were produced. Organic green bean production was also tested in 2014. Organic compost was added to the field at a rate of 24.8 cubic yards per acre and resulted in a 19% (0.64 ton/acre) increase in yield compared to the control. In 2014 SCACROP also tested municipal compost impacts on beet seed production. Compost was applied at a 55 cu yd/acre application rate and resulted in a 21% increase in yield.

2015 research: SCACROP completed two research trials on sweet corn utilizing 7.8 and 8.6 dry tons/acre of municipal compost and 4 different rates of nitrate fertilizer. Both studies found that the ground where the corn was planted already had significant available nitrogen to grow corn, likely due to a history of manure application, and no significant nitrogen or compost effect was detected at either site. However, it was found that compost reduced bulk density at both sites, indicating that compost had a positive influence on the soil's physical properties.

2016 research: SCACROP again conducted research trials on sweet corn. This time an effort was made to find fields that had been underperforming in the past. At the first site, a notable compost effect was detected for both corn ear weight (p value=0.074) and corn biomass (p value = 0.097), along with a significant fertilizer effect for ear weight (p value = 0.043). Across all fertilizer treatments at the first site, compost increased corn ear weight by 19% and at the highest nitrogen application rate compost increased corn ear weight by 45%. At the second research site there was a compost by fertilizer interaction for ear weight (p value= 0.076); at the two lowest fertilizer rates (0x and 0.5x) compost resulted in an increase in ear weight (p value = 0.059 and p value = 0.049, respectively). Once processed, soil nitrate and corn nitrogen content results should help us interpret and explain the increased yield with compost.

The final measurement of achievement of Expected Measurable Outcomes regarding crop production is available via the 2016 SERC survey. In the survey, 83% of farmers in demonstration trials reported that compost either greatly or somewhat improved their specialty crop production. In addition, 73% of responding farmers reported that compost improved their farm's profitability.

Outcome 3: Increase resilience of local specialty crop farmland through enhanced soil quality, increased water infiltration rates and reduced run-off.

For the two research trials the original metric benchmark was increasing resilience of farmland via water infiltration rates and soil nutrient qualities. 2013 research trials revealed that infiltration rate testing was time consuming and did not prove to be a useful indicator of soil quality. It was thought that infiltration testing might be performed at the end of the three-year grant cycle, testing only those research sites that received additional compost each year. However, during the course of the project it was determined to forgo infiltration rate testing on demonstration trials and instead focus efforts on interactions between nutrient availability and soil quality in the research trials. Infiltration was evaluated in the 4 research trials conducted during 2015 to 2016. Each site received just one application of compost (not multi-year experiments) and no differences in infiltration rates were detected.

For the demonstration trials the original metric benchmark was 90% of participants will experience enhanced soil quality, nutrient retention and increased water infiltration rates. In the June 2014 survey, 95% of demonstration trial participants reported that the compost had improved or greatly improved their soil quality. In the SERC 2016 survey of demonstration trial participants, 97% reported that compost improved their soil quality and 84% reported that compost improved their soil's water retention capabilities.

BENEFICIARIES

The primary beneficiaries of the SCACROP program are the participating specialty crop farmers. SCACROP provided farmers a first-hand opportunity to use food and yard waste municipal compost in their fields and see the benefits of compost on their crops. The WSU extension and larger academic communities will benefit from the results of the farm research trials. And ultimately the environment is a beneficiary of approximately 3688 yards (1844 tons) of food and yard waste being diverted from the local waste stream and returned as critical nutrients back to the agricultural landscape as compost.

The farmers associated with the SCACROP program received compost at an estimated value of $60,447.54. They also are the beneficiaries of a $10,000 King County funded compost cost benefit analysis. The compost companies that donated to SCACROP received the 2016 SERC survey of farmers valued at $5,000 and an unknown value of positive publicity regarding their involvement in the program.

LESSONS LEARNED

SCACROP positive lessons as a result of completing this project included:

- Compost generally does have a beneficial impact on crop production and soil quality.
- The ability to spread compost has a large bearing on whether or not a farmer will use compost.
- The use of compost with certain specialty crops may or may not help the farmer break even or yield a net gain. For example it was found that the compost breakeven price for green beans in the 2014 trial was $12.58 per yard of compost and $4.80/ yard of compost for beet seed.
- Compost on u-pick Christmas trees showed excellent growth and may be a future market for municipal compost.

SCACROP negative lessons as a result of completing this project included;

- Farmers in western Washington are generally not willing to pay the breakeven price that compost producers require largely because they have been accustomed to receiving free manure or other waste nutrient products.
- Farmers generally indicated that they would not use municipal compost on root crops for fear that the root crop would grow around any plastic contamination in compost.
- Environmental challenges of western Washington farms (smaller, wetter, more nutrient rich fields than eastern Washington) were part of the barrier to western Washington farmers purchasing and using compost on their fields.
- Fields with a history of manure or compost application are less likely to observe a yield increase with compost application.

SCACROP did not expect to find Christmas tree farmers to report such positive results from their demonstration trials. SCACROP also anticipated that the farmers would be more willing to purchase compost on a large scale after the program ended. However, it may be that many smaller organic farmers will continue to use compost as part of their standard farm practices, while larger acreage conventional farms may only purchase compost for fields that are in need of rehabilitation or water retention.

As previously noted in the annual performance reports, significant delays during the production of the extensive 3-part "Learning from the Composters" film made the original SCACROP goal to create a second film that focused on the 3-year research findings unattainable. Lessons learned would include budgeting more time and resources for film production (scripting, editing, shooting, reshooting, legal/release processes, etc.) However, due to the availability of funds and flexibility of WSDA, SCACROP was able to shoot a second short high quality film with one of the participating King County farmers. This second film does an excellent job highlighting some of the successes of SCACROP program and provides a glimpse at the world of municipal compost on a small organic specialty crop farm.
(See http://extension.wsu.edu/snohomish/agriculture/compost/)

SCACROP will submit an article about the research trials in early 2017 to the peer-reviewed journal *Compost Science and Utilization*.

ADDITIONAL INFORMATION

Overall SCACROP had a total of $183,352.00 obligated as either a cash or in kind match. SCACROP ended the program with $180,282 total match listed below:

Washington State University-facilities and overhead fees for a total of $53,062.

Snohomish County Conservation District provided staffing assistance and compost outreach for a total of $18,764.

Snohomish County Office of Energy and Sustainability provided research assistance and program feedback for a total of $13,182.35.

Snohomish County Public Works Solid Waste Division assisted in collaboration between local food and yard waste haulers and the WSU SCACROP program participated in overall coordination and review of activities for a total of $24,120.21.

Snohomish County Office of Economic Development, provided program guidance, research and reviewing program deliverables for a total of $1,989.

Compost Council Research and Education Foundation provided program guidance, research and reviewing of program deliverables for a total of $2,725.

Snohomish County Public Works: Surface Water Management provided the funding to pay for soil and tissue sample tests for a total of $5,991.90.

Lenz Enterprises provided compost for a total contribution valued at $27,727.04.

Cedar Grove Composting provided compost for a total contribution valued at $22,704.50.

Bailey Compost provided compost for a total contribution valued at $10,016.00.

Biocycle Article: Commercial compost application on western Washington Farms. (See below)
Other fact sheets created for the projects can be downloaded at the SCACROP website: http://extension.wsu.edu/snohomish/agriculture/compost/

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Carpenter, S.R. e.a. 1998. Nonpoint Pollution of Surface Waters With Phoshphorus and Nitrogen. *Ecological Application*, 8(3), 1998, pp. 559-568.

Collins, D.P., H. Harness, and A.I. Bary. 2016. Commercial compost application on western Washington Farms. Biocycle. 57(3):63-65

Faucette, L.B.e.a. 2004. Runoff, erosion, and nutrient losses from compost and mulch blankets under simulated rainfall. *Journal of Soil and Water Conservation* 59: 154-160.

To read the publication titled Fertilizing with Manure and Other Organic Amendments, please click here: https://puyallup.wsu.edu/soils/wp-content/uploads/sites/411/2016/07/Paper_FertManure2016.pdf

For more information on Compost Trials in Agriculture; A Survey of Study Participants (Data Report 16-54), please go to http://www.sesrc.wsu.edu.

WSU Compost Outreach Project
Recommended Best Management Practices for Compost Use (Working Draft) January 2016
WSU Snohomish County Extension

Incorporating Compost into Fertility Plan

1. Obtain Compost Analytical Data/Nutrient Analysis from compost producer.
2. Determine the amount of Nitrogen you desire to supply with your compost application. Use one of these methods to determine Nitrogen need:
    a. Soil lab recommendations: Conduct soil sampling in the field where you plan to add compost, provide information about previous crop and crop you will be growing in the amended soil. (The lab recommendation may not be as accurate if a cover crop is utilized or if organic matter has been applied regularly over previous seasons).
    b. Most reliable method: Determine Nitrogen required for a certain crop, taking into account N from soil OM and N from a cover crop.[3] (See Table 2, on page 5).
3. Upon delivery of compost, delivery driver should provide delivery ticket with weight and estimated volume of compost received along with the most recent compost testing data. If not provided upon delivery, this information can be provided by composter.
4. Determine NPK nutrient value of compost (using Compost Analytical Data sheet, provided upon request by the compost producer), by looking at the % values in the "As Rcvd" column and converting them to lb/ton through the following steps:
    a. Nitrogen
        i. Multiply the % total Nitrogen of the compost (provided in the compost analytical data) by 20 to get lb of N wet ton of compost.

Ex: .94% total N x 20= 18.8 lb of N/wet ton of compost (enter into worksheet on line D).

% total N Your value: _

x 20 =_____lb of N/wet ton of compost
(Enter this ^ value into worksheet on line D)

b. Phosphorus (P_2O_5)
    i. Multiply the % by 20 to get lb/wet ton (enter into worksheet on line E).
c. Potassium (K_2O)
    i. Multiply the % by 20 to get lb/wet ton (enter into worksheet on line F).

5. Follow the steps in the worksheet to determine the compost application rate needed to meet the nitrogen needs of your crop.
    a. You may need to base rates on P to avoid excessive P in the soil, and supplement with other N sources to meet the total crop N requirement.

Table 1: Work sheet for Calculating Compost Application Rate

Worksheet for Calculating Compost Application Rate:
Example: I am growing sweet corn and the recommendation is 100 lbs/acre of Nitrogen. I have compost that contains 18.8 lbs of N, 6.4 lbs P, and 11.6 lbs K per wet ton of material.

#	Step	Units	Example	Your Value
A	Type of material		Food & Yard Waste Compost	
B	Crop		Brassicas	
C	Desired N application rate	lb N/acre	85	
D	Compost N concentration (from laboratory analysis).	lb N/ ton as-is	18.8	
E	Phosphorus concentration (from laboratory analysis).	lb P_2O_5/ton as-is	6.4	
F	Potassium concentration (from laboratory analysis).	lb K_2O/ton as-is	11.6	
G	Plant availability of N in compost	Percent	7	7
H	Calculate compost available N Line D x (line G/100)	lb N/ton as-is	1.3	
I	Calculate application rate Line C/line	wet tons compost/acre	65	
J	Calculate the amount of phosphorus applied Line I x line E	lb P_2O_5/acre	416	

K	Calculate the amount of potassium applied Line I x line F	lb K_2O/acre	754

Worksheet adapted from PNW0533 Fertilizing with Manure
http://cru.cahe.wsu.edu/CEPublications/pnw533/pnw533.pdf Andy Bary, Craig Cogger, Dan M. Sullivan, 2000.

Calibrating your rear discharge manure spreader to achieve desired application rate:

6. (Manure spreader calibration can be done using this method or the method defined in step 7). Use Tarp Method to determine actual compost application rate:
    a. Measure tarp to determine square footage (area), record the tarp area
        i. use a tarp that is no wider than the spreader spray pattern
    b. Record original weight of tarp or container you will utilize for weighing
    c. Place tarp on ground in the pathway of the tractor and manure spreader
    d. Drive over the tarp in a single pass and spread compost evenly over the tarp
    e. Gather tarp and take care to contain all compost in the tarp
    f. Weigh the compost, subtract the weight of the tarp or bucket, and record the weight
    g. Divide the weight of the compost by the tarp area to get lbs. of compost per sq.ft. Ex: 75 lb of compost / 144 ft2 = 0.5 lb of compost per sq. foot

Your Value: (lb of compost) / _ (lb of compost per sq ft) (size of tarp in sq ft) = _

    h. Convert to lb per acre. There are 43,560 sq. ft. per acre.

Ex.: 0.5 x 43560 = 21,780 lbs of compost per acre (or 11 wet tons/acre)
Your Value: _(lb of compost per sq ft) x 43560 =(lb of compost per acre) (Divide by 2000 to get wet ton per acre)

    i. Adjust your application equipment settings, or make multiple passes with the spreader to achieve desired compost application rate
    j. Use actual compost application rate to determine actual quantity of nutrients applied. (see worksheet in table 1)

**To convert cubic yards of compost to tons or tons to cubic yards, utilize this conversion rate: 1150lb/cu yd or find actual bulk density by following step 7a (below).

7. Use compost Bulk Density and spreader capacity to determine application rate (Bulk Density of compost can be calculated from Compost Analytical Data or you can use the assumed Bulk Density of 1150 lb/cu yd):
    a. Find the "As Rcvd" Bulk Density of the compost by referencing the Compost Analytical Data sheet. Bulk Density is provided in lb/cu ft. (Ex: 39 lb/cu ft)
    b. To convert the Bulk Density to lb/cu yd multiple the provided number by 27. (Ex: 39 lb/ cu ft x 27= 1053 lb/ cu yd)
    c. Determine the capacity of the manure spreader. If capacity is provided in bushels, divide the bushels by 21.7 to find capacity in cubic yards.

d. Multiply the spreader capacity by the Bulk Density of the compost to determine the weight of a full load of compost. (Ex: if spreader capacity is 2 cu yds x 1053 lb/ cu yd= 2106 lb of compost in one full manure spreader load)
e. Spread a load on the field in a rectangular pattern and measure the length and width covered by one full load. Multiply the length and width to determine sq footage of the covered area. (Ex: 100ft length x 6ft width= 600ft2)
f. Divide the weight of the compost in the spreader by the square footage of the covered area to determine lb/sq ft of actual compost applied. (Ex: 2106lbs / 600ft2= 3.51 wet lb/sq ft)
g. Convert to tons/acre by multiplying the wet lb/sq ft of actual compost applied by 21.78. (Ex: 3.51 lb/sq ft x 21.78 = 76.45 wet tons/acre)
h. Modify the application rate through tractor or manure spreader adjustments.
i. To convert wet tons/acre to dry tons/acre assume a compost moisture content of 50% and divide by two (Ex: 76.45 wet tons/acre ÷ 2= 38.2 dry tons/acre). 5

8. Once compost is applied, it's recommended to incorporate the compost into the soil within twelve hours. If top-dressing a pasture or hay field, use a harrow.
9. After incorporating compost, wait at least 10 days before planting for annual crops. This allows compost to stabilize in the soil and nutrients from compost to become available to plants.

General Compost Use Recommendations:

1. Know the needs of your crops and the current soil nutrient content.
2. Compost application rate can be determined based on your **goals** (listed in order of lowest to highest compost application rate)*:

*Compost can be assumed to have 50% moisture content.

a. -**improve health/microbial life**, 7 - 70yds^3/acre (2 - 20 dry tons/acre*) **(lowest rate)**
b. -**nutrients: N,P,K, micros**, determine rate using compost nutrient content and crop needs (steps 4-8 above)
c. -**increase organic matter**
d. -**nursery and planting bed establishment**, ½ - 3 inch layer or 30 – 200 yds^3/acre (9-60 dry tons/acre*)
e. -**reclamation:** increase productivity of crop land, 1 - 2" layer or 200+ yds^3/acre (60+ dry tons/acre*)
f. -**mulch**, 1-2 inch layer or 200+ yds^3/acre (60+ dry tons/acre*) **(highest application rate)** [1]

*Assumptions: 1 yd^3 weighs approx. 1150lbs and has 50% moisture content

3. For annual crops, apply and incorporate compost 10 days prior to crop planting to ensure the compost is stabilized and nutrients are available to the crop(s).
4. Rear discharge manure spreaders are a common tool for field application of compost.
5. Incorporation of the compost is recommended whenever possible. Incorporating compost within 12 hours of application is important to reduce Ammonium-N volatilization losses. [2]
6. Establishing new planting beds:
   a. New planting beds can benefit from one to three inches of compost incorporation to improve the soil's physical properties. [3]
7. Yearly compost application:
   a. Smaller amounts are needed to maintain organic matter and soil fertility (ie, ¼–½ inch). [3]
8. Compost will provide approximately 1.3 lb Total N /wet ton compost, 6.4 lb P_2O_5/wet ton of compost, and 11.6 lb K_2O/wet ton of compost in the first season after application (calculate nutrient values from Compost Analytical Data, see worksheet in Table 1 above), additional nutrients may need to be supplied using other fertilizer sources with plant available nutrients.

Table 2: Calculating the amount of nitrogen (N) fertilizer needed (lb/A) for a vegetable crop when taking into account soil reserves and cover crop contributions.

Fertilizer N needed	=	Crop demand (lb N/A)	- [	N from soil organic matter (lb /A)	+	N from cover crop (lbs N/A)	]
Example:							
Fertilizer N needed	=	85 lb N/acre					
Fertilizer N needed	=	225 lb N/acre (Nitrogen needed for brassicas crop)	- [	70 lb N/acre (moderate organics applications over recent seasons)	+	70 lb N/acre (legume cover crop, dense stand)	]
Solving for this number indicates how much N application is needed for this growing season.		Obtain recommended fertilizer application rates from production guides. Ex: *The Pacific Northwest Vegetable Production Guides* (Oregon State University 2012)		Depends on soil management. Range of N yielded by soil OM: 50 to 200lb N/acre Regular organic matter inputs lead to higher end of the range= 200, moderate applications of organics lead to lower N mineralization= 70 lb N/acre. [3]		Did you plant a cover crop? If no, use a 0 in this category. Typical values for PAN are 30 to 70 lb N/a for winter cereal/legume cover crops killed in mid-April. [6]	

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YIELD BENEFITS

Commercial Compost Application On Western Washington Farms

WSU Cooperative Extension in Snohomish County's Compost Outreach Project has worked with over 70 farmers since 2011 doing research trials and on farm demonstrations.

Doug Collins, Hallie Harness and Andy Bary

Photos courtesy of Washington State University Extension

In the 2015 research trials, compost made from yard trimmings and food scraps was applied to fields at "Farm B" at a rate of 8.6 dry tons/acre.

WITH over 13 commercial composting facilities, and over 900,000 tons of food scraps and yard trimmings composted annually at these operations, western Washington is at the forefront of organic materials recovery. Although compost is available on a large scale, agricultural markets make up less than 5 percent of the total compost market in Washington State. The Washington State University (WSU) Compost Outreach Project is working to evaluate the benefits of compost on local crops and address the challenges faced when using compost.

Since 2011, WSU Cooperative Extension in Snohomish County (WA) has collaborated with local compost producers, county offices and local Conservation Districts to promote and evaluate use of commercial food scraps and yard trimmings compost on farms in Snohomish and northern King County (WA) through compost use trials. While

es of organic matter, in 2015, 81 percent of farmer respondents (35 out of 43 WSU Compost Trials Participants) had not used food scraps and yard trimmings compost prior to participating in the trials. Local compost producers, Bailey Compost, Cedar Grove Composting and Lenz Enterprises, have donated over 4,500 tons of compost to the project since 2011, with the goal of expanding its use in agriculture.

The research trials and on-farm demonstrations conducted as part of the Compost Outreach Project are described in this article. Scientific research trials validate use of compost on local crops, while demonstration trials provide the opportunity for farmers to get firsthand experience using commercial compost and test it out in their operations.

with farmers in Snohomish and King Counties have revealed several challenges to using compost. The most significant barriers to using more compost in agriculture are compost price, compost spreading (time and equipment), and lack of information.

PRE-2015 RESEARCH TRIALS

Research trials conducted through the program prior to 2015 compared two treatments: A growers' Business As Usual (BAU) chemical fertilizer application vs. BAU + Compost. Trials took place on several farms in Snohomish County. At Carleton Farm, trials

evaluated the effect of cumulative multiyear compost applications. In 2012,

proximately 20 dry ton/acre) increased pumpkin yield by 28 percent. In 2013, with three years of compost application

weight increased by 24 percent. In 2014

post was applied and the three previous years of compost application resulted in

In 2014 at Darrell Hagerty Farms, a light application rate (6.5 dry tons/

creased organic green bean yield by 19 percent. Beet seed at Williams Farm showed a 21 percent increase in yield

with a 20 dry ton/acre application. Each of these results was statistically significant and utilized commercial food scraps and yard trimmings compost.

ON-FARM DEMONSTRATIONS IN 2015

There were 49 demonstration trials in 2015, which involved qualitative observation of crop growth with compost applied next to ano-compost treatment. Crops included sweet corn, hay, mixed

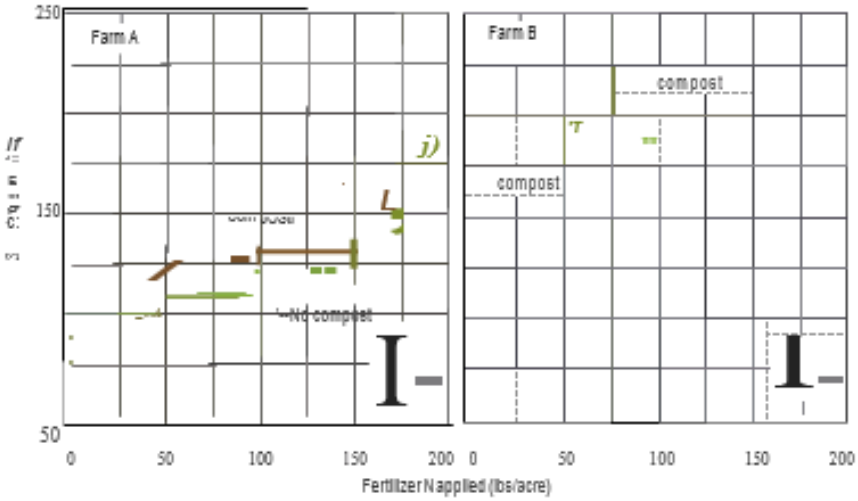
Table 1. Soil physical and chemical parameters at on-farm experiments in 2015

	Farm A	Farm B
Organic matter %	5.7	7.3
Bray P (ppm)	38	130
K (ppm)	178	366
pH	5.7	5.4
Texture	Puget silty clay loam	Puget silty clay loam

vegetables, berries, tomatoes, pumpkins, Christmas trees, salad greens, cut flowers, hazelnuts, brassicas, and more. Farmer feedback was collected through the Compost Outreach Project's annual survey (conducted since 2012). Farmer collection of yield and/or soil testing data is optional in the demonstration program. While the drought in 2015 posed significant challenges, farmers reported that compost improved crop production in 68 percent of the trials (out of 47 trial crops). Fifty-five percent of farmers found compost increased soil water retention.

Christmas tree farmers have observed improved treegrowth and health and hope to sell the trees mulched with compost earlier than anticipated, which translates to potential increased profit for these growers. A farmer using compost on sweet peppers reported larger and more productive plants; blueberry plants have thrived in rows mulched with compost, and compost consistently has shown positive crop yield and

Figure 1. Mid-season soil nitrate (mg/kg) with different spring fertilizer applications and with and without compost on two western Washington farms, 2015 (bars are standard error of the mean)



health results on pumpkins. Several participant s reported that the compost did nothing, i.e., there was no obvious observable effect of the compost on the crops. These arejust a few highlights of the 2015 demonstration trials.

2015 RESEARCH TRIALS

Experimental Design

Research trials in 2015 were designed to evaluate the nitrogen contribution from compost as well as changes to soil physical properties on two separate farms with sweet corn as a crop. The design was a replicated strip-plot experiment where compost was either applied or not applied in strips and nitrogen fertilizer (urea) was broadcast preplanting at four different rates within the strip, including a zero-N application. The authors hypothesized that compost would compensate for some nitrogen deficiency through mineralization of the organic nitrogen in compost to plant-available nitrogen.

A different high rate of nitrogen fertilizer was chosen at each farm based on preseason soil testing and estimated nitrogen contribution from organic matter. In addition to the high rate, three other rates were applied for a total of four, where "X" is the full rate: LOX, 0.75X, 0.5X, and 0.0X. Corn ear weight, plant biomass, soil nitrate concentration, and bulk density were evaluated. Soil nitrate concentrations are an indication of nitrogen availability for plant uptake.

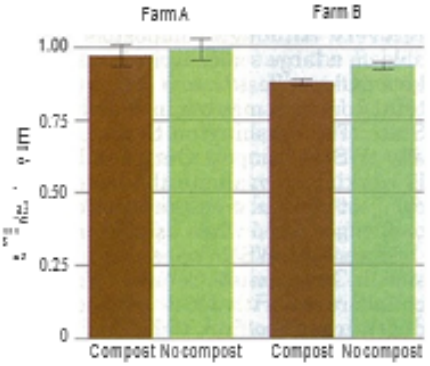
The two collaborating farms ("Farm A:' and "Farm B") have been involved in the Compost Outreach Project since 2011. At Farm A, compost (from Cedar Grove) was applied at a rate of 7.8 dry tons/acre and at Farm B, compost (from Bailey) was applied at a rate of 8.6 dry tons/acre. The difference in application rates was due to differences between manure spreaders used at each farm. At Farm A, the IX rate of nitrogen was 196 lbs/acre and at Farm B the IX rate was 100 lbs/acre. Other pre-experiment soil properties are shown in Table 1.

Results

Neither corn ear weight or plant biomass were significantly affected by fertilizer or compost. Mid-season soil nitrate concentrations were not affected by compost, but were significantly affected by fertilizer nitrogen application (Figure 1).

The mid-season soil nitrate test was meant to be taken around the same time that farmers would test their soil to decide if a sidedress application of nitrogen is necessary. This test, also known as the pre-sidedress nitr ate test (PSNT), can be used to guide mid-season nitrogen applications. Fertilizer rates should be made based on soil nitrate levels when sweet corn is at the five or six leaf stage. If soil nitrate levels are less than 10 ppm, then as much as 145 lbs N/acre are recomm ended. If mid-season nitrate levels are greater

Figure 2. Bulk density with and without compost application, 2015



than 40 ppm, then perhaps no fertilizer nitrate is necessary (Hart, 2010).

Mid-season nitrate levels were nearly 100 and 175 ppm at the zero nitrate fertilizer rate, much greater than what would suggest that crops would likely be deficient in nitrogen. There was likely no compost or fertilizer effect on crop yield because of naturally high levels of available nitrogen from previous management. Fields with a history of application of manure or other organic amendments are not likely to result in a yield increase from compost. In previous experiments on different fields, compost resulted in a 20 percent or larger increase in yield on several specialty crops.

Bulk density was decreased by compost applications at both farms, though the effect was only significant at Farm B where there was a 6 percent decrease (Figure 2). Bulk density (weight/volume) is a measure of soil compaction. Practices that improve soil structure such as cover cropping, reduced tillage, or organic matter application, can reduce soil bulk density. The 2015 research study designed to evaluate the effects of fertilizer and compost use will be repeated again in 2016.

ADDITIONAL PROJECT ACTIVITIES

Farmers have continually pinpointed compost price, spreading (equipment and time), compost delivery, plastic contamination of compost, and lack of information as challenges to using compost. Educational workshops and presentations have increased farmer knowledge of when and how to use compost. An ongoing dialog with composters and farmers is shaping a mutually beneficial relationship. Conservation Districts continue to enhance their focus on compost education, targeting farmers and landowners. Snohomish and King County Solid Waste Divisions, with support from Waste Management, continue to develop and expand the agricultural end use market to ensure the success of the local composting industry and the continued availability of compost for use on local farms.

Nitrogen fertilizer was applied at different rates in the 2015 trials based on preseason soil testing and estimated nitrogen contribution from compost.

The Compost Outreach Project has achieved notable success, working with nearly 73 farmers since 2011. In 2015 62 percent (23 out of 37 participating farmers) reported that they are motivated to continue using compost and nine farmers purchased loads of compost outside of the program in 2014 and 2015.

The Compost Outreach Project continues to leverage diverse funding sources and partners to break down barriers to increased farmer use of compost. Financial support comes from Snohomish County, a Washington State Department of Agriculture Specialty Crop Block Grant, and King County. Additional partners include Snohomish and King Conservation Districts, compost producers, and Waste Management.

Doug Collins is Extension Specialist at Washington State University.

Compost Outreach Project at WSU Snohomish County Extension. Until recently, Hallie Harness was the Program Coordinator of the Andy Bary is Soil Scientist at Washington State University Puyallup.

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PROJECT #19

Project Title: Integration of Weather Predictions into AgWeatherNet

Partner Organization: Washington State University (WSU)

PROJECT SUMMARY

The Washington Tree Fruit Research Commission has been instrumental in establishing AgWeatherNet (AWN) in support of tree fruit production in the State of Washington. The network currently encompasses over 175 stations that are located in economically important sites across the state. The data collected by the network have been the backbone for providing near real-time weather conditions and decision aids for producers. A critical application of the AWN has been for frost and freeze protection, but until recently no local forecasts or weather predictions have been provided.

In 2011, the Washington Tree Fruit Research Commission provided a one-year grant to explore how well a weather prediction model performed for Washington, especially the main fruit tree-growing region of the state. This grant allowed us to purchase a small High Performance Computer on which the Advanced Weather Research and Forecasting (WRF-ARW) has been implemented. Since implementation of the WRF model in 2012, hind-cast and real-time (operational) model predictions evaluated showed that WRF could be a significant informative tool in agricultural decision-making. A successful implementation of a high-resolution weather forecasting model with AgWeatherNet could have multiple outcomes, such as linking it to the many models and decision aids that are available on AgWeatherNet as well as for freeze forecasting.

The overall goal/motivation of this project was to evaluate the potential of implementing the WRF model as a tool for AgWeatherNet for weather and freeze predictions for Washington, specifically for regions where tree fruits are vital. Specific objectives included the following:

- To evaluate the performance of the WRF model for local conditions using the data and observations collected by AgWeatherNet.
- To develop a protocol for implementing the WRF model as a weather and freeze prediction tool for AgWeatherNet and associated decision aids.
- To develop freeze protection advisories for dissemination via the web, phone applications and other information technologies.

In 2011, the Washington Tree Fruit Research Commission provided a one-year grant to explore how well a weather prediction model performed for Washington, especially the main fruit tree-growing region of the state. That grant allowed us to purchase a small High Performance Computer (HPC) on which the Advanced Weather Research and Forecasting (WRF-ARW) has been implemented. As the model evaluation results were promising, further research was needed on the integration of the WRF model forecasting into other AgWeatherNet models and decision aids. It is this project that complimented and enhanced the previously started, but not completed work. This project supported further model tests, validations and evaluations, as well as the purchase of more compute nodes that grew the capacity of the HPC, (currently with 10 nodes, 320 processors), to complete the daily operational WRF prediction in which growers can get post-processed model results in time.

PROJECT APPROACH

As the custom of presentation of results to growers, the AgWeatherNet team presented one poster every year during the Annual Meeting of the Washington Association of Wine Grape Growers (WAWGG) since 2012. This year, it was held during the second week of February (9-11 Feb), 2016 in Kennewick and was attended by hundreds of growers, industry representatives and others interested in viticulture and enology. The AgWeatherNet team also had a booth during this meeting where the team displayed the AgWeatherNet hardware for monitoring local weather conditions and the AgWeatherNet portal with new features, including weather predictions.

•User survey on the use and application of the decision support systems on AgWeatherNet

The AgWeatherNet team provided questionnaires for in-person survey for the participants of the WAWGG annual meeting that was held in February 2016. While only 22 persons volunteered to complete the survey, weather (frost/freeze) prediction information and decision support tools came out as very important information that is needed by the specialty crop industry, especially tree fruit growers.

•Comparison of Performance of WRF Operational Model Predictions and Fox MtnRT Diagnostic Downscaling Model for the 2016 Growing Season for the Cherry, Apple and Wine Grape growing season

It was previously documented that the AgWeatherNet Advanced Weather Research and Forecasting (WRF-ARW) model was evaluated and validated in numerous times against AgWeatherNet observations and National Weather Service (NWS) National Digital Forecast Database (NDFD) outputs to infer its prediction ability of meteorological variables for the state of Washington. Those previous evaluations had shown that the model predicts more accurately over several AgWeatherNet stations with less topographic structural complexity as well as during the fair weather of a year. It was also proved that WRF forecasting accuracy drops as the region gets complex topographically and the weather conditions become so extreme, as the model generally showed underestimation of maxima and overestimation of minima temperatures over Washington State. Therefore, as the AgWeatherNet WRF data becomes available online for public use, the comparison against a diagnostic downscaling model called Fox MtnRT was imperative to further validate the products of WRF, particularly air temperature, which is critical meteorological variable for specialty crop growers for freeze/frost prediction. Fox MtnRT is a diagnostic weather forecasting model provided by Fox Weather, LLC (www.foxweather.com) and is widely used in the western agricultural regions of the US (Fox Weather, LLC, 2011).

It was also repeatedly reported that WRF has been undergone through model sensitivity analyses and evaluations in recognizing the optimal choice of combinations of physics options to predict near-surface meteorological elements, particularly air temperature for freeze/frost forecasting. To further cross-examine the performance of WRF against a widely used Fox MtnRT, 22 AgWeatherNet stations around the agricultural areas of eastern Washington were utilized in the statistical analyses for October 1-31 2015. However, only two stations are discussed in this final report (Detailed report can be request from the AgWeatherNet weather forecasting office). The two stations used in the analyses of air temperature forecast evaluations were: Roza (1,180ft) in Benton, and Wenatchee Heights (2,321ft) in Chelan counties. The WRF model requires several static and dynamic input variables to run. The Global Forecast System (GFS at 0.5-deg grid-resolution) analyses output provided "first guess" initial and boundary conditions (ICs and BCs) at 6-hr intervals for the daily WRF operational run. The Fox Weather, LLC runs the MtnRT diagnostic model by downscaling the NOAA's WRF forecast at 7.46 mil to a horizontal scale of 0.93 mil for the Pacific Northwest regions (Fox Weather, LLC, 2011).

The October 1-31, 2015 operational WRF forecast with the first 24 hours outputs after the first eight hours were removed as a "spin-up" period were used in the comparison against the Fox MtnRT model first 24 hours results by adding the four-hours (0000-0300 PST; as their daily diagnostic simulation begins at 0400PST or 1200UTC) missing data from the previous day model outputs. Both WRF and MtnRT results were evaluated using the AgWeatherNet (www.weather.wsu.edu) observations. The AgWeatherNet temperature sensors are situated at 4.9ft, at which height the Fox MtnRT is provided and the WRF model provides temperatures at 6.6ft above ground level.

The WRF model, which started running operational once daily with WRF version 3.4 in August 2012, has now utilized an upgraded version 3.7.1. As of this reporting, there are more than four years of archived gridded data with the highest horizontal resolution of 1.9mi over Washington State and other coarser domains that cover the Pacific Northwest, which is expected to be helpful for further model evaluations and weather-related research and crop management studies. In this report, model results of air temperature are presented and compared against the Fox MtnRT model using the AgWeatherNet observations. The October 1-31, 2015 was used as an important period for the freeze/frost season over the state of Washington. Here, the daily WRF and Fox MtnRT 24-hour forecasts (after 8-hr 'spin-up' WRF mode period was removed, and 4-hours missing data from MtnRT was added from the previous day MtnRT output) were extracted from the October 2015 outputs to compare independently with AgWeatherNet observations. The analyses are discussed using time series plots and histograms, as shown below.

In the time-series plots (Fig. 2), observed temperatures are labeled by black line, while WRF control run with only the first eight-hour spin-up period removed in broken deep blue line, and the Fox MtnRT results after the first four-hours missing data were added from the previous day output are plotted in a broken deep red. Similar color- coding was also used to represent the same models' variables for the histogram figures.

In general the model analyses persisted to show that WRF underestimated daytime temperature maxima and overestimated nighttime temperature minima. In this analysis, while the model reproduced temperatures more accurately, Roza station under predicted (negative bias) daytime maximum and over predicted (positive bias) nighttime minimum temperatures (See histograms in Fig. 2 below), while analysis results from Wenatchee Heights showed both daytime and nighttime temperature overestimation. Roza (Wenatchee Heights) station had daily average error (RMSE) of approximately 2.2oF (2.5 oF) and daily average bias (MB) of close to zero (1.8oF), as shown in the histograms below, respectively. Statistical analysis results for the Fox MtnRT model generally showed overestimation of observed temperatures over Roza (Wenatchee Heights) with the daily average error (RMSE) of 7.1oF (3.4oF) and daily average bias (MB) of 4.0oF (-2.4oF). In general, the WRF model predicted temperatures more accurately than the Fox MtnRT model for most of the 22 stations tested (all plots not shown).

In summary, while WRF generally predicted temperature values well for the first 15 stations, areas mostly located in the flat surface of the Columbia basin, the performance reduced slightly in the next four stations and significantly in the last three stations analyzed as the terrain structures and orographic complexities increase, in agreement with the previous sensitivity analysis reports. While further WRF comparisons against Fox MtnRT model is required using different weather cases, WRF performed much better than the Fox MtnRT for October 2015. This project report is another proof that the WRF model is a good forecasting tool that can help growers in decision-making.

The operational WRF modeling system provides predictions once daily since August 2012, using the Global Forecast System (GFS at 0.5-deg or ~35miles recently upgraded grid-resolution) analysis "first guess" data. The Fox MtnRT software is a diagnostic model owned privately by Fox Weather, LLC (2011) that downscales coarser horizontal resolution outputs from WRF to a higher resolution of 0.93mi. In general, the WRF run performed better in the prediction of air temperatures over the 22 stations evaluated. These stations were selected to represent locations with tree fruit (e.g. cherries, apples and grapes) growing areas of eastern Washington in the 2016 growing season. Therefore, with twice daily operational forecasting, the model can predict accurately and hence serve as an information tool in tree fruit and other specialty crops growers' decision making.

•Integrate the output of the WRF model with the AgWeatherNet data base

The WRF model currently operates on a daily basis. The operational WRF model results that include 2-D color coded air temperature, wind speed and wind direction as well as precipitation of the Northwest Pacific regions and Washington state regions are shown on a daily basis on the AgWeatherNet website (weather.wsu.edu). The post-processed results also contain time-series plots of air temperature, dew point, wind speed and precipitation for three-day forecast, updated daily.

•Recommendations and ongoing projects

WRF used to run twice daily to perform two types of runs: first, the formal run initialized by GFS large-scale analyses and second, when the whole process is repeated by adding observations through observational nudging method. As the anticipated positive impact from the ingestion of observations was limited, the observations assisted model simulation was interrupted following the introduction of the latest WRF model version (v3.7.1) as operational. Future activities should include either to make the operational twice daily or extend the forecasting length from the current 3-day to maybe 10-day forecast so that growers will have extended weather and crop modeling forecasts for their decision-making. While the additions of compute nodes to the HPC didn't help much in saving computational time, a fourth domain with horizontal resolution of 0.62mil can still be included to the WRF modeling configuration to help forecast overnight weather for freeze/frost prediction. It is to be noted that the WRF post-processing results are posted on the web (weather.wsu.edu) daily for growers & public use.

Interested people who accessed the online informative AgWeatherNet decision-making tools increased by more than 1,750 from October 1, 2014 to October 1, 2015 (Table 1). Although, the latest figure is not estimated, interested parties in AgWeatherNet program are growing. The information they seek and additional requests asked are tracked and are given particular attention for improvement.

GOALS AND OUTCOMES ACHIEVED

The overall goal of this project was to evaluate the potential of implementing the WRF model as a tool for AgWeatherNet for weather and freeze predictions for Washington, specifically for regions where tree fruits are vital. Therefore following objectives were achieved:

- Continuous evaluations of the performance of the WRF model for local conditions using the data and observations collected by AgWeatherNet was performed between 2012 – 2016 to infer that the WRF model can be used as agricultural informative tool in the state of Washington.
- The WRF model was later developed and implemented the WRF model as a weather and freeze prediction tool for AgWeatherNet and associated decision aids.
- The WRF model was developed to assist in the freeze protection advisories disseminated officially via the web starting October 2015. Further dissemination techniques such as phone applications and other information technologies are recommended for future use.

The current measurable outcome researched provides anticipated results for specialty crop growers and other researchers. However, further research work on the project would make the model results more reliable by increasing in time and space resolutions.

- Improve the hardware components of the High Performance Computer (HPC) system of AgWeatherNet for operation of the WRF model

    - Previously, two new compute nodes were added to the HPC to improve computational efficiency. The addition of the new nodes improved the time taken to complete the operational forecast. However, the hope of adding a high-resolution domain to the WRF model didn't help in completing the forecast to be available for use by growers and other end-users in a reasonable time. Although the HPC has added two new compute nodes, the test of the addition of the high-resolution fourth domain to the WRF model didn't help much in computational efficiency and therefore, the intended implementation of a fourth model was not made operational. Instead, the currently operational WRF completes the 3-day weather forecast in 2.5hrs from pre- to post-processing.
- Improve initialization of the WRF model using Global Circulation models and local AgWeatherNet observations
    - The addition of AgWeatherNet observations to the initialization was operational in the daily model forecast. However, further inspections and statistical analysis found that the WRF simulation drifted away from the synoptic input data once the AgWeatherNet observational data was not available into the future during model run. For this reason, the addition of observation for the operational forecast was interrupted.
- Compare WRF predictions with historical data from AgWeatherNet for the Cherry, the apple and the grape growing season
    - The project plans were performed successfully at their expected completion time and results were reported in their successive quarterly reports and is explained in the Project Approach section of this report.
- Integrate the output of the WRF model with the AgWeatherNet database
    - The post-processing is prepared and certain model results are currently posted in the AgWeatherNet webpage accessible to people who subscribed online.

The AgWeatherNet website's attraction for needy people is increased with time and the public online load will continue to grow as the decision making tools now include the WRF model (Table 2). Note that Google analytics does not currently include counts from automated data feeds (DAS, Tim Berk, Wine Map, MADIS, etc.). It is known that AgWeatherNet has a broad presence and impact beyond what is tracked by Google and the user counts, although currently there is little to no information about how frequently the AgWeatherNet data is viewed or used outside of the program's immediate realm of control.

BENEFICIARIES

Specialty crop growers, researchers and other interested bodies that have subscribed to the online free memberships have potentially benefited from this project. Also benefited are the project workers who have learned through research activities performed during the project work. A scientific survey is necessary to quantify the benefits/impacts people acquired by using this short-range operational weather forecast.

A survey is needed to clearly state the quantitative impact to the beneficiaries.

LESSONS LEARNED

The WRF prediction is a powerful tool for a short-range weather forecast. However, the prediction ability of the model weakens as the forecast target date is farther from the initialization time.

The model bias also increases as the complexity of the topography increases, due to poor geographical and other land/vegetation cover data.

The model requires a super computing system, computationally powerful enough, to be a real-time forecast information tool.

Availability of improved initial and boundary conditions data helps the model to forecast more accurately.

No unexpected outcomes or results affected the project.

Most goals were achieved. However, the goal and success of implementation of the operational model are only known when a survey to people with access to the AgWeatherNet website that provides the model predictions is performed and quantified.

ADDITIONAL INFORMATION

Match for Project: Cash match of $156,037 met in way of salaries and benefits for Gerrit Hoogenboom, Derek Weaver and Nic Loyd as well as unrecovered F&A from WSU.

Fig. 2. Diurnal time-series and their corresponding histogram plots of average temperatures from WRF and Fox MtnRT results plotted against observations averaged for October 1-31, 2015.

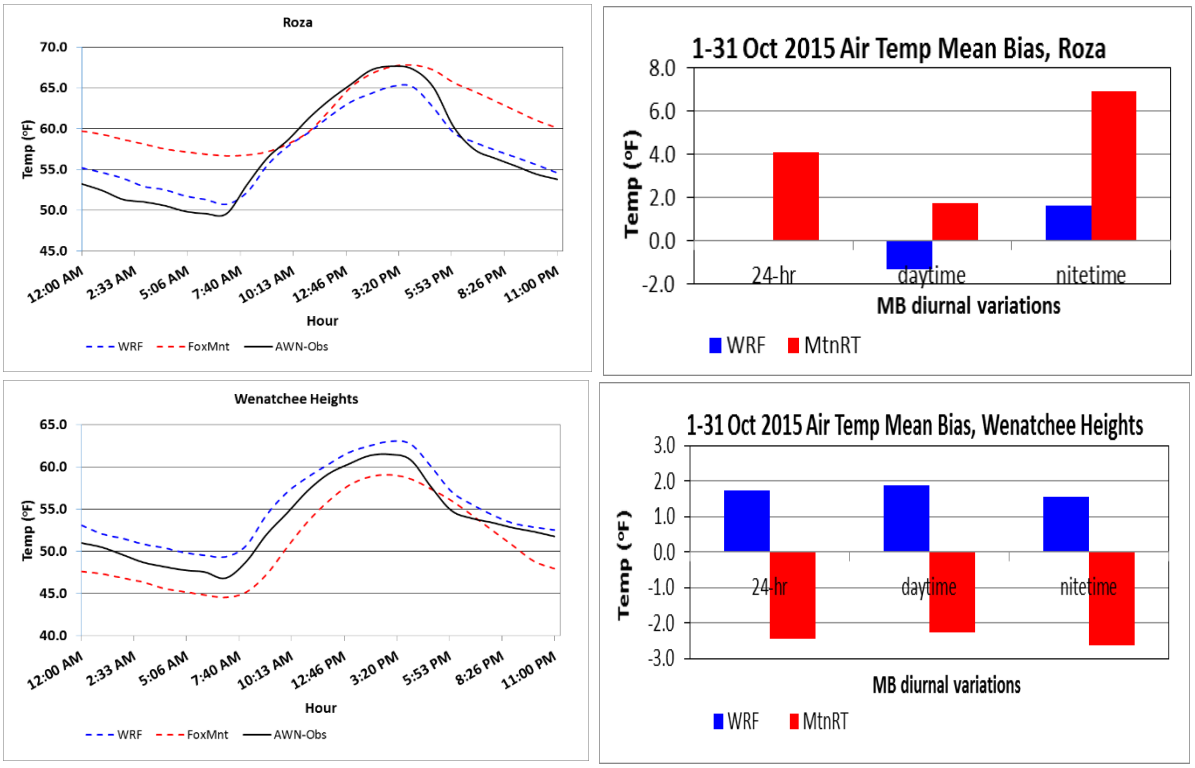

Table 1. Number of AgWeatherNet website subscribers and Facebook friends.

Date	AWN	Facebook Likes
Oct 1, 2012	6595	73
Oct 1, 2013	7608	299
Oct 1, 2014	8960	497
Oct 1, 2015	10,710	730
Oct 1, 2016		

Table 2. Google analytics of AgWeatherNet website as viewed by the public.

Google Analytics for weather.wsu.edu					
Date Range	Sessions	Users	Page Views	Pages/Session	Avg Session
Oct 1, 2012 – Sep 30, 2013	311,423	77,777	2,771,218	8.90	00:21:30
Oct 1, 2013 – Sep 30, 2014	922,777	225,108	8,232,522	8.92	00:18:16
*Oct 1, 2014 – Sep 30, 2015	429,054	118,066	4,162,152	9.70	00:10:55
*Oct 1, 2015 – Sep 30, 2016					

* - Changed the way that the page-views, etc., were counted to get a more realistic metric.

PROJECT #20

Project Title: Developing Camas as a dry-farmed specialty food crop

Partner Organization: Kwiáht: Center for the Historical Ecology of the Salish Sea

PROJECT SUMMARY

Although North American plants have been a major part of food production worldwide, little attention has been paid to "lost" and underutilized North American crop plants, including the "root foods" of the Pacific Northwest. Camas was the major staple crop in the Salish Sea and along much of the Pacific Coast of Canada and the United States prior to the introduction of the potato to this part of the world. Ethnographic records suggest that pre-Contact Coast Salish gardeners harvested over 138 metric tonnes of camas in the San Juans each year. Camas, the edible bulbs of "lilies" in the genus Camassia, are adaptable perennials that are currently only grown in gardens for their ornamental value. This was not always the case: prior to 1915, the great plant breeder Luther Burbank worked on developing camas as a food plant in California, as chronicled in the Chapter "The Camassia: Will it Supplant the Potato?" of Luther Burbank: His Methods and Discoveries and their Practical Application (1915). In a time of drought, climate change, and threats to native pollinating insects Kwiaht researchers identified the reintroduction of locally adapted flowering crops, such as camas (Camassia leichtlinii and C. quamash) as a unique opportunity for new, sustainable local food production.

Since the time when camas was the primary staple crop grown in the San Juans, the landscapes in which it was cultivated have been irreversibly altered through the introduction of non-native grasses, livestock grazing, and residential development. For this reason, Kwiaht researchers focused on developing methods for cultivating food camas in modern gardens and farms rather than recreating pre-Contact agricultural conditions.

Because camas has not been grown as a food crop in over 200 years, this project also needed to develop a market for food camas and introduce both consumers and producers to the food value of camas. Convincing farmers and gardeners to produce a crop with no market was not a feasible option. At the same time, Kwiaht's partners at the Skagit River Systems Co-op helped to identify the existing demand for a supply of food camas: traditional food and ceremonial use by Tribal Communities.

The overall aim of this project was to develop methods for producing camas as dry farmed food crop in the San Juans and western Washington, build consumer interest and demand for food camas and value-added camas products, work with value-added producers and outlets to bring camas products to market, and to ensure that Tribal members and food programs have sufficient access to food camas.

Farmers and gardeners worldwide are currently facing the challenges of a changing climate, the globalization of plant diseases, and concerns about pollinator health. In the Pacific Northwest and the Salish Sea region much of the challenge is facing longer summer droughts and an increasing amount of overall annual rainfall occurring during severe weather events. At the same time the interest and demand for local food is at an all-time high, and local market gardeners are interested in producing unique, local, heritage foods that grow well in their region and appeal to consumers. Uniquely adapted to the climate of the Pacific Northwest, and able to withstand long summer droughts and very wet winters, perennial native camas bulbs are a crop that meets these needs. If allowed to flower in production beds, camas also provides food and habitat for native bees and pollinating flies, and can attract these highly effective pollinators to the surrounding cultivated areas as well, providing pollinator services beyond the camas bed itself.

At the same time, wild populations of camas are increasingly threatened by development, non-native invasive species, and, particularly in the Salish Sea region's coastal meadows, by rising sea levels and increased storminess. Bringing camas cultivation into farms and gardens is important to preserving the genetic diversity and genetic resources of this native crop plant.

Now is also a time of cultural revitalization among the Coast Salish in Washington State and British Columbia, leading to the potential for increased demand for food camas for ceremonial and cultural use. Wild harvesting cannot meet this demand, and it is the right time to support and promote food camas cultivation by emerging Tribal farmers and gardeners.

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

PROJECT APPROACH

During this project Kwiaht researchers tested camas cultivation methods in research garden plots on Lopez Island and on the Swinomish Reservation. Beds of Camassia leichtlinii and C. quamash were experimented with at different planting densities, and with the application of straw mulch. Additional C. leichtlinii beds were cultivated with the

addition of fish bone meal fertilizer and straw mulch, straw mulch alone, and using a weed torch for fire weeding. During the 2016 growing season, Kwiaht gardeners removed flowering stalks from a third of the bulbs before seed-set. Kwiaht gardeners compared productivity, the proportion of bulbs that formed contractile roots, and the proportion of bulbs that grew bulblets under each treatment. The formation of contractile roots reduces productivity and harvest results led to the conclusion that contractile root development can be significantly reduced by applying straw mulch, and that flowering stalk removal increases productivity when combined with mulching. Bulbs that produced bulblets were recorded in nearly every treatment, allowing Kwiaht gardeners to begin propagating more productive camas varieties.

Kwiaht researchers provided camas cultivation information to local and regional farmers and gardeners through direct targeted e-mail contact; outreach at the 2014 Vancouver Island Traditional Foods Conference; presentations at the 2015 and 2016 San Juan Islands Agricultural Summits; camas tastings at the Agricultural Summit, Kwiaht's research garden on Lopez, the Orcas Island Food Coop, and Blossom Organic Grocery; and through the First Annual Camas Festival in 2016. At least 39 farmers and gardeners were supplied with camas seed and/or bulbs to cultivate. Kwiaht researchers distributed over 6,000 camas seed to 20 farmers and gardeners (16 in the San Juans and 4 in neighboring Western Washington) and distributed camas bulbs to at least 29 gardeners.

Kwiaht's botanist and ecologist worked with elementary students at Friday Harbor Elementary, Lopez Island School, and Orcas Island School to plant camas plots in their school gardens. Students received lessons on the history of camas cultivation, food camas chemistry, and camas pollinator ecology. The Orcas Farm to Classroom program (with 180 elementary students) scheduled a lesson based on harvesting, preparing, and eating the camas they grew, while the Friday Harbor and Lopez classes plan to continue making observations of pollinator visits to their camas plots in 2017.

Kwiaht researchers conducted outreach to value-added food producers to gauge and build interest in value-added camas product production. Barn Owl Bakery proposed camas scones, Mirabelle Ice-Cream expressed interest in trying in ice cream, and Vortex Juice Bar and Cafe planted local camas on Lopez for use in their products.

Kwiaht researchers discussed camas based dishes with local chefs and cooks, working to build interest from local restaurants for camas based dishes. Discussions were held with cooks from the Bay Cafe, Bucky's Island Grill, Vortex Juice Bar and Cafe, the Love Dog, the Doe Bay Cafe. Based on these discussions most, if not all, of these venues would trial a camas based dish when local production has a consistent supply of food camas available. Kwiaht is planning on scheduling individual camas tastings with interested chefs and cooks as a next step in getting camas on the plates of local restaurant goers.

For camas tasting and increasing interest in food camas, Kwiaht's botanist tested and documented using a slow cooker to cook camas until the inulins are fully broken down into fructose. Using this method Kwiaht served at least 300 people prepared camas at tastings at the 2016 San Juan Islands Agricultural Summit, a camas tasting at Kwiaht's Lopez camas garden, and tastings at the Orcas Island Food Co-op and Blossom Organic Grocery. At each tasting Kwiaht collected feedback on the camas samples, offered information on camas cultivation and preparation, and distributed camas bulbs to interested growers. The tasting at Kwiaht's Lopez camas garden was part of Washington State's local history month, and advertised statewide; attendees included students and instructors from the Northwest Indian College. For that tasting Kwiaht's botanist developed a sweet camas spread, a chocolate-almond-coconut camas spread, and a smoked salmon and camas spread. Kwiaht's ecologist also served prepared camas to 80 attendees at his Roads Scholar Native History lectures for Skagit Valley College.

In 2016 Kwiaht held the First Annual Camas Festival which included seven unique camas based dished developed by Kwiaht's botanist: sweet onion camas salsa, camas kanten, camas panna cotta, camas albondigas (meatballs), sweet camas spread, chocolate camas spread, camas and honey ice cream. Kwiaht's research gardeners also served a camas cheesecake. The camas dishes were served alongside traditionally cooked sockeye salmon and fry bread prepared by Rosie Cayou James and William Bailey of Salish Tacos.
Working with artist and designer Camilla Loyd, Kwiaht's botanist tested and refined recipes for the most popular dishes served at the festival and put them together in an illustrated online cookbook that will be available on Kwiaht's website.

Throughout the project Kwiaht's gardeners and botanist collected and preserved leaf tissue samples from camas for genotyping. Kwiaht's botanist initially genotyped 40 camas samples at up to 6 microsatellite loci. The genotyping work overlapped with Kwiaht acquiring a new genetic sequencer, which expanded capacity, but also required that the initial genotypes be redone for consistency on the new instrument. The camas genotyped so far makes up the beginning of a baseline of genotypes of camas populations from the San Juan Islands, which can be used to characterize particularly productive, nutritious, or flavorful varieties. Students and Lopez High School assisted with genotyping work.

Kwiaht's botanist contacted the food programs at Lummi and at the Small Tribes of Western Washington (which provides the food program for many Tribes in the State including Samish, Swinomish, Tulalip, and Upper Skagit) to offer them camas bulbs for distribution. While neither of these programs requested camas during this project, Kwiaht's botanist and gardeners supplied camas bulbs for growing to the Samish Community Garden, and to gardeners who are Tribal Members at Samish and Upper Skagit. Kwiaht's botanist also supplied cooked bulbs to the Swinomish Tribal Council for a traditional meal served during a council meeting, and to the Samish and Stilliguamish Canoe Families during a Leave No Trace training event on Lopez Island.

The Skagit River Systems Cooperative (a collaboration of the Swinomish and Upper Skagit Tribes) provided Kwiaht with the research garden on the Swinomish Reservation during this project. In 2013 they plowed approximately 2 acres and donated over 5,000 2-year old Camassia quamash bulbs. SRSC also donated approximately 20 hours of labor assisting with planting camas bulbs in 2013. Additional Tribal partnerships include the Samish Community Garden planting food camas bulbs in 2015, Sam Barr with the Samish and Stilliguamish Canoe Families helping to serve camas to Tribal youth during a Leave No Trace training on Lopez in 2016, and Jessica Gigot at the Northwest Indian College and Myk Heidt at the Swinomish Community Health Program coordinating having Kwiaht supply prepared camas for a traditional meal served during a Swinomish Tribal Council Meeting in 2016. The Toquaht Nation in British Columbia hosted the 7th Annual Vancouver Island Traditional Food Conference and funded travel by Kwiaht's botanist to attend and present on this project.

The farmers and gardeners who tried growing food camas donated a great deal of space and time to this project. 39 farmers and gardeners tried growing camas during this project, donating their garden space and time. These gardeners included both small scale kitchen gardeners, and large scale market gardeners including Helen's Farm on Lopez Island, Blue Moon Farm on Waldron, Frog Tree Farm on Orcas, and Mamma Bird Farm on San Juan.

Island Schools were an important partner in this project, hosting camas beds in their school gardens, and with approximately 300 students participating in designing camas beds, planting bulbs, observing pollinators, and sampling prepared camas. In addition Lopez School hosted bulbs in their school atrium and hosted Kwiaht's genetics lab throughout the project.

Orcas Food Coop and Blossom Organic Grocery on Lopez hosted camas tastings making a table available and encouraging their customers to sample prepared camas and take home information on food camas.

The San Juan County Agricultural Resources Committee invited Kwiaht botanist to present at the San Juan Islands Agricultural Summit in 2015 and 2016, waiving the registration fee (a value of $50 each year). Kwiaht was supported in developing camas preparation methods by WSU County Extension and by the Taproot: The Lopez Island Community Kitchen.

Because camas is such a unique crop, none of the activities in this project benefitted any other commodities

GOALS AND OUTCOMES ACHIEVED

To achieve the goal of at least 30 market farmers and gardeners growing food camas, Kwiaht contacted farmers and gardeners, held outreach events, and supplied camas seed and bulbs. Targeted outreach included e-mails to 33 farmers and gardeners in the San Juans and western Washington, and presentations at the 2014 Vancouver Island Traditional Food Conference and the 2015 and 2016 San Juan Islands Agricultural Summits. Kwiaht's botanist and ecologist also distributed camas bulbs during camas tastings and included information about camas cultivation during presentations on Native history for the Roads Scholar programs at Skagit Valley College.

Kwiaht worked towards the goal developing a market for value-added camas products through three group of activities: outreach to value-added producers, outreach to specialty markets, and camas recipe development and tastings. Camas tastings gave market owners and their customers the opportunity to sample prepared camas and to demonstrate its acceptance by customers. Both of these markets, as well as the San Juan Island Food Co-op have committed to stocking prepared camas and value-added camas products as soon as a consistent supply is available. Most of the value-added producers reached also sell their products at farmers' markets, including the Lopez, Friday Harbor, and Orcas Farmers' Markets. Product ideas were developed with Barn Owl Bakery (camas scones), Mirabelle Ice Cream (camas ice cream), Kraut Pleasers (camas pickles). Value-added producers and potential customers were also reached through the First Annual Camas Festival, where they were able to sample example camas dishes prepared by Kwiaht's botanist alongside traditionally grilled sockeye salmon and fry bread.

Progress on the goal of getting camas based dishes served in local restaurants was made by direct outreach to local restaurant owners, chefs, and cooks. None of the cooks and chefs approached had eaten camas before, and needed

information on the flavors and textures and ideas for how camas could be included in recipes. Kwiaht's camas cookbook is also aimed at chefs and cooks to give them an idea of how camas can be utilized in the kitchen.

Kwiaht achieved its goal of making food camas available to the Tribal food programs at the 5 US Tribes with historical connections to the islands by reaching out to food programs serving all 5 communities in 2016 with an offer of prepared or living bulbs. While Lummi and the Small Tribes Organization of western Washington (which serves 17 Tribal communities including Tulalip, Samish, and Upper Skagit) did not request any bulbs, Kwiaht provided prepared bulbs for a traditional food meal served to the Swinomish Tribal Council. Through outreach, particularly through the 2016 Camas Festival, Kwiaht was also able to provide living bulbs to the community garden at the Samish Tribe, and to individual Tribal gardeners at Samish and Upper Skagit (one gardener from each community), partially achieving the goal of having at least one gardener from each community growing food camas. Targeted outreach at the planned 2017 Camas Festival is likely to reach gardeners at Swinomish, Lummi, and Tulalip as well.

Achievement of the Expected Measurable Outcomes was not anticipated to be long term, but during the project it became clear that the goals of bringing camas to market were dependent on first building reliable food camas production, and are indeed longer term goals. Kwiaht researchers laid the basis for value-added camas products being sold in three specialty markets, and production of value-added camas products by producers who sell at three farmers' markets. Outreach to restaurants laid the basis for camas based dishes to be served to at least four restaurants in the San Juans. Based on the feedback from value-added producers, specialty markets, and restaurant owners and cooks Kwiaht anticipates that interest in food camas will continue to grow rapidly, such that as soon as a reliable production and processing framework exists the Outcomes of 88% of Farmers' Markets in San Juan, Skagit, and Whatcom County and camas based dishes served in 50% of San Juan County restaurants will be achieved.

This project built the interest and knowledge to achieve the goals that were established at the outset. The goal of building a network of camas growers was accomplished, and the research conducted during the project on best camas cultivation techniques is helping these growers. During the course of the project Kwiaht researchers identified initial camas processing (cooking to convert inulins into fructose) as a separate necessary step to food camas production and value-added product development. This step created a barrier between camas growers and food camas sales. Kwiaht researchers developed small scale processing methods and started conversations with the county extension office to begin making progress on collective camas processing. The need to achieve a consistent supply of food camas and coordinated processing meant that the goals of commercial camas availability were not achieved during the project period. However significant progress was made on these goals through camas tastings, and the First Annual Camas Festival, all of which demonstrated to specialty markets and value-added producers the versatility of camas, and its attractiveness and acceptance by their customers. Although it was not a goal at the outset of the project, an important accomplishment was having around 500 people (including students) sample food camas during this project, and having prepared camas available in two specialty markets (as samples, with commitments to stock it once a consistent supply is available).

At the start of this project Kwiaht's botanist contacted 33 farmers and gardeners in the San Juan Islands and western Washington and was unable to find any farmers or gardeners growing food camas. Over the course of this project additional farmers and gardeners were reached through outreach events, and none of them were growing food camas prior to receiving seed or bulbs as part of this project. Through seed and bulb distribution, as well as outreach on camas cultivation and preparation methods, this project directly led to at least 39 farmers and gardeners in the San Juans and neighboring western Washington growing food camas by 2016. Based on the demand for bulbs that Kwiaht researchers observed during outreach events, this number will continue to rise as long as food camas outreach events occur, and include the opportunity for farmers and gardeners to receive bulbs at these events.

With no sources of food camas, there were also no groceries, co-ops, or farmers markets offering food camas for sale at the beginning of this project. Kwiaht researchers visited farmers markets on Lopez, Orcas, and Friday Harbor, as well as the Skagit Valley Co-op, Orcas Food Co-op, and Blossom Organic Grocery, none of which had any food camas products for sale. To achieve the goal of having food camas and value-added camas products available at these venues Kwiaht researchers made contact with value-added food producers, and with the Friday Harbor and Orcas Food Co-ops and with Blossom Organic Grocery on Lopez Island. Prepared camas tastings were held at the Orcas Food Co-op and Blossom Grocery in 2016 and all three retailers have agreed to carry prepared food camas once it is available for them to stock. Throughout this project Kwiaht researchers conducted outreach to value-added food producers in the San Juan Islands, and worked to build interest in camas-based value-added food products. Camas tastings, and particularly trialing camas based dishes at a tasting and at the First Annual Camas Festival proved to be critical to gaining interest by value-added producers, since none of the producers contacted by Kwiaht's botanist had ever tasted camas prior to the tastings held during this project. Through the tastings, and the interest generated, Kwiaht was able to build interest from value-added producers that sell products at the Lopez, Orcas, and Friday Harbor farmers markets. Camas was served in 2

specialty markets in the San Juans (achieving that portion of the Expected Measurable Outcome) and once a steady supply of locally grown food camas, and of cooked camas is available to these producers the Outcome of having camas in 88% of farmers markets in Skagit, Whatcom and San Juan County is likely to be rapidly achieved.

At the start of this project none of the restaurants in the San Juan Islands were offering any camas based dishes on their menus. Through the project contact was made with restaurant owners, chefs, and cooks at the Bay Cafe, Love Dog, Bucky's Island Grill, Vortex Juice Bar and Cafe, and the Doe Bay Cafe all of whom were interested in trialing camas based dishes once a steady supply of food camas is available in the islands. The owner of Vortex Juice Bar and Cafe planted a bed of local camas to begin producing her own food camas. These commitments to trial camas based dishes represent 40% of the restaurants on Lopez Island and around 10% of the restaurants in San Juan County.

An important goal of this project was to ensure that Tribal food programs and gardeners had access to food camas. None of the Tribal food programs contacted by Kwiaht's botanist (Lummi, Samish, Swinomish, and the Small Tribes of western Washington which serves many Tribal communities including Tulalip, Upper Skagit, Samish, and Swinomish) had or were providing food camas at the start of this project. In 2016 Kwiaht offered food camas to all of these programs. Kwiaht's botanist also supplied prepared camas to the Swinomish Tribal Council, camas bulbs for planting to the Samish Community Garden, and bulbs to gardeners who are enrolled at Samish and Upper Skagit. Two Swinomish Tribal members participated in research gardening during this project. The camas grown on the Swinomish Reservation is available to Swinomish Tribal gardeners and to the Swinomish Branch of the Northwest Indian College. The goal of making food camas available to Tribal food programs was fully achieved, and the goal of having Tribal gardeners growing camas at the five communities with historical ties to the San Juans was 40% achieved (not including the camas garden at Swinomish, as it continued to be maintained by Kwiaht's research gardeners). Targeted outreach through tastings and the Second Annual Camas Festival (in 2017) should allow Kwiaht to reach more Tribal gardeners.

BENEFICIARIES

Farmers and gardeners in the San Juan Islands and western Washington, including Tribal members at Samish and Upper Skagit who received camas seeds and/or bulbs and cultivation information benefited from this project.

Tribal partners, including the Swinomish Tribe, the Samish Community Garden, the Samish Canoe Family and the Stilliguamish Canoe family benefited from receiving bulbs or prepared camas during this project.

Specialty markets on Lopez and Orcas (the Orcas Food Co-op and Blossom Organic Grocery) benefited from camas tastings held at their stores during this project.

Friday Harbor, Orcas, and Lopez Schools benefited from including this project in their science or farm to classroom curriculum, as well as by including camas in their school gardens.

Thirty-nine farmers and gardeners received camas seeds and/or bulbs during this project, all of whom were still growing camas when contacted at the end of the project in 2016. Kwiaht is working to ensure that any camas they produce has a waiting market, either by a processing collective, value-added food producers, restaurants or through a specialty market or farmers market.

Partners at Swinomish have 25 beds of 90-180 bulbs of camas each planted at the research garden on the Reservation, and received enough prepared bulbs for a meal served to their Tribal Council in 2016. Approximately 100 bulbs were provided to the Samish Community Garden. Two gardeners who are Tribal members at Samish and Upper Skagit, respectively received approximately 50 bulbs each. The Samish and Stilliguamish Canoe Family youth (8 youth and 3 instructors) received a camas meal, and instructions on cooking camas.

Approximately 100 customers at the Orcas Food Co-op and 100 customers at Blossom Organic Grocery sampled camas during tastings, and Kwiaht advertised these tastings to over 2000 people through social media and websites. While many of the tasters were customers who came to the store for regular shopping, some of the tasters visited these markets specifically to come to the tastings (approximately 20% based on feedback).

Friday Harbor, Lopez, and Orcas schools received 36-200 camas bulbs each for their school gardens and science enrichment for students by Kwiaht researchers (botanist and ecologist). Over 350 students participated between these three schools, receiving approximately 25 classroom hours of enrichment. Approximately 180 students at Orcas elementary also sampled a camas based dish prepared by Kwiaht's botanist.

LESSONS LEARNED

Embarking on bringing a “new” food crop to the market provided many lessons for Kwiaht's staff during this project. Positive lessons included discovering that there is an existing demand for food camas for Tribal ceremonial and cultural use, which provides an added incentive for supporting new Tribal farmers and gardeners in getting into camas growing. This demand was identified by project partners at the Skagit River Systems Co-operative (a collaboration of Swinomish and Upper Skagit). Kwiaht's research gardeners also learned that contractile root growth can very effectively be reduced by mulching bulbs, even if they are planted close to the surface, and preliminary results show that reducing contractile root growth increases productivity, and ease of harvest. Research gardeners also experimented with removing flowering stalks from camas, and found that when combined with mulching, removing flowering stalks increases productivity, and makes summer harvesting easier (cut bulbs do not have hard flowering stalks through the middle of the bulb). Through preparing camas for the Swinomish Tribal Council in May, Kwiaht's botanist learned that camas harvested and cooked during the flowering period is practically indistinguishable as food from camas harvested when dormant, though it is slightly harder to process due to the flowering stalks (which can be removed prior to flowering as stated above).

In developing camas preparation methods, Kwiaht's botanist learned that sweet, digestible camas can be consistently produced using a slow cooker, and that cooked bulbs can be dehydrated for storage and retain their quality when re-hydrated. Camas tastings provided the opportunity for Kwiaht researchers to learn that nearly everyone who sampled plain food camas found it pleasing (98% of the tasters who gave feedback). Based on wild food books and websites Kwiaht's researchers had expected cooked camas to be more unusual and perhaps something of an “acquired taste”, which was not at all the lesson from tastings held throughout the San Juan Islands.

The First Annual Camas Festival was an opportunity for Kwiaht researchers to find out whether camas-based dishes and potential camas value-added products were accessible to consumers. Of the eight camas based dishes presented at the First Annual Camas Festival, seven were very well liked (camas kanten or agar was rejected based on texture), including both sweet and savory dishes, and in combination with grilled sockeye salmon and Coast Salish style fry bread. These dishes created an opportunity for Kwiaht's botanist and researchers to explore the types of camas dishes and value-added products that will appeal to consumers and restaurant goers, and to build a cook book of example dishes to expose more people to food camas and camas based dishes.

When Kwiaht's botanist followed up with farmers and gardeners who grew food camas during this project, she found that while their growing experiences were mostly positive (particularly for those that started with bulbs rather than seeds) that they were reluctant to harvest the bulbs, and unenthusiastic about undertaking the long cooking that prepared camas requires. Based on the identification of camas processing as a bottleneck in food camas production, Kwiaht's botanist was able to explore options for organizing/processing camas from many small producers, and started discussions with County Extension and Taproot (Lopez' community kitchen) to develop processing capacity.

Researchers faced challenges during this project as well, including learning that some of the proposed activities would not lead as quickly to the expected outcomes as hoped. For example attempting to grow harvestable camas from seed during the period of the project was impractical. Small bulbs were also found to be much more vulnerable to competition from weeds during summer drought, and weed control for seedling and small camas survival was found to be critical but very challenging. In order to produce eating sized camas, Kwiaht's gardeners had to purchase restoration stock bulbs. Once harvestable bulbs were available Kwiaht researchers were able to make much more significant progress on building a value added market, but the delay between working on cultivation methods and being able to provide prepared camas to consumers, value-added producers and restaurateurs meant that this project came to completion while food camas products and production methods are still in development and not yet available commercially.

Identifying camas processing as a bottleneck in the market for food camas is an important lesson, but one that delays the release of camas into the market until processing can be coordinated and producers organized. While camas tastings showed that prepared camas is well liked by consumers, researchers learned that very few consumers had heard of camas, or had any conception of how prepared camas would taste. Before camas products will have a wide market, more tastings and education needs to take place so that consumers will be interested in purchasing products.

Based on this project Kwiaht has developed a strategy for developing and introducing additional “lost” Salish Sea crops to producers and consumers, and has received private funding (from the Mills Davis Foundation) to begin work on developing production and a market for 10 more native food crops. Because of Kwiaht's role in testing camas processing, this project resulted in camas being available to Tribal youth participating in the Samish and Stilliguamish Canoe Families during a visit to Lopez. This project has resulted in Kwiaht working with county extension and Taproot to develop a camas processing co-operative that can purchase, process, and distribute camas from local farmers and gardeners.

Kwiaht researchers learned that when bringing a “new” food crop to market it takes time to build interest and experience in the new food, and that a lot of time needs to be devoted to sharing methods and ideas for preparation and providing samples for both consumers and producers to try. Value-added producers and restaurateurs need sufficient time to learn about an ingredient before they want to try it out on their customers. Even in the San Juan Islands many of the people who tried camas at Kwiaht's tastings had never heard of camas as a crop, and had no idea what kind of a plant the new food came from. Even tasters who were aware of camas' edibility had no idea what it was going to taste like, and often were (pleasantly) surprised by the sweet flavor. The initial phases of introducing a new crop require not just education about growing methods and supplementing production, but also extensive outreach and opportunities for producers and customers to try the new crop, and ways in which it can be utilized.

ADDITIONAL INFORMATION

Match expended on this project totaled: $109,006 ($15,500 cash and $93,506 in kind)

Kwiaht provided in-kind match of genotyping equipment (valued at $66,038) and received a cash donation of $15,000 from an Orcas Island donor to purchase a capillary sequencer. This equipment was used in building a baseline of camas genotypes with which productive or unique strains can be characterized, and which supports the breeding of food camas varieties. 20% of the annual lease of Kwiaht's office on Lopez was included as match ($2,851) this office was used for coordination and outreach on Lopez. The Skagit River Systems Cooperative donated $2,500 worth of Camassia quamash bulbs and $620 worth of labor planting to this project. Kwiaht provided $1000 worth of Camassia leichtlinii bulbs and $320 worth of C. leichtlinii seed. Ryan Drum of Waldron Island donated 1,163 small camas bulbs and 2lbs of camas seed (for a value of $2470). Bulbs were used for researching effective camas cultivation methods in the gardens at Swinomish and on Lopez Island, seeds were distributed to local farmers and gardeners and used for producing camas in the research gardens. Kwiaht provided use of chemistry supplies and equipment for soil testing (valued at $4,707) for testing nutrients and salinity at the camas gardens. The San Juan Agricultural Resources Committee waived the registration fee for Kwiaht's botanist to participate in the 2015 and 2016 San Juan Island Agricultural Summits ($50 each summit, for a total of $100), and the Toquaht Nation paid for Kwiaht's botanist to attend the 7th Annual Vancouver Island Traditional Food Conference ($500 cash). Kwiaht apprentices volunteered 30 hours towards this project (valued at $25/hr for a total of $750). Students at Friday Harbor, Lopez, and Orcas Schools donated approximately 700 hours to this project in planting and maintaining camas gardens and in observing pollinators (valued at $17/hr for a total value of $11,900). Whispers of Nature donated the use of their herb garden and labyrinth for the First Annual Camas Festival (valued at $200 for the afternoon), and Julie Galbraith donated alder firewood for the fish cooking at the festival (valued at $50).

Camassia:

Camas is a perennial bulb related to Agave with blue or (more rarely) white flowers, blooming between April and mid June. Two species of camas are native to the San Juan archipelago: blue camas (*Camassia quamash)* and great camas (*Camassia leichtlinii*). After flowering and producing seed camas goes dormant until winter when leaf growth begins, even under snow! Camas habitat includes rocky open bluffs or balds as well as open meadows.

Ethnobotany:

Camas was a vital food crop for the native Coast Salish people who inhabited these islands. The bulbs were dug in large quantities and pit roasted until they became sweet. Because it was carbohydrate rich, camas was highly prized and widely traded throughout the region. Coast Salish families traditionally cared for and cultivated large camas patches; cultivation increases bulb size, productivity and range. Traditional management utilized a combination of transplantation, weeding, hoeing and burning.

Management and Care:

Camas can be propagated from seeds planted in the fall or stratified by mixing with moist, sterile media such as coir and chilled in the fridge for 60+ days before planting outside. Seeds should be lightly covered. First-year seedlings have very small grass-like leaves; they will grow contractile roots that pull them down into the soil.

Bulbs can also be purchased or requested from Kwiaht's camas growers network. Bulbs should be planted in the fall and winter.

Camas is very tolerant of different *soil* types and can tolerate both drought and periodic inundation. Moist, loose soil, rich in inorganic matter is likely to produce larger bulbs.

To produce the largest bulbs, with few contractile roots: plant bulbs between August and December in a narrow trench approximately 1-2 inches deeper than your largest bulbs, adding approximately 1 tablespoon of bone meal or fish bone meal if desired to each foot of trench and mixing into the soil at the bottom before planting the bulbs. Cover with soil and mulch with at least 2 inches of straw.

Harvesting Camas

When flowering stalks form in spring remove from any bulbs you wish to harvest that year (they can be removed as soon as they form, or while the plants are in full flower). Bulbs may be harvested for cooking at anytime, but are easiest to harvest and largest once all the leaves are brown. Return small bulbs and any bulblets formed by larger bulbs to the camas bed.

If you join our growers network we will keep you up to date with our research results as well as work to connect producers with markets and makers of value-added products.

Contractile roots

For more information or to join our camas growers network contact
Madrona Murphy
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Funding for this project provided by the Washington State Department of Agriculture.

Our thanks also to Brook Brouwer, the Swinomish Tribe, Skagit River Systems Cooperative, Linda and David Hudson and Liz and Jeff Malinoff.

Cooking Camas:

Camas is inedible until properly cooked! It is rich in inulins: short chains of fruit sugar that humans lack the enzymes to digest. Long, moist cooking breaks the inulins down into fructose, a simple sugar that is easy to digest. The traditional method for cooking camas is by pit roasting large quantities of camas for two days.

Smaller quantities of camas can be cooked in a crock pot: clean bulbs (saving the root end of replanting). Line a crock pot or slow well with washed thimble berry leaves, soaked corn husks, or crumpled parchment paper. Add water to cover the leaves on the bottom (around a cup). Line a well in the middle with parchment paper and fill with cleaned bulbs (a full pot will cook more evenly), fold the paper over the top the bulbs, and cook on low for 48 hours, adding more water as needed (every 12 hours or so).

After 48 hours the bulbs will be soft and brown and can be eaten as is, added to recipes or frozen or dried for storage, freshly cooked they are quite perishable and will keep for only a few days in the fridge.

Chopping bulbs before drying makes them easier to re-hydrate and use in recipes. Dry chopped bulbs until fully dry in a dehydrator. Bulbs may be frozen whole with no loss of quality. To re-hydrate dried camas: cover with boiling water .

Cooked camas is mildly sweet and slightly nutty. For recipe ideas see the cookbook on Kwiaht's website.

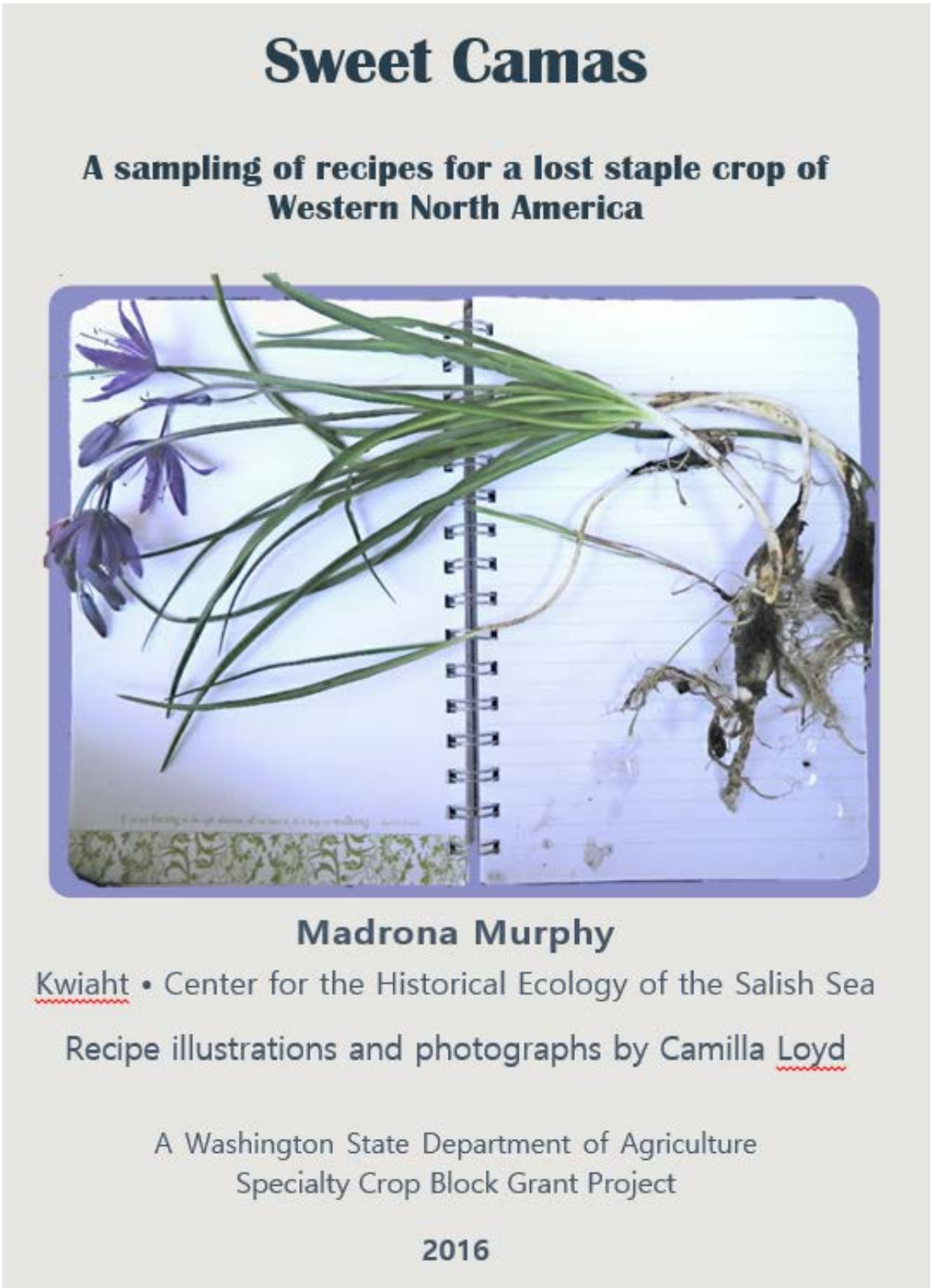
Growing a Local Market

Pre-Contact Coast Salish farmers are estimated to have produced and harvested over 138 tons of camas bulbs in the San Juans each year! We are enthusiastic about recovering a small amount of that local productivity. Kwiaht is working on developing camas as a dry-farmed specialty food crop in the San Juans, and that includes building a market for camas bulbs, cooked camas and value-added camas products. If you are interested in trying food camas, as a grower, produce market, restaurant, consumer or producer of value-added products, we'd be delighted to include you in the project and to insure that our work supports your ideas and interests. For more information contact us at kwiaht@gmail.com.

We are also dedicated to preserving the unique genetic diversity of camas in the San Juans; our food camas seed sources are regional and intended only for farm and garden use. If your interest is restoration rather than, or in addition to food production, we are always happy to work with you to source locally appropriate seed. Kwiaht researchers are also using genetic tools to investigate this local diversity and identify promising local varieties.

Growing Food Camas

Camas (*Camassia spp.*) was the most important plant food grown by native Coast Salish in the Salish Sea and San Juan Islands. As a drought tolerant, disease resistant native plant camas has great potential as a regionally unique, sustainable food crop for the San Juans.



About Camas

Camas, the edible bulb of North American native Camassia leichtlinii and C. quamash, was cultivated and harvested by Native American and First Nations communities up and down the Pacific Coast of North America. This hardy bulb thrives both in the wet coastal meadows of the Pacific Northwest and the rain shadow climates of the San Juan Islands. Careful cultivation that included hoeing, weeding, fertilizing, and periodic burning allowed the Coast Salish communities of the Salish Sea to produce camas in quantities great enough to sustain their communities and to create a surplus to supply regional trade.

Raw camas bulbs are indigestible, and relatively resistant to pests. This is because they store energy in the form of inulin, a oligosaccharide or short chains of simple sugars that cannot be digested by mammals. Eating camas

requires that the inulin be broken down into fruit sugar (fructose) through long, slow, moist cooking. Cooked camas is sweet, mildly nutty and rich in fruit sugar.

Proper preparation for easily digestible camas requires 48 hours of moist, slow cooking. Traditionally camas was prepared by pit roasting large quantities from family harvests all at once. A slow cooker works well to bring this sweet, nutty, ancient crop plant into modern kitchens.

This cookbook gives an overview of preparing camas, and provides a sampling of the recipes that were enjoyed at Kwiaht's 2016 First Annual Camas Festival on Lopez Island, WA.

Our development of camas production and preparation techniques was funded by a Specialty Crop Block Grant through the Washington State Department of Agriculture (WSDA).

For more information about Kwiaht's work to bring food camas back as a sustainable food crop in the San Juan Islands visit our website http://www.kwiaht.org

Properly Prepared Camas in a Slow Cooker

Mature camas bulbs may be harvested for cooking at anytime during the growing season, but are easiest to harvest and prepare when they are mostly dormant (July-January). Wild harvesting of camas may not be safe or sustainable, and all of these recipes we're developed for garden grown bulbs. If bulbs are harvested in summer each bulb may need to be split in half to remove the flowering stalk. This can be avoided by removing the flowering stalks at the beginning of the season, which can also encourage the growth of larger bulbs.

Clean bulbs, remove the root end (which may be replanted to form new bulbs) and the top end, and any insect damage or mold, if necessary split bulbs in half and remove the hard central stalk.

To diffuse the heat and avoid overcooking the bulbs on the edge, line the slow cooker well with washed thimbleberry leaves, soaked corn husks, or crumpled parchment paper. Add around a cup of water (depending on the size of your slow cooker—the water should come up to the top of the leaves). Make a large well in the middle and line with two sheets of parchment paper crossed over one anther. Fill this well with cleaned bulbs; a full pot will cook more evenly. Fold the edges of the parchment paper over the bulbs and put on the lid. Set the cooker on low, and allow to cook for 48 hours, adding water as needed (check approximately every 12 hours).

After 24 hours the bulbs will begin to take on an ivory color, and after 48 hours they will be dark brown and very soft. At this point they can be used in any of the following recipes, or frozen, or dried for storage. Fresh cooked bulbs are quite perishable will only keep for a few days in the fridge.

To make camas paste from fresh bulbs, puree in a food processor with enough water to make a very thick paste, use a food mill or sieve to remove any remaining pieces (these pieces may be added to camas ice cream with the paste, but will detract from the smooth texture of camas spread).

To dry camas bulbs for storage, chop fully cooked bulbs, dry in a dehydrator until completely dry, and store in an airtight container. Whole bulbs can be dried as well, but are more challenging to re-hydrate.

Dry camas can also be powdered in a coffee grinder and re-hydrated into camas paste. Grind very fine, and shift, or sieve, to remove remaining larger chunks (which can be added to chopped camas).

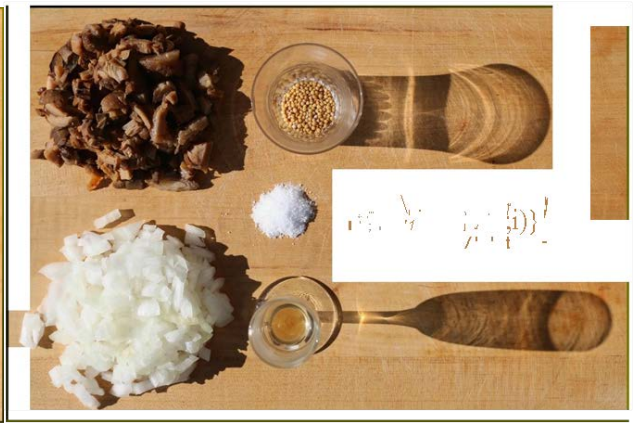
To rehydrate dried camas: cover with boiling water (approximately 2 parts water to 1 part dried camas). To make camas paste from powered, dried camas: add 3 parts boiling water to 1 part camas and stir well.

Camas and Sweet Onion Salsa

Spiced only with sweet onion and yellow mustard seed, this mild salsa shows off the nuttiness of camas, and is good alongside salmon or served with fry bread or chips.

½ cup chopped sweet onion
½ cup chopped prepared camas (or re-hydrated dried camas) 1 teaspoon rice vinegar or cider vinegar
1 teaspoon whole yellow mustard seeds
½ teaspoon kosher salt (or ¼ teaspoon table or sea salt) ground black pepper to taste

Mix all ingredients, adjust salt and vinegar to taste. Camas salsa will keep for a week in the fridge.



Sweet Camas Spread

A mildly sweet spread, reminiscent of chestnut jam. The chocolate version is lighter and less sweet than chocolate nut spreads like Nutella:

¼ cup camas paste (or camas paste made from dried, powdered camas) 1 tablespoon water
1 tablespoon sunflower oil

(Chocolate Camas Spread variation—add 1 tablespoon Dutched cocoa)

Re-hydrate dried, powered camas if needed. Stir water and oil into camas paste until very smooth. Add more water if the texture is too stiff. For chocolate version stir in cocoa. Sweet Camas Spread is very perishable, and only keeps for a few days in the fridge, chilled camas spread may need to be thinned with a little more water. Serve on crackers or toast, or with cheese.

Camas Albondigas (meatballs)

The mild nutty, sweetness of camas pairs very well with beef, and this recipe can also be used to make camas hamburgers (which may be served with camas salsa). Recipe makes enough for 2 burgers or around 20 small meatballs.

1/2 lb ground beef (80/20 or lean, not extra lean)

1/2 cups chopped prepared camas (or re-hydrated dried camas) salt to taste (optional)

Re-hydrate camas if necessary. Mix beef and chopped camas, roll into marble sized meatballs and cook covered in a hot pan over medium-high heat, shake the pan frequently to keep the albondigas from sticking. Serve warm.



Camas Ice Cream

Creamy and gently sweet, ice cream shows off the subtle flavor of cooked camas. Camas and honey provide all of the sweetness in this recipe. Camas ice cream can be prepared over 2 days, making and chilling the custard the first day, and churning and freezing it on the day you plan to serve. Ice cream can also be made ahead and kept frozen, but with no stabilizers, it should not be allowed to thaw and refreeze.

2 cups whole milk (divided) 2 cups cream
½ cup honey
1 cup camas paste (or re-hydrated paste from dried, powered camas) 6 egg yolks

Re-hydrate dried, powdered camas if necessary. Mix camas paste and 1 cup milk in a pot until very smooth, bring to a simmer over medium low heat, stirring frequently, and cook for 10 minutes. It will thicken. Add the remaining cup milk, cream, and honey and heat, stirring frequently, until steaming. Meanwhile lightly beat egg yolks.

Slowly stir 1 cup of hot mix into the egg yolks to temper. Add the yolk mix to the pan and heat, stirring frequently, until very hot but not boiling, at this point the custard may thicken more. Remove from heat and let cool. Freeze 1 cup of custard, chill the remaining custard in the fridge overnight, or until quite cold. Add frozen custard to chilled custard and stir until the frozen dissolves.

Freeze in an ice cream maker according to the manufacturer's instructions.

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PROJECT #21

Project Title: Evaluating New Asparagus Varieties for Disease Resistance

Partner Organization: Washington Asparagus Commission

PROJECT SUMMARY

The asparagus industry is rapidly changing its production methods by switching to new varieties and more intensive planting methods. Some new varieties are known to be more susceptible to diseases in other asparagus growing regions. More intensive production practices include planting crowns at higher densities which can create conditions favorable to foliar fungal pathogens and increase stress on crowns which can favor soil pathogens. This project proposes to evaluate for the first time the over 150 varieties currently in a variety trial for the asparagus industry and to do disease evaluations in the first plantings of the newly commercial varieties of asparagus, several of which are of varieties more susceptible to disease.

Growers are concerned that the varieties they have planted which have much higher yields than traditional varieties are more susceptible to diseases. Before more acres are planted they want some assurances that diseases will not become more of a problem due to varietal selections. Additional objectives is to ascertain where a new disease, Phytophthora crown, root and spear rot, has reached Washington and to increase grower awareness on asparagus diseases.

This project did not build on a previously funded SCBG.

PROJECT APPROACH

The project was initiated by surveying the asparagus growers about their interest, concerns and vulnerabilities to asparagus disease at the annual grower meeting. Over the next two years the Washington Asparagus Commission research plots and grower fields that represented a large percentage of the new varieties planted in Washington were surveyed. Initially the project began with vegetable pathologists from Michigan State University. They did not fulfill their agreement on how often they would visit and sample fields. As a result a contract with WSU vegetable pathologist (Dr. Dennis Johnson) was established. During the course of the field work one asparagus spear (out of thousands and thousands) was thought to have phytophthora and WSU vegetable pathologist was unable to confirm it had the disease. Fusarium and asparagus rust was not an issue in the fields or the plots. Perhaps one of the most interesting outcomes of this project is that it became apparent that growers were misdiagnosing Stemphyllium (purple spot) for asparagus rust. This was a significant issue. Dr. Johnson spoke at the annual meeting and field days and he provided grower education on proper diagnosis and treatment for both diseases. Additionally Dr. Johnson created an asparagus disease website for growers to use and obtain additional information on the diseases. The disease management guidelines are on Dr. Johnson's website at: http://plantpath.wsu.edu/dajohn/asparagus/.

University plant pathologists provided technical assistance, training and survey support to the industry. The Commission funded additional survey and monitoring. Both Commission funded personnel and University plant pathologist provided training to the industry. The industry seemed appreciative, especially growers who had been applying the wrong fungicides because they had misidentified an asparagus disease.

All but one of the diseases involved are specific to asparagus. This project was very specific to asparagus.

GOALS AND OUTCOMES ACHIEVED

Project Activity	**Measureable Outcomes**
Conduct Survey at Annual WAC Meeting	Growers representing over 75% of production were surveyed
Develop disease management guidelines	Johnson and Schreiber did this
Asparagus variety trial will be surveyed every 2 weeks in 2014	The set of asparagus trials were surveyed every two weeks during the appropriate seasons (harvest, post-harvest)
Commercial asparagus fields will be surveyed every 2 weeks in 2014	Johnson/WSU did this, and when he could not, Schreiber's staff did this
Asparagus variety trial will be surveyed every 2 weeks in 2015	Johnson/WSU did this once a month and when he could not Schreiber's staff did this
Analyze Data in 2015	Johnson/ WSU did this
Commercial asparagus fields will be surveyed every 2 weeks in 2015	Johnson/WSU did this once a month and when he could not, Schreiber's staff did this

Prior to WAC Annual Meeting develop disease management and educational materials	Johnson/WSU did this. The results of this were provided to growers and placed on the asparagus disease website
Prior to season start (April) 2015 growers representing 75% of Washington asparagus production trained on disease management	Johnson/WSU this was done at the annual meeting and at the grower field day. Growers representing more than 75% of production were trained
Develop Disease Management Guidelines	Schreiber/ADG, Johnson WSU was done

There were no plans for long term outcomes.

The planned goals were all accomplished. The one challenge was the lack/poor cooperation with the MSU scientists. When the WSU scientist became involved all tasks were accomplished and the work ended up costing less than planned.

The biggest finding was not finding asparagus crown, stem and spear rot in the state (Washington is the only major asparagus production region in the U.S. that does not have it. Purple spot, Fusarium and asparagus rust did not show up in either the variety trial or the commercial fields that were surveyed at levels that were any different from the more traditional varieties. At this point there has not been an increase in disease pressure that has been seen in other growing regions (Michigan, Ontario) that are growing the new varieties that Washington is growing.

Growers representing more than 75% of production were trained on disease identification, biology and management.

BENEFICIARIES

The primary group who have benefited from this are Washington asparagus growers. A secondary group who have benefited from this are the handlers who purchase asparagus from Washington growers.

This is difficult to state. One of the objectives of this project was to determine if the new asparagus varieties were more likely to have disease than the traditional varieties. A project conclusion was that at this point in time is that the new varieties do not have more disease. It is unclear how to quantify the economic value of this. It is estimated that one in five applications of fungicides were misapplied due to inaccurate diagnosis of disease. It is quite likely that as many as a thousand acres of fungicides may have been applied for the wrong disease.

LESSONS LEARNED

The MSU plant pathologist were good to work with but it was simply too far for them to come here on a monthly basis to work on this project. Initially WSU scientists were unavailable and unable to commit to this project. If the project were to done again, it wouldn't be started without having more locally available scientists to work with. One has to be flexible in measuring outcomes. At one point the objective had been hoped to reach 75% of growers but ended up working with growers that represented 75% of production. This is a lower number of growers, but likely to represent a higher percentage of production.

It was expected that it would be found that the newer varieties of asparagus had more disease issues due to their higher level of susceptibility than traditional varieties. It was unexpected to find that disease pressure was no different across all varieties. It is thought that since 2014 and 2015 were warmer years perhaps conditions were not conducive to disease development, or simply they are not more susceptible to disease in local growing conditions.

The industries goals were achieved. The industry seems happy with the project, particularly since it was determined that planting the newer varieties has not resulted in higher disease pressure.

ADDITIONAL INFORMATION

The Washington Asparagus Commission contributed $8,000 in 2014 and $10,000 in 2015 and the WAC sought and received $10,000 and $20,000 from the Washington State Commission on Pesticide Registration to support this project (all in cash). The asparagus growers provided fields to survey and the variety trials were financially supported by the WAC. It is hard to place an in-kind value on this but will call it $10,000 in 2014 and in 2015.

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PROJECT #22

Project Title: Implementing Water Supply Strategies

Partner Organization: Whatcom Farm Friends

PROJECT SUMMARY

Specialty crop growers in Whatcom County have been actively working on addressing the disconnect between water use for irrigation and the state water code for over 20 years. In 1993 farmers became aware of the potential problems this might cause when the local tribes determined to quantify their in-stream water right on the Nooksack River. Growers formed an organization to address this challenge and through a survey it was determined that up to ¾ of Whatcom irrigation water use was either unpermitted or not adequately permitted. The grower group, Whatcom Farm Friends, worked through the legislative process, as the agriculture representative in the watershed planning process, and in direct negotiations with the other major water users in the area to find creative solutions to a problem that challenges the very existence of crop production in Whatcom County.

There are over 450 Whatcom County specialty crop farmers who require secure access for irrigation water. The first two elements of the Whatcom Farm Friends water strategy that are funded in this project were completed within the timeline of the project and provided specialty crop growers with a solid organizational foundation for addressing water issues and outline the partnerships with other non-ag water users.

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

PROJECT APPROACH

Farm Friends provided the administrative support for the committee that explored organizational options and led the creation of 4 new Irrigation Districts (called Watershed Improvement Districts) which followed the leadership of the two existing Districts in Bertrand and North Lynden. Farm Friends helped raise $157,000 from farmers and ag-businesses and $35,000 from a partnership grant via the Whatcom Conservation District. These funds were used to organize the farmers to prepare the petitions to form the 4 new WIDs, post the bonds to conduct the elections under the direction of Whatcom County, and provide the legal help to get the WIDs formed and organized according to State statutes.

Farm Friends then shepherded the collaboration of the six Whatcom County Watershed Improvement Districts (WIDs) into the Ag Water Board (AWB). The AWB was established by an Interlocal Agreement of five of the six WIDs in early 2015 and the sixth WID has agreed to join in 2016. Specialty Crop producers led this effort as access to irrigation water is a crucial issue for specialty crop farmers.

The Out-of-stream water users group was transformed into a reincarnation of the WRIA #1 Watershed Planning Unit. Farm Friends, which transitioned into Whatcom Family Farmers, provided the designated ag representation to this body throughout 2014-16. Farm Friends has also worked with the Public Utility District and the cities of Lynden and Bellingham to organize a Whatcom Water User's Group consisting of the AWB, city water managers, the PUD, water associations, and Whatcom County which has been meeting since fall, 2015.

Farm Friends was assisted by the Whatcom Conservation District with multiple maps and parcel databases. The Whatcom PUD provided advice and support with the organization of the Out-of-Stream Water Users group. Whatcom County cooperated with proving the facilitation services for the Watershed Planning Unit.

The project has multiple funders. SCBG funds provided less than 30% of the project budget. Specialty Crop farmers made up 60% of the leadership team directing the project.

GOALS AND OUTCOMES ACHIEVED

Goal #1 Ag water use and needs fully integrated into the County water use plan

Goal #1 will always be ongoing. The project has had strong ag investment in large part due to the SCBG funding. Agriculture is clearly represented in all water related policy discussions occurring throughout Whatcom County. This is evidenced in that the Ag Water Board fill the ag seat in the Watershed Planning Unit and on the Water Users Group.

Goal #2 Decision on an Ag Water District

Goal #2 was accomplished with the creation of 4 new WIDs in 2014 and the organization of the Ag Water Board in 2015. Development of the Scope of Work and budgets of the AWB in 2016 and beyond are current projects. There are

also discussions around water settlement negotiations initiated by Lummi Nation which would be strongly supported by the AWB provided the details of how these settlement negotiations are developed.

In water policy all goals are long-term! The purpose of Whatcom Family Farmers and the Ag Water Board is to ensure that farmers have the ability to access legal water to irrigate their crops and to do so in a manner that respects the in-stream flow needs of fish and Native American neighbors. The structure to both discuss these difficult issues is much improved because of the Water Strategies implemented in this project. The ability to actually implement projects on a watershed scale is also much improved with the ability to use the assessments and powers of the WIDs to actually implement water agreements.

#1 Ag water use and needs fully integrated into the County water use plan
Goal: Consistent ag participation in the County Water User's Group
Target: Farmers believe that water use information and plans to provide long term water certainty are accurate and incorporated into water plans.
Benchmark: TBD
Performance measure: % of meetings attended, farmers water interests recognized.
Farm Friends provided agriculture representation to the Planning Unit's monthly meetings throughout 2015-16. The development of a separate Water User's Group was initiated by Farm Friends in partnership with the Whatcom PUD and is actively functioning.

#2 Decisions on an Ag Water District
Goal: Creation of an Ag Water District to sustain long-term ag participation in water management
Target: Documented process to identify best means to organize specialty crop water users, amount of contacts with growers to prepare proposal, final decision on what type of district to create, where the district is located, who will govern the district, and what powers are provided for the district to use to implement water strategies that address grower needs.
Benchmark: no existing countywide district representing ag water interests.
Performance measure: Decision by farmers whether to establish a district or not.
The Ag Water Board was organized by the member WIDs in early 2015. It established an aggressive 2015 and 2016 work plan and budget and now serves as the indisputable and accountable voice of farmers on water issues. Farm Friends, now Family Farmers, provided all the administrative effort for this organization and provides water quantity and quality services through a contract with the AWB.

All activities accomplished within the timelines.

Project Activity	**Responsible Party**	**Timeline (*month and year*)**
Identify AG representative to out-of-stream water users group	WFF Board and staff	October 2013
Identify organizing options for Ag Water District	WFF staff and contractors	October 2013
Select preferred option for organizing	WFF Board	November 2013
Farmer and farm group meetings to discuss Ag Water District	WFF Board and staff	Nov 2013 – Sept 2014
Referendum of growers on Ag Water District	WFF, County	November 2014
Assist initial functions of Ag Water District	WFF staff and contractors	Dec 2014 – Dec 2015
Support Ag Water representative to County out-of-stream water users group – serve as the portal for information for growers and water management modelers and planners	WFF staff and contractors	Nov 2013 – July 2016
Maintain grower communication through website, newsletters, presentations at grower meetings, WFF board meetings.	WFF Board, staff, and contractors	Oct 2013 – July 2016

BENEFICIARIES
Beneficiaries of this project are specialty crop farmers, all Whatcom farmers, community partners, Tribal community, and natural environment.

There is no question over who speaks with authority for agriculture on water issues. This project allowed for the ability to make and enforce commitments on behalf of farmers.

LESSONS LEARNED
A lesson that was reinforced is how difficult it is to get many famers working together and how valuable it is when it is achieved! Whatcom farmers had no clear history of working together across commodity groups. There were efforts by non-profits like Farm Friends but with voluntary membership it was difficult to get more than 30% of farmers

involved and because of that the impact of the Farm Friends voice was always suspect. Implementing the Water Strategic Plan has left us in a much better place!

Plans proceeded according to expectations. The time it takes to get organizing activities together is always longer than expected.

All goals were met. WSU is in a good position to engage with the rest of the community in water settlement negotiations proposed by Lummi Nation.

ADDITIONAL INFORMATION

COST CATEGORY	Grant Funds	Amended	Invoiced	Balance	Total Project Cost
Salaries	$44,138	$29,925	$29,925	$0	$29,925
Benefits	$6,621	$4,489	$4,489	$0	$4,489
Travel	$3,132	$521	$521	$0	$521
Supplies	$3,795	$3,450	$3,450	$0	$3,450
Contractual	$16,500	$33,595	$33,173	$422	$33,595
Other	$814	$3,020	$3,442	-$422	$3,020
Matching Time	staff hours	720 @ $40/hr.	$28,800	-	$28,800
Matching Time	farmer hours	4,843 @ $25/hr.	$121,075	-	$121,075
Matching Funds	farmer and ag business contributions		$157,000	-	$157,000
TOTAL	**$75,000**	**$75,000**	**$75,000**	**$0**	**$381,875**

Additional project information can be found at:
ADC Flyer
Lynden Tribune article
Bill Clarke - new solution to old problem _ Lynden Tribune.pdf
Structure Diagram
Map of WIDs
www.agwaterboard.com
Includes:

- Story Board
- Each WID website link
- Recent newsletters

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PROJECT #23

Project Title: Access to Sustainability Resources

Partner Organization: Northwest Food Processors Association (NWFPA)

PROJECT SUMMARY

Through a survey of food processors in 2012, NWFPA determined that while leadership in most companies was committed to sustainability, most companies, and especially the smaller companies, struggled to know where or how to begin their sustainability planning and efforts. Information, training and resources were identified as high priority needs. The purpose of the project was to develop, promote and disseminate sustainability information, training and resources for food processors.

Over the past five years, there has been a dramatic "changing national (as well as global) landscape" that is impacting food processing operations, their costs of production, and potentially their competitiveness. Elements of this change include: Energy price increases/volatility; greenhouse gas emissions and carbon regulation (taxes/market approaches); water availability and cost concerns; more stringent environmental laws and regulations; climate change impacts; and customer demands for "green and sustainable" products. The project was designed to provide information and resources to food processors to help them address and mitigate the impacts presented by the above elements.

This project builds on work funded under an Oregon-Idaho Bi-State Food Processors Specialty Crop Sustainability Initiative (2010-2012), which developed resources for the food industry. Resources produced with those funds were evaluated, revised, further developed and expanded and converted to forms that are easily accessible and useable by food processors. For example, the Sustainability Guide was revised and redeveloped into a step-by-step, on-line tool to assist food processors in creating a sustainability plan. The Industrial Water Training was beta-tested on-site at a food processing facility and then revised and converted into a complete package of instructions and resources that food processors can use on-site to train their employees in water conservation and efficiency. The Sustainability Micro Case Studies publication was updated and revised and the number of case studies increased by over 50%.

PROJECT APPROACH

Establish Industry Advisory Groups to gain input on training and resource development; meetings

NWFPA's Sustainability Committee was established as a key advisory group for the project. About 83% of the members are specialty crop and of these, 90% have plants in Washington. The Committee provided extremely valuable advice and recommendations on project deliverables as well as review and evaluation of training and resource products. The NWFPA Energy and Environmental Committees provided input and review as well.

Two additional regional advisory groups were established, one in Bellingham, Washington and one in Quincy, Washington. A sustainability workshop was held in both of these locations. Twenty specialty crop food processors attended the Bellingham workshop and twenty-five attended the Quincy workshop. The purpose of the workshops was to educate attendees on sustainability, distribute resources, and to facilitate discussions with attendees on their companies' needs and challenges and on training and resource needs.

Feedback from attendees on the workshops was very positive. They particularly appreciated that the workshops were local as such training is not often available near rural areas. NWFPA collected and analyzed the input from the workshops and determined the priority needs and challenges. Top challenges were: environmental regulations; identifying opportunities at plants and resources to provide solutions; metrics, data interpretation and management; and water use and efficiency and wastewater.

Develop Industrial Water Use Training – Train-the Trainer

NWFPA beta-tested at a specialty crop food processing facility the Industrial Water Use Training that was developed for NWFPA under the Oregon-Idaho Bi-State Food Processors Specialty Crop Sustainability Initiative. Based on feedback from the test site, the training was considerably modified and expanded. The "Water Sustainability Training Course" now consists of a group of materials, which can be used by facility team leaders or consultant trainers to deliver the Course on-site to facility employees. The Course includes an instruction document for the trainer that includes questions to assist the trainer in compiling information specific to the facility and in customizing the training materials to the facility. A facility water balance exercise is part of the Course and a workbook and video instructions for the trainer were developed. The employee training consists of three Power Point presentations (modules) designed to educate and engage facility line, line supervisory, maintenance, engineering and management staff on the importance of water sustainability and the activities routinely performed to achieve efficient and cost-effective use of this natural resource. Each module was developed to first educate and then build off the prior module. Another document provides

examples of water conservation and efficiency actions that employees could adapt or modify for use in their facility. These examples came from the latest edition of the Sustainability Micro Case Studies for the Food Industry.

The *Water Sustainability Training Course Materials* are available at no cost for download on NWFPA's website at www.nwfpa.org/water.

Develop E3 Training "Taster" and Conduct Assessments

NWFPA's partner, Impact Washington, developed a presentation that gives an overview of the federal multi-agency program E3 – Economy, Energy, and Environment. It describes who can benefit from E3 and the benefits that can result for food processors. The presentation also includes a brief summary of savings achieved at one food company as well as the savings opportunities, including potential financial savings, at the two specialty crop companies that received assessments under the project. The E3 "Taster", E3 Assessments for Food Processors: Energy, Environment, Economy, is available for download on NWFPA's website at www.nwfpa.org/planning-resources.

E3 Assessments were conducted at two specialty crop food processors in Washington State. One was at a bakery, Bake Works, in Vancouver, Washington that produces fruit bars using Northwest specialty crop fruit, which are distributed to many school districts around the country. The second site was Tieton Cider Works in Yakima, Washington, which produces many varieties of fruit ciders that it distributes nationally.

Impact Washington was responsible for the Energy Assessments (conducted by Tim Burrows of Northmore) and Lean Productivity Assessments (conducted by Bill Paugh, River States, Inc.). Impact Washington concluded that "Even though the companies that underwent the assessments are small, the project educated these companies on their opportunities and showed them that even small productivity gains and energy changes can add up to significant dollars and time savings, and can prevent future capital expenditures that can be avoided with better stewardship of resources. It also showed that the E3 approach pays off on companies' bottom lines as well as creating energy, water, and environmental benefits that go to the Triple Bottom Line."

The Energy Assessments provided: an energy baseline; analyzed energy consumption; reviewed energy tariffs; provided high level energy breakdown; described relevant installed equipment; and identified potential opportunities to reduce energy cost. Cold storage was found to be a highest energy use and key area of potential opportunities for savings. Summaries of the results and recommendations from the Energy Assessments, E3 Energy Assessments for Food Companies, are available on NWFPA's website at www.nwfpa.org/sustainability-energy.
NWFPA's consultant, John Thornton of CleanFuture, conducted the two Water Assessments. The Water Assessments provided: a water baseline; analyzed water consumption; analyzed water bills; developed a water balance/water flow diagram; described current water use; and identified potential opportunities for water and cost savings. The most significant water cost savings identified is on the wastewater side—managing discharges to avoid BOD loading and charges. Due to different layouts and equipment configurations within facilities, water monitoring is not straightforward and often must be customized. Based on the needs observed by Mr. Thornton at the assessment sites, he prepared a guide on *Water Assessments and Lessons Learned* that will assist food processors in measuring and monitoring their water use. This guide and information from the water assessments will be available on NWFPA's web site at the Water tab.

Online Sustainability Guide

The Sustainability Guide that was created under the Oregon-Idaho Bi-State Food Processors Specialty Crop Sustainability Initiative was redeveloped and repurposed into a step-by-step approach that food processors can use to develop their sustainability plans. The Guide provides case examples for the three areas of sustainability, examples of vision statements, and examples of objectives, goals and metrics. A recommended time-line for planning is included and fillable and printable forms are provided for companies to record sustainability opportunities, vision statements, and objectives, goals, and metrics for use in planning. The *Guide to Sustainability Planning* is available on NWFPA's website at www.nwfpa.org/planning-resources.

Update the Sustainability Micro Case Studies

Under the project, NWFPA prepared and published a second edition of the *Sustainability Micro Case Studies for Food Processors: Working to Make a Better Tomorrow*. The new title is *Sustainability Micro Case Studies for the Food Industry: Working to Make a Better Tomorrow*. This slight change (from "processors" to "industry") reflects that case studies from suppliers and customers of food processors are included as well as food processor case studies. These other organizations are part of the food industry and sustainable practices throughout the supply chain contribute to the sustainability of the overall industry. The second edition contains the original case studies, many of which have been updated to reflect changes and/or more recent results since the first edition. Further 28 new case studies were added (a 55% increase over the first edition).

Sustainability Micro Case Studies is available at www.Amazon.com. It is also can be accessed through a link on NWFPA's web site at www.nwfpa.org/priorities/sustainability.

Purchase Portable Ultrasonic Equipment for Industrial Water Use Monitoring
NWFPA purchased a Sierra Portable Ultrasonic Flow Meter (Model 210i) that was used in the Water Assessments. This flow meter is now available on loan for food processors to use in assessing and monitoring their water use. John Thornton has prepared a use guide to accompany the meter based on his experiences using it in the Water Assessments.

Gather Information on Metrics used for Measuring Success of Sustainability Practices
NWFPA conducted a survey of its food processor members to determine what metrics are used to measure progress toward sustainability goals, whether they use software to manage and track sustainability work, and whether they communicate or publish the results of their efforts. The results of the survey, *NWFPA Membership Sustainability Survey*, are available on NWFPA's website at www.nwfpa.org/planning-resources. The survey revealed that most companies are measuring and tracking key environmental sustainability efforts: electricity and natural gas consumption; freshwater consumption; wastewater discharge and waste to landfill. Social and economic sustainability efforts are not as widely measured and tracked. Many companies do not use software to manage and track progress, but those that do track, use Excel.

Compile Metrics into a Resource and Disseminate for Use
NWFPA created a "Metrics" tab on the Sustainability page of its website at www.nwfpa.org/priorities/sustainability. The Metrics page includes a discussion and examples of the relationship of metrics to sustainability plan objectives and goals. It also includes three Power Point presentations from NWFPA's 2014 Sustainability Summit on practical application of planning, use of metrics and tracking progress. In addition, there are links to two key metrics resources. NWFPA used the metric topics identified in the survey of the membership described above and developed a table that shows examples of metric units and metric ratios for each of the topics. This table, NWFPA Member Metrics, is available at www.nwfpa.org/metrics.

NWFPA's project partner was Impact Washington, a non-profit organization specializing in manufacturing consulting services for Washington manufacturers. Impact Washington is part of the NIST Manufacturing Extension Partnership (MEP) network. Impact Washington prepared the E3 "Taster" presentation and managed the Energy and Lean Productivity Assessments.

The companies that received the E3 Assessments – energy, water, and lean productivity were specialty crop processors. While NWFPA has posted the project publications and resources to the web site, specialty crop processors have received personal notifications of the availability of these resources. Specialty crop processors made up the attendees at the Sustainability Workshops in Bellingham and Quincy and received hard copies of the Sustainability Micro Case Studies for Food Processors and the Sustainability Guide. They also personally met with their electric and natural gas utilities at these workshops to discuss efficiency programs and incentive opportunities for their facilities and had individual conversations with NWFPA staff regarding resources and sustainability questions.

GOALS AND OUTCOMES ACHIEVED
Outcome 1: Increase knowledge and ability to create plans and achieve efficiencies.
NWFPA tracked registrations and participation rosters and set up a tracking system on the NWFPA website whereby the documents downloaded and the identity of persons downloading the documents could be compiled.

Outcome 2: Pilot development of metrics.
NWFPA conducted a survey that focused on metrics. Two energy assessments and two water assessments were conducted.

Both expected measurable outcomes 1 and 2 should be considered long term as gathering of this information and implementation is complex and subject to delays and other factors. See discussion under the Lessons Learned section of this report.

- **Establish Industry Advisory Groups and hold meetings**. NWFPA's Sustainability Committee and Environmental Committees served as advisory groups as well as a processor advisory groups in Quincy and Bellingham, Washington. These groups provided valuable input on resources and training.
- **Develop "Train-the-Trainer" Industrial Water Sustainability Training**. A complete package of training materials was developed and is available for download on NWFPA's website.

- **Develop "Taster" materials for E3 training and deliver assessments**. Impact Washington developed the "Taster" materials, which are available on NWFPA's website. Two E3 assessments and two water assessments were conducted.
- **Develop Online Sustainability Guide**. The Guide to Sustainability Planning was developed and is available for download on NWFPA's web site.
- **Update and Disseminate Sustainability Micro Case Studies**. The original Sustainability Micro Case Studies has been updated, expanded, revised and published. It is available for purchase on Amazon. NWFPA ordered copies which will be disseminated at NWFPA's Expo and Sustainability Summit. Thousands of copies of the original Sustainability Micro Case Studies have been disseminated over the course of the project.
- **Purchase portable ultrasonic equipment for water use monitoring**. This equipment was purchased and used in the water assessments. It will be available for loan to food processors.
- **Gather information on Metrics used to Measure Success of Sustainability Practices**. A survey was conducted that provided considerable information on these metrics.
- **Compile Metrics into a Resource and Disseminate for Use**. Metrics from the survey were compiled into a document. A Metrics tab was created on the NWFPA web site's Sustainability page that includes this document as well as other metrics resources.
- **Goal to increase knowledge and ability of specialty crop processors to create sustainability plans**. Through the Sustainability Workshops, NWFPA has directly increased knowledge and ability. The resources and tools that were developed under the project will significantly contribute knowledge and increase their ability to create these plans.
- **Goal to pilot development of metrics**. The survey results, metrics resources and Sustainability Planning Guide will help processors understand the importance of metrics to their sustainability plans. While NWFPA did not establish baselines for facilities other than those that underwent the assessments, issues have been identified and a path forward to achieve this has been determined.

Outcome 1:
Target: The project targeted 250 processor personnel in at least 30 Washington specialty crop facilities accessing sustainability resources. While NWFPA exceeded the facility target, the personnel target was not achieved. NWFPA recorded 84 processor personnel in 45 Washington specialty crop facilities.
Benchmark: Based on a survey conducted prior to the start of the project, 2/3 of specialty crop processors were estimated to have no sustainability plan, budget or training. The survey conducted as part of the project indicates that about 60% of the responding sample are actively engaged in sustainability. This sample was largely composed of the bigger specialty crop processors. These facilities are more likely to have sustainability programs and budgets, so this may be skewing the results.

Outcome 2:
Target: Electricity, natural gas and water baselines were established for the facilities that underwent the E3 assessments. NWFPA was not able to gather baselines from other participants.
Benchmark: NWFPA was not able to establish baselines for other participants. See the Lessons Learned section of the report for further details.

BENEFICIARIES
Two specialty crop processors in Washington benefitted from E3 assessments at their facilities. Other specialty crop food processors in Washington benefitted from the local workshops that NWFPA conducted as well as the consultations with their electricity and natural gas utilities at those workshops. Several processors made appointments for on-site visits with their utilities.

Specialty crop food processors and the food processing industry in the Northwest and the nation have benefitted from the publications and tools completed under the project, all of which are available for download or accessible on NWFPA's web site. NWFPA's Member Survey, the Sustainability Workshops, and NWFPA's Advisory Groups have all indicated that these publications and tools are the resources that food processors need to jump start or advance their sustainability efforts.

The two food processors that underwent the E3 Assessments each received about $12,000 in consulting services. One company received recommendations for productivity efficiency opportunities estimated at $110,600 as well as extensive recommendations for future energy savings (cost savings not estimated). The other company received recommendations for productivity efficiency opportunities estimated at $65,500 as well as recommendations for future energy savings (cost savings not estimated).

LESSONS LEARNED

Through the Sustainability Workshops in Bellingham and Quincy, NWFPA learned that bringing resources and personnel to training that is held locally is very important to rural food processors. It also provides an opportunity to reach companies and personnel that typically do not travel to Seattle or Portland for training.

Closely monitor the progress of partners and consultants toward completion of activities and take immediate action to correct if delay occurs as other dependent activities may be delayed as well.

Find a way to assure that medium-sized and smaller specialty crop processors are included in surveys so that the larger companies, which usually participate, are not skewing the results.

NWFPA was not able to conduct a water assessment at the first facility selected for the assessment because nearly all of the pipes were insulated and many of its water pipes were behind walls. The insulation would need to be cut and walls would have needed to be removed in order to attach the portable monitoring device. NWFPA should have conducted an on-site visit before it started the assessment to assure that the necessary monitoring was feasible. This required NWFPA to engage another site for one of its two water assessments.

The quality and relevance of the input provided by the specialty crop processors at the Sustainability Workshops was an unexpected result. NWFPA's Sustainability Committee is using the input from these workshops to inform NWFPA's sustainability program development and future resources and training. NWFPA was able to combine the input from the workshops with concurrent work by NWFPA's Technology Steering Committee. As a result, NWFPA was able to create a list of the priority needs, challenges and solutions for food processors. Few industry sectors have produced such a list. NWFPA has shared this list with the Idaho university system and Washington State University, which are using this input to guide research and development and educational curricula to benefit food processing. In collaboration with the Idaho university system, NWFPA and food processors in Washington, Oregon and Idaho will be piloting a new innovative wastewater treatment methodology, which addresses one of the top challenges identified in the Sustainability Workshops.

A second unexpected result is that the resources and tools developed under this project are the same resources and tools that the specialty crop processors told NWFPA they needed at the Sustainability Workshops. It is also interesting that they address their identified top challenges and needs.

A third unexpected outcome was that NWFPA's Sustainability Committee found the Member Sustainability Survey to be highly informative. They have asked that NWFPA expand the pool of respondents (especially to include more medium-sized and smaller facilities) and conduct an annual survey that will be used to track food processing industry progress in sustainability.

Outcome 1: NWFPA did not achieve its personnel target of 250. In retrospect, perhaps the personnel target was unrealistic, or unrealistic given the time-frame. Nevertheless, a different approach to contacting and engaging personnel at specialty crop facilities is required. NWFPA typically uses email to contact personnel. While 45 facilities accessed NWFPA resources, only 84 different individuals were involved. About half of these individuals consistently participated and accessed resources, and incidentally were from the large processing facilities that are consistently taking action to become more sustainable. The challenge going forward is how to significantly expand the numbers and sources of individuals accessing resources.

Outcome 2: NWFPA has determined that few food processors, except the large companies, are monitoring and tracking water use, wastewater discharge, waste and carbon emissions. Therefore, it is not possible to establish baselines for these companies. NWFPA's Sustainability Committee has recommended that NWFPA advance this tracking and monitoring in food processing facilities by setting an industry water intensity (water used per unit of production) reduction goal like the 25% in 10 years energy intensity reduction goal that was set in 2009. NWFPA would assist facilities, through use of this project's Water Sustainability Training tools and the portable water monitoring equipment, in establishing water baselines and tracking progress to the goal. A water intensity goal would also heighten awareness of water use and promote conservation and efficiency solutions. This approach works. Prior to 2009, many of NWFPA's members did not have energy baselines, but now most facilities do and they are making progress toward reducing their energy intensity. The Sustainability Committee has also requested that NWFPA educate and provide food processors access to carbon emissions calculation tools so they can establish carbon baselines and track progress on carbon reduction.

ADDITIONAL INFORMATION

NWFPA Cash Match -- $53,681.63 total

Item	Amount
Indirect Administration (29.1% federal approved rate)	$46,140.01
Travel to Sustainability Workshops	$327.63
Supplies	$2,530.26
Production costs for Sustainability Workshops and Sustainability Micro Case Studies	$3,637.30
Sustainability Workshop Expenses (catering, printing, AV)	$1,046.43

In-Kind Match -- $50,873.81 total

Source	Amount	Use
Bake Works, Inc.	$8,300	Plant personnel work on the E3 assessments.
Bake Works, Inc.	$600	Supplies for the E3 assessments.
John Thornton/Clean Future	$30,798.81	Charged the project a much reduced rate, the difference was contributed as in-kind match. This funded work on the following: water assessments, Micro Case Studies, Water Training materials and beta testing of the training, investigation of portable water monitoring equipment and training at the Quincy Sustainability Workshop.
Food Industry Personnel	$10,650	Participation of industry personnel in advisory group meetings and workshops.

To accommodate the tools and resources developed under the project and as a means to disseminate the tools and resources, NWFPA totally revised the Sustainability pages on its web site. NWFPA will continue to develop out its Sustainability pages and add tools and resources.

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END OF REPORT