

Washington State Department of Agriculture

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Final Performance Report

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Project Title: The Weed Link in Zebra Chip Epidemiology

Project Summary

The potato industry of Washington is substantially threatened by the 2011 expansion of zebra chip disease into the Pacific Northwest. This pathogen can result in millions of dollars in losses for some larger growers. Zebra chip disease is caused by a bacterial plant pathogen called *Liberibacter solanacearum* that is transmitted by the potato psyllid. Managing zebra chip requires that growers control the psyllid. Washington growers have met this threat with a risk-adverse and insecticide-reliant psyllid control program. Insecticide applications now often begin in June and continue on a calendar-basis almost to harvest. The need for this insecticide-intensive approach is due to one overriding factor: growers are unable to predict what fields are most likely to be colonized by infective psyllids, nor are they able to predict how early or late in the season at-risk fields are likely to be colonized.

The current difficulty in predicting which fields are at risk to be colonized by psyllids is due to not knowing the weed or habitat source of those colonizing psyllids. Because potato is unavailable to psyllids for much of the year, colonization of potato fields each year is due to movement by psyllids from non-crop host plants. Potato psyllids in other growing regions are found on annual and perennial weeds closely related to potato (Families Solanaceae and Convolvulaceae). At least a dozen potential host plant species occur within the potato growing region of Washington, but for most of these species there is little or no information about the suitability to potato psyllid. There is even less information about whether these non-crop species are also reservoirs of the zebra chip pathogen. Without this knowledge, growers struggle to predict whether stands of a given species of weedy Solanaceae or Convolvulaceae near their fields might be an important source of infective psyllids.

The project goal was to provide this missing knowledge for each weedy and perennial Solanaceae and Convolvulaceae in the potato growing region of Washington and to rank the overall risk of each species serving as a source of infective psyllids. This risk-index was based on a combination of plant traits: 1) suitability to potato psyllid, 2) suitability to the zebra chip pathogen, 3) whether it is a preferred host of the psyllid, 4) and seasonal availability of the plant.

Pest control costs have jumped noticeably since the 2011 zebra chip outbreak, largely due to insecticide costs for controlling the psyllid. Information that would allow extension personnel and growers to more effectively judge which fields are most at risk to colonization by infective psyllids would substantially help in guiding their psyllid control programs. The risk rankings would also allow growers to take direct action against high risk weeds through mechanical or chemical control. Indeed, some of the targeted plant species are weedy pests of row crops, including potato.

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

Project Approach

Briefly summarize the activities performed and tasks achieved during the project period. Whenever possible, describe the work accomplished in both quantitative and qualitative terms. Include the significant results, accomplishments, conclusions and recommendations. Describe favorable and unusual developments.

Researchers at the USDA-ARS in Wapato, WA tested the suitability of ten annual and perennial weeds and two ornamental plant species as hosts of potato psyllid and the zebra chip pathogen. The ten weed species included three native annual Solanaceae (coyote tobacco, buffalobur, and cutleaf nightshade), three introduced annual Solanaceae (jimsonweed, henbane, and hairy nightshade), three introduced perennial

Solanaceae (matrimony vine, ground cherry, and bittersweet nightshade), and one perennial Convolvulaceae (field bindweed). The ornamental Solanaceae included *Nolana* and *Petunia*. Potato psyllid occurs in Washington as two biologically-distinct haplotypes, namely the western and northwestern haplotypes. These haplotypes differ with respect to fecundity, host preference, presence of bacterial endosymbionts, and other biological traits. Therefore, the researchers examined suitability to both northwestern and western haplotypes of the psyllid.

Suitability of weed species to the potato psyllid. The survival and development time from egg to adult of potato psyllids on each weed versus potato was compared in laboratory assays. Because of asynchrony of seed availability and germination, each weed species was assayed alone against potato. Psyllids survived on all ten weed species, but survival rates were comparatively low on coyote tobacco, henbane, jimsonweed, and field bindweed. Although psyllids of the western haplotype survived well on hairy nightshade, psyllids of the northwestern haplotype did not survive on this weed species. Psyllids completed development on ornamental *Nolana*, but did not survive on *Petunia*. Mean development times from egg to adult were similar on potato and several of the non-crop species. The exceptions to this trend occurred on field bindweed, jimsonweed, and matrimony vine.

Egg-laying preference. For preference assays, a weed seedling and a potato seedling were paired in cages, and five female psyllids of the western or northwestern haplotype were released in the center of each cage. The number of eggs on each plant was determined after 48 hours. Psyllids oviposited a similar number of eggs on potato and most of the wild plant species. However, psyllids of both haplotypes noticeably preferred cutleaf nightshade over potato, and noticeably avoided field bindweed and *Petunia*.

Susceptibility to the zebra chip pathogen. To examine the susceptibility of non-crop species to the zebra chip pathogen, plants were inoculated with *Liberibacter* by confining males to a leaf on each plant for one week. The plants were maintained in a greenhouse for 1 week after removing the inoculation psyllids to allow the pathogen to spread and multiply within the plant. The uninfected psyllids were confined to leaves of each plant for two weeks before testing the psyllids and leaves for the presence of *Liberibacter* using PCR. Plants were considered susceptible to *Liberibacter* if PCR detected the pathogen in leaves, or if uninfected psyllids acquired *Liberibacter* from plants previously exposed to infected psyllids. *Liberibacter* was detected from foliar samples of henbane, coyote tobacco, groundcherry, *Nolana*, and *Petunia*. The pathogen was acquired by uninfected psyllids on all plants except field bindweed, matrimony vine and *Petunia*.

Descriptions of key characteristics and life histories of weed species. We developed a rudimentary key to weedy Solanaceae and Convolvulaceae that occur in Washington to aid the identification of weed species that are potential sources of potato psyllid and the zebra chip pathogen. Taxonomic descriptions were obtained from multiple sources, including Strausbaugh and Core (1977. *Flora of West Virginia*, 2nd edition, Seneca Books, Morgantown, WV), Cronquist et al. (1984. *Intermountain flora: Vascular plants of the intermountain west*, U.S.A., Volume 4. New York Botanical Garden, Bronx, NY), and Whitson et al. (2009. *Weeds of the west*, 10th edition. Color World Press, Jackson, WY). Important life history traits were also noted, especially the seasonal availability of each weed species. Species that are available for psyllids before the emergence of potato allow psyllid populations to increase and become available to colonize psyllids in early summer. Therefore, the perennial species – field bindweed, matrimony vine, groundcherry, and bittersweet nightshade – likely pose a more significant risk as sources of early season psyllids than do the annual species.

Sampling of wild stands of weed species. Wild stands of weed species, when located, were sampled for the presence of potato psyllid. Large populations of potato psyllid naturally occur year-round on stands of matrimony vine and bittersweet nightshade. Groundcherry appears rare in Washington, and the researchers

were not able to find psyllids on this plant. Psyllids were occasionally observed on cutleaf nightshade during the summer, but other annual Solanaceae were not sampled.

W. Rodney Cooper led assays to examine the suitability of weed host to the zebra chip pathogen, and David R. Horton led psyllid performance and preference assays. Both Cooper and Horton contributed to locating and sampling wild weed stands for psyllids and the zebra chip pathogen.

If the overall scope of the project benefitted commodities other than specialty crops, indicate how project staff ensured that funds were used to solely enhance the competitiveness of specialty crops.

This project focused solely on potato psyllid and the zebra chip pathogen, which is a pest only of potato in Washington. The psyllid and pathogen cause economic injury to other crops in Solanaceae including tomato and pepper, but these crops are not grown on a large commercial scale in Washington.

Goals and Outcomes Achieved

The performance goal was to determine what species of non-crop and weedy Solanaceae in the potato growing region of Washington are mostly likely to be sources of infected psyllids arriving in potato field. To complete this goal, researchers at the USDA-ARS in Wapato, WA performed laboratory assays to examine the suitability of potential hosts to the potato psyllid and zebra chip pathogen. This information was used develop a risk index for each weed species as sources of infective psyllids colonizing potato. Photographs of plants and a list of diagnostic traits for high risk species were included with the risk index. Results of studies were presented to about 300 researchers, growers and industry representatives at the 2017 Potato Association of America annual meeting, to about 60 researchers and extension personnel at the 2018 Pacific Branch of the Entomological Society of America annual meeting, and to a group of about 15 growers and researchers at the annual SCRI stakeholder meetings. A manuscript summarizing results of this project is currently being considered by the American Journal of Potato Research, which is a peer-reviewed journal associated with the Potato Association of America and disseminated to researchers, growers, and other industry representatives. A manuscript with the risk index is currently in preparation to be submitted to Potato Progress pending any issues that might arise from peer-reviews from the American Journal of Potato Research. Potato Progress is an industry publication disseminated to over 1000 email addresses.

The expected measurable outcomes of the project were relative to the time frame of this grant.

The activities and goals of the original proposal were fully met.

By assaying native or naturalized Solanaceae and Convolvulaceae, the researchers were able to assess the risk of each non-crop plant species as a source of potato psyllid and the zebra chip pathogen. The data obtained from this project increases the basic understanding of the ecology and landscape movements of potato psyllid, and the epidemiology of the zebra chip pathogen. This information is the basis for ongoing hypothesis-driven research to identify which non-crop plant species are the primary sources of infective psyllids colonizing potato, and provides the basis for models to predict the timing and extent of potato psyllid infestations. The models are based on observations that populations of potato psyllid occurring on weeds in early spring is directly correlated with the percentage of potato fields that become infested with psyllids in late summer.

Beneficiaries

All of the ~175 potato growing operations in Central Washington are potentially affected by zebra chip and therefore potentially helped by this research. In addition, potato processors and growers in Oregon and Idaho will also benefit from this research.

The ability to predict psyllid pressure is of critical importance in helping growers make proactive management decisions for potato psyllid and to tailor their psyllid control programs according to the predicted risk for psyllid infestation, rather than having to rely on calendar-driven applications of insecticides. Insecticide applications targeting potato psyllid led to an increase in annual production costs of \$28 to \$158 per acre, depending upon the region, following the 2011 zebra chip outbreak. Elimination of one or more insecticide applications using a targeted control program could reduce these extra costs. It is estimated that elimination of even a single unneeded insecticide treatment on the most affected acreage in the Pacific Northwest could lead to savings of about \$20-30/acre. Additionally, eliminating unnecessary insecticide applications reduces the likelihood of secondary pest outbreaks. Outbreaks of secondary pests such as mites and aphids are common in potato fields when calendar-based insecticide programs are used, forcing growers to make often one or two additional insecticide applications.

Lessons Learned

- 1) Hairy nightshade is not a suitable host for the northwestern haplotype of potato psyllid but is a highly suitable host for the western haplotype. This is the first direct evidence for differences in host suitability between the different psyllid haplotypes.
- 2) Matrimony vine, although a suitable host for potato psyllid, does not appear to be susceptible to the zebra chip pathogen and therefore is not likely a source of infective psyllids colonizing potato.
- 3) Ornamental plantings of Petunia are not suitable hosts for potato psyllid. Petunia is the only genus of Solanaceae currently known not to be a suitable host for potato psyllid.
- 4) Field observations suggest that population counts of potato psyllid occurring on perennial Solanaceae in early spring may serve as an indicator for the timing and extent that potato psyllids will infest potato in late summer.

The discovery that hairy nightshade is not a suitable host for northwestern haplotype was an entirely unexpected result. Published results have suggested that northwestern and western haplotype may differ with respect to plant preference, but results from project research provide the first direct evidence that the two haplotypes differ in their ability to survive on host plants.

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

Contact Person

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Additional Information

Total match: \$272,537

- 1) \$40,000 (FY 2015) from the Northwest Potato Research Consortium for partial support of a GS-6 technician (Merilee Bayer), a GS-5 part-time technician (Tara Culbertson), and a GS-3 technician (open). Funds were provided to examine interactions between potato psyllid, the zebra chip pathogen, and weedy Solanaceae, and to develop molecular methods with which to detect species-specific plant DNA within the guts of potato psyllids.
- 2) \$26,000 (FY 2015) from the Washington State Commission on Pesticide Registration for partial support of a GS-6 technician (Merilee Bayer), a postdoctoral scientist (Jenita Thinakaran), and a GS-3 technician

(open). Funds were provided to examine the role of weedy Solanaceae as overwintering hosts of potato psyllid, and to develop molecular methods with which to detect species-specific plant DNA within the guts of potato psyllids.

3) \$56,250 (FY 2015-2016) from the ARS-State Partnership Potato Program for partial support of a postdoctoral scientist (Jenita Thinakaran). Funds were provided to examine incidence of the zebra chip pathogen in wild and cultivated host plants.

4) \$134,246 (FY2015-2018) from the USDA-Specialty Crop Research Initiative awarded to Washington State University for partial support for two post-doctoral scientists (Jenita Thinakaran and Navneet Kaur), and one graduate student (Cesar Reyes). Funds were provided to examine the role of weedy Solanaceae as overwintering hosts of potato psyllid, and to screen Convolvulaceae for suitability to potato psyllid.

5) \$20,000 (FY2017) from the Washington State Commission on Pesticide Registration for partial support of a GS-5 technician (Sally Longoria). Funds were provided to examine the role of matrimony vine as a source of potato psyllids entering fields of potato.

6) \$30,000 (FY2017) from the ARS-State Partnership Potato Program for supplies to identify non-crop sources of infective psyllids colonizing potato fields in south Texas.

7) \$16,666 (FY 2015-2016) included for USDA-ARS indirect costs. These costs were calculated at 11.1% of total direct costs ($\$150,143 \times 11.1\% = \$16,666$)

Peer-reviewed Publications

Kaur, N., W. R. Cooper, J. M. Durringer, I. E. Badillo-Vargas, G. Esparza-Diaz, A. Rashed, and D. R. Horton. 2018. Survival and development of potato psyllid (Hemiptera: Trioziidae) on Convolvulaceae: Effects of a plant-fungus symbiosis (*Periglandula*). PLoS One. e0201506.

Thinakaran, J., D. R. Horton, W. R. Cooper, A. S. Jensen, C. H. Wohleb, J. Dahan, T. Mustafa, A. V. Karasev, and J. E. Munyaneza. 2017. Association of potato psyllid (*Bactericera cockerelli*; Hemiptera: Trioziidae) with *Lycium* spp. (Solanaceae) in potato growing regions of Washington, Idaho, and Oregon. Am. J. Pot Res. 94: 490-499.

Cooper, W. R., D. R. Horton, T. R. Unruh, and S. F. Garczynski. 2016. Gut content analysis of a phloem-feeding insect, *Bactericera cockerelli* (Hemiptera: Trioziidae). Environ. Entomol. 45: 938-944.

Other Publications

Kaur, N., A. Rashed, D. R. Horton, W. R. Cooper, I. E. Badillo-Vargas, G. Esparza-Diaz, A. Jensen, D. Johnson, and L. Kawchuk. 2018. The "morning glory" psyllid? Potato psyllid development on morning glories and bindweed. Potato Progress. XVIII, #11.

Horton, D. R., E. Miliczky, J. Thinakaran, W. R. Cooper, J. E. Munyaneza, C. H. Wohleb, T. D. Waters, and A. V. Karasev. 2017. Potato psyllid and the South American desert plant *Nolana*: an unlikely psyllid host? Potato Progress XVII, #16.

Horton, D.R., J. Thinakaran, W.R. Cooper, J.E. Munyaneza, C.H. Wohleb, T.D. Waters, W.E. Snyder, Z. Fu, D.W. Crowder, and A.S. Jensen. 2016. Matrimony vine and potato psyllid in the Pacific Northwest: a worrisome marriage? Potato Progress XVI, #14.

Presentations

Cooper, W. R. and D. R. Horton. "Pinpointing the weed sources of potato psyllid in Washington." 2018 WA/OR Potato Conference, Kennewick, WA. January 2018.

Cooper, W. R. and D. R. Horton. "The weed link in zebra chip epidemiology: Annual and perennial weeds as sources of the zebra chip pathogen." Annual meeting of the Pacific Branch Entomological Society of America, Reno, NV. June 2018.

Cooper, W. R., D. R. Horton. "Non-Crop sources of insect pests: Weedy sanctuaries and non-host whistle stops." Annual meeting of the Pacific Branch Entomological Society of America, Reno, NV. June 2018.

Cooper, W. R. "Use of molecular tools to investigate biology of psyllids." Heritage University Gathering of the Scholars (keynote speaker), Toppenish, WA. April 2018.

Cooper, W. R., and D. R. Horton. "Use of molecular techniques to study psyllid ecology." Annual meeting of the Pacific Branch Entomological Society of America, Portland, OR. April 2017.

Horton, D.R. and J. Thinakaran. "What is the source of potato psyllids colonizing potato fields in the Pacific Northwest?" Plant Management Network, Focus on Potatoes. Invited Webinar. June 2017.

<https://www.plantmanagementnetwork.org/edcenter/seminars/potato/PsyllidsPacificNorthwest/>

Cooper, W. R., and D. R. Horton. "The weed link in zebra chip epidemiology: Annual and perennial weeds as sources of the zebra chip pathogen. Potato Association of America annual meeting, Fargo, ND. July 2017.

Thinakaran, J., D. R. Horton, W. R. Cooper, and A. V. Karasev. "Use of Lycium by potato psyllid in the Pacific Northwest: lessons from the desert southwest?" Potato Association of America annual meeting, Fargo, ND. July 2017.

Cooper, W. R., D. R. Horton, T. R. Unruh, and S. Garczynski. "Gut content analysis of the phloem feeding insects, *Bactericera cockerelli* and *Cacopsylla pyricola*." Annual meeting of the Pacific Branch Entomological Society of America, Honolulu, HI. April 2016.

Project Title: Managing Washington Berry Diseases

Project Summary

Diseases are a major threat to berry production in WA and controlling them represents a significant production cost for WA berry producers. The efficacy of fungicides applied to control these diseases is under severe threat due to the development of resistance to the fungicides currently used in WA berry production. The goals of this project were to determine the extent of the fungicide resistance problem in several key berry pathogens in WA and also to identify new disease control tools. These new tools included both biofungicides as well as conventional synthetic fungicides with different modes of action from those currently used. This project will take an integrated approach to the development of strategies to manage fungicide resistance in berries that will extend the useful life of our most effective fungicides as well as provide a new set of disease control tools for WA growers.

From 2011-2013, Washington red raspberry growers suffered severe fruit losses to *Botrytis* gray mold, the most economically significant disease facing the industry. Four of five fungicides typically used in berry production (Pristine, Switch, Rovral, and Elevate) have documented resistance. In 2014, samples of *Botrytis* from raspberry in Whatcom and Skagit counties were screened for resistance to 5 fungicides. Forty and 0% of isolates were resistant to cyprodinil and fludioxonil, respectively, the two active ingredients in Switch, 13% were resistant to boscalid, the active ingredient in Pristine and 68% of isolates were resistant to fenhexamid, the active ingredient in Elevate. Similar frequencies of resistant isolates are present in *Botrytis* infecting blueberry and strawberry in Skagit and Whatcom counties. Captan is currently considered the only *Botrytis* fungicide without risk of resistance development. Unfortunately, due to MRL restrictions, use of this fungicide is restricted to early in the growing season on berries exported to Canada, the largest export market for Washington raspberries. Growers are in desperate need of resistance management strategies to preserve existing fungicides and access to new fungicides with different modes of action. The Washington Red Raspberry Commission and Blueberry Commissions consider this a crisis for their industries. Many of the same fungicides are used to control *Botrytis* on raspberry, blueberry, blackberry and strawberry as well as mummyberry and other diseases of blueberry. Control of *Botrytis* and mummyberry are intertwined as these crops are grown side-by-side, have common fungal pathogens that move between crops. [Resistant botrytis has been documented moving between berry fields in Northwest Washington.] Blueberry growers are overreliant on triazole (FRAC Class 3) fungicides for control of mummyberry creating a high risk for fungicide resistance development to these materials as well. Additional fungicides with novel modes of action are desperately needed to control *Botrytis*, mummyberry and other blueberry diseases. This project addressed three interrelated objectives: 1) determine the extent of fungicide resistance in *Botrytis* infecting raspberry, blueberry, blackberry and strawberry and mummyberry infecting blueberry in Western Washington, 2) provide necessary information for the development of resistance management strategies for WA berry crops and 3) screen new products to control *Botrytis* and mummyberry in WA berries.

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

Project Approach

Widespread resistance to 4 of 5 fungicides used in PNW berry production has been identified. All berry crops had similar resistance profiles but substantial field-to-field variation in resistance profiles was observed, even fields located adjacent to each other. The effectiveness of several new FRAC Group 7 fungicides for the control of boscalid resistant strains of *Botrytis cinerea* have been demonstrated. Preliminary surveys of boscalid resistance mutations in PNW berry fields has confirmed the predicted usefulness of these new FRAC 7 fungicides in PNW berry production. The effectiveness of Switch

fungicide despite the widespread occurrence of resistance to the cyprodinil component of Switch has been confirmed.

Several new fungicides that will be useful to PNW berry production through in-field efficacy testing of new products (Schreiber) have been identified. Widespread resistance to 4 of 5 fungicides used in PNW berry production (Peever) and confirmed the ability of several new FRAC Group 7 fungicides to control boscalid-resistant strains in both field efficacy trials (Schreiber) and in the laboratory (Peever) have been identified.

For each of the three years of the project, we conducted an efficacy trial screening new fungicides products, particularly those with new modes of action against botrytis gray mold. Each year, the trial included about 30 treatments. This number of treatments is a very large efficacy screening program. Additionally, we conducted a second trial looking at various programs of existing registered fungicides that determined the best ways of using existing fungicides to control fungicidally resistant botrytis. The programs in the trial included all of the major botrytis disease control programs used in Washington raspberries, from low cost programs to higher end programs to intensive resistance management programs. A third trial was conducted annually on blackberries. Blackberries were used as a trial site due to the higher disease pressure in that crop and the presence of all four times of resistant botrytis at that location. During the course of the three year projects, three fungicides became registered on raspberries and those products were moved from the efficacy screening trial to the program trial. Information from these trials now form the basis of all raspberry fungicide trials in Washington State. This work was done in close cooperation with WSU's Dr. Tobin Peever's program and with his Ph.D. student Olga Kozhar. This data was used to obtain a Section 18 emergency exemption for Kenja.

This project exclusively benefitted specialty crops.

Goals and Outcomes Achieved

Project Activity	Responsible Party	Timeline	Progress	Status
Establish Technical Advisory Task Force	Schreiber, Bierlink	October, 2015	Initial meeting was held February 15 th . 20+ attended and agreed to help direct the project.	Completed.
<i>Botrytis</i> resistance management strategy deployed	Peever, Schreiber, Bierlink	April, 2016 – April, 2017	Discussions with participating berry growers about fungicide resistance status in their fields and modifications of their fungicide programs for 2016 and 2017.	Completed in 2016 and confirmed in 2017.
Monitor fungicide resistance and estimate cross resistance	Peever	May, 2016 – August, 2017	Analysis of fungicide resistance data from 2016, design sampling strategy for 2017. Analysis of cross resistance patterns of Botrytis to support new registrations.	Completed in 2016 and confirmed in 2017.

Develop Efficacy Research protocols	Tech Task Force, Peever, Schreiber	May, 2016 - May, 2017	Approved by Task Force.	Completed in 2016.
Grower Surveys	Tech Task Force, Peever, Schreiber	Feb 2017	Grower survey conducted at February botrytis meeting.	Completed.
Testing new control products	Tech Task Force, Peever, Schreiber	May, 2016 – August, 2017	Products are being tested.	Completed in 2016.
Update resistance management strategies	Tech Task Force, Peever, Schreiber	October, 2016 - October, 2017	Resistance management strategies modified according to results of resistance surveys and efficacy results from 2016 and 2017.	Completed.
Evaluate strategies with grower survey	Tech Task Force, Peever, Schreiber	November, 2017	Strategies evaluated.	Completed in early 2017.
Present at Annual Small Fruit Conference	Peever, Schreiber	December 2016 – 2017	Presented efficacy and cross resistance data at Small Fruit Conference.	Completed.
Botrytis resistance management meeting and task force meeting	Schreiber, Peever	February 22, 2017 February 21, 2018	Task force met with growers and outside experts to discuss and implement resistance management strategy in 2017 and 2018.	Completed.
Prepare Final Report	Peever, Schreiber	February, 2018	Final Report completed in April.	Completed.

Expected Measurable Outcome(s)

Goal 1. Develop a resistance management strategy for Washington berry growers based on knowledge of fungicide resistance status of the Botrytis pathogen affecting Washington berries

Target 1. Maintain or reduce frequencies of resistant Botrytis isolates in each year of project (i.e. no net increase in frequencies of resistant isolates over duration of grant 2015-2018)

Benchmark 1. Current frequencies of resistance to five major fungicides used in Washington berry production mentioned above

Performance Measure 1. Surveys of fungicide resistance status conducted under this project provided data to measure performance. Resistances to each of the 5 major fungicides used in small fruit production have not changed in any significant way on a regional basis during this project. This suggests that resistance management strategies have been effective in preventing the further buildup of resistance. There is some evidence from certain fields that resistance to fenhexamid (Elevate) may be declining since this fungicide

was withdrawn from use on a voluntary basis in 2012. As a result of this project, and additional projects funded by the Washington Red Raspberry Commission and the Northwest Center for Small Fruit Research, there is now a comprehensive understanding of the status of fungicide resistance in the gray mold pathogen throughout the Pacific Northwest on a regional basis. The surveys indicate that fungicide resistance profiles can vary substantially on a very local scale. For example, adjacent fields of raspberry can have very different resistance profiles which suggests that the gray mold pathogen may not readily move long distances. This observation begs to find a cost-effective way to increase the number of fields surveyed so that information can be provided to each grower on the resistance status in his/her fields.

Goal 2. Improve control of Botrytis in Washington berry production and increase profits of producers

Target 2. 50% reduction in losses due to Botrytis and 20% increase in profits

Benchmark 2. Current disease levels in 2015 (will be determined)

Performance Measure 2. Disease control strategy effectiveness was measured through grower surveys conducted at annual botrytis workshops. In excess of 90% of fungicides applied for disease control in berries are applied in Snohomish, Skagit and Whatcom counties. Growers and crop advisors representing 75% of production from this area provided information on effectiveness of new disease control strategies. A comparison between disease control success in the previous two years as compared to 2011 and 2012 indicated a significant improvement in the level of disease control in berries. Reduction in losses from botrytis exceed 80% compared to the 2011-2012 seasons. Seasonal conditions are the most likely contributor to this decline in losses but reliance on more effective fungicides were also contributors.

Goal 3. Identify new fungicides with alternate modes of action that can be used for disease control each in blueberry and raspberry

Target 3. Identification of 2-4 new fungicides with efficacy against Botrytis in berries

Benchmark 3. No new fungicides have been introduced into Washington berry production in the last 10 years

Performance Measure 3. Number of new fungicides registered or in the registration process for Washington berry production one year after completion of project (2019) Based on feedback from growers and crop advisors representing 67.5% of berry production receiving fungicides, found that 90% of growers were using resistance management strategies including rotation of modes of action, tank mixing, use of appropriate rates and not using fungicides with widespread known resistance. New fungicides registered or in the registration process include: *Luna Tranquility*, *Luna Privilege*, *Kenja*, *Miravon*, and *Inspire Super Fungicides*.

Goal 4. Adoption of resistance management strategies by Washington berry growers

Target 4. 75% of raspberry and 50% of blueberry producers in Washington will be using resistance management strategies upon completion of this project (2018)

Benchmark 4. Percentage of WA berry producers employing resistance management strategies in 2015

Performance Measure 4. Percentage of WA berry producers employing resistance management strategies in 2015 and 2018 was measured through grower surveys conducted at annual botrytis workshops. Based on feedback from growers and crop advisors representing 67.5% of berry production receiving fungicides, found that 90% of growers were using resistance management strategies including rotation of modes of action, tank mixing, use of appropriate rates and not using fungicides with widespread known resistance.

One long term goal of this project was to provide PNW berry growers with new disease management tools. Enormous success has been experienced in this area and that was facilitated by the project. Prior to the project, no fungicide resistance management strategy existed in PNW berry production and now every major berry producer in WA is using information provided through our research efforts to optimize fungicide use.

- 1) *Determine the extent of fungicide resistance in Botrytis infecting raspberry, blueberry, blackberry and strawberry and mummyberry infecting blueberry in Western Washington.*

This goal has been met. A comprehensive picture of fungicide resistance in berry production in the PNW has been established.

- 2) *Provide necessary information for the development of resistance management strategies for WA berry crops.*

This goal has been met but research to increase the throughput of the fungicide sensitivity assays and to incorporate information on boscalid-resistance mutations is ongoing.

- 3) *Screen new products to control Botrytis and mummyberry in WA berries.*

This goal has been met. Several new products have been identified with excellent activity against *Botrytis cinerea* through in-field efficacy testing as well as laboratory assays

No fungicide resistance management programs existed in PNW berry production prior to initiation of this project. Current data suggest that a large percentage of PNW berry growers are using fungicide resistance management guidelines that have been developed as a result of this project.

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 have relied on the fungicide research provided in this program and have moved away from products indicating a high level of resistance. Disease control tools are priority concerns for the future of this industry.

There are approximately 200 blueberry growers in western Washington that are applying fungicides for control of diseases. Growers representing 90% of production have changed their fungicide use practices as a result of this research. Additional fungicides have become available and are now incorporated into grower's spray programs. Almost all Washington berry growers using fungicides have adopted significant fungicide resistance management programs. No new types of fungicide resistance have developed since work was started on this problem.

90% of Washington red raspberry growers and 90% of Washington blueberry growers in western Washington (which represents 85% of all blueberry growers) are using resistance management tactics. No new types of fungicide resistance have developed since the deployment of resistance management strategies.

Lessons Learned

There is substantial variation in fungicide resistance profiles among berry fields, even fields that are adjacent. This means that a regional assessment of fungicide resistance in berries will not be sufficient for individual growers to customize fungicide resistance strategies for their own operations and has

necessitated the development of higher-throughput fungicide resistance assays. The new FRAC 7 fungicides will be effective for PNW berry growers because of the profile of boscalid resistance mutations that are present in PNW berry fields. Several of the new FRAC 7 fungicides can control boscalid-resistant strains of *B. cinerea* under field conditions.

Now that resistance has been documented to botrytis and there is a well-developed means for evaluating products for resistance, and for resistance by resistance mechanism, there is increased interest in testing new products in this market.

The goals and Expected Measurable Outcomes of this project were achieved.

Contact Person

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Additional Information

	2015-2016	2016-2017	2017-2018	TOTAL
ADG Personnel		\$13,902	\$13,902	\$27,804
ADG Benefits		\$2,548	\$2,548	\$5,096
WSU Personnel	\$23,492	\$23,892	\$24,798	\$72,182
WSU Benefits	\$5,106	\$5,114	\$5,176	\$15,396
Travel	\$2,200	\$2,200	\$2,200	\$6,600
Supplies		\$14,000	\$6,000	\$20,000
TOTAL	\$30,798	\$61,656	\$54,624	\$147,078
WBC match	\$30,000	\$30,000	\$30,000	\$90,000
WRRRC match	\$15,000	\$15,000	\$15,000	\$45,000
TOTAL CASH	\$75,798	\$106,656	\$99,624	\$282,078
WRRRC in-kind match	\$1,500	\$1,500	\$1,500	\$4,500
Crop Destruct		\$21,000	\$21,000	\$42,000
TOTAL IN-KIND MATCH	\$1,500	\$22,500	\$22,500	\$46,500
TOTAL PROJECT	\$77,298	\$129,156	\$122,124	\$328,578

COST CATEGORY	Grant Funds	Invoiced to Date	Balance
Contractual	\$147,078	\$147,078.00	\$0.00

TOTAL	\$147,078	\$147,078.00	\$0.00
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Matching Funds	WRRC, WBC, Crop Destruct		\$180,000
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All funds were contracted with Washington State University and Ag Development Group. WRRC contributed an additional \$67,432 to the Project and the WA Blueberry Commission contributed \$90,000. WRRC administered the project with costs totaling \$4,500 and the estimated crop destruct contributions totaled \$42,000.

Publications and Posters:

Colonization dynamics of red raspberry flowers and fruit by *Botrytis cinerea*

O. Kozhar and T.L. Peever

Department of Plant Pathology, Washington State University, Pullman, WA 99164.

Presented at the International Congress of Plant Pathology, Boston MA, July 2018

How does *Botrytis cinerea* infect red raspberry?

O. Kozhar and T.L. Peever

Department of Plant Pathology, Washington State University, Pullman, WA 99164.

Presented at the American Phytopathological Society Annual Meeting San Antonio TX, August 2017

- Mar, 23, 2018 Oral presentation of *B. cinerea* ecology project at the Skagit Berry Workshop, Mount Vernon, WA, USA. "*Dynamics of B. cinerea colonization of raspberry flowers and fruit*"
- Feb, 21, 2018 Oral presentation of *B. cinerea* ecology and fungicide resistance projects at Annual Botrytis meeting, Lynden, WA, USA. Progress report
- Dec, 15, 2017 Oral presentation of *B. cinerea* ecology project at Washington Small Fruit Conference, Lynden, WA, USA
- July, 30, 2018 Oral presentation of *B. cinerea* ecology project at the Annual APS meeting, San Antonio, TX, USA. "*How does Botrytis cinerea infect red raspberry?*"
- Feb 22, 2017 Oral presentation of *B. cinerea* ecology and population genetics at 2017 Berry Fungicide Resistance Working Group, Lynden, WA. Progress report of two projects
- Dec 8, 2016 Poster presentation of Botrytis population genetics project at Annual Conference of Northwest Center for Small Fruits Research, Kennewick, WA. "*What do we know about B. cinerea populations infecting small fruit in Pacific Northwest*"

Project Title: Pre-plant Management techniques for nematodes and soilborne raspberry diseases

Project Summary

Washington State is a national leader in the production of processing red raspberry (*Rubus idaeus*). In 2017, 9,600 acres were harvested in Washington with an estimated total value of production at \$57 million dollars (NASS, 2018). Approximately 97% of the crop is grown in northwestern Washington, which demonstrates the importance of this agricultural industry to the regional economies and livelihoods of people in these communities (WRRC, 2018). Despite the economic significance of the raspberry industry, Washington raspberry growers have faced significant challenges threatening the viability of their industry. One key challenge is management of soilborne pathogens, including the plant parasitic root lesion nematode (*Pratylenchus penetrans*, abbreviated RLN) and root rot [caused by *Phytophthora rubi* and likely exacerbated by other soilborne fungi and fungi-like organisms (e.g. *Pythium* and *Fusarium* spp.]. Growers rely on pre-plant fumigation to control these organisms, but relief has been temporary and populations can rebuild rapidly. An additional complication is that most fumigated fields are not tarped after fumigation because of increased costs. Tarping helps retain the fumigant in the soil, thereby increasing the amount of time that pathogens are exposed to a lethal dose. In the absence of tarping, residual pathogen populations are often left in the upper soil profile and likely contribute to rapid disease development in new plantings and overall reduced productivity.

The inability of fumigation practices to effectively control these organisms is suspected to contribute to “replant disease”, which describes the phenomenon whereby raspberry plantings that used to remain productive for 15-20 years are now lasting only 4-7 years in fields replanted to raspberry. Land suitable for raspberry production is limited, necessitating continuous plantings without rotations. Fumigation methods utilized at the time that this proposal was written were often not adequately controlling soilborne pathogens. Poor control resulted in more frequent fumigation and replanting costs, as well as increases community exposure to fumigant emissions. Compounding these problems are Reregistration Eligibility Decisions issued by the US Environmental Protection Agency, which severely limits fumigant usage. In 2014, it was also discovered that winter wheat (*Triticum aestivum*) cover crops, which are planted immediately before or after fumigation and protects soils from erosion over winter, serves as a maintenance host between raspberry plantings (Rudolph et al., 2018).

Combined, these circumstances left raspberry growers with a significant problem regarding the lack of effective tools that can be used as part of an Integrated Pest Management (IPM) program for soilborne pathogen management. This project addressed the need to develop an improved IPM program for soilborne pathogens by developing knowledge and evaluating tools that allow growers to better manage soilborne pathogens. This was accomplished through two experiments. The first experiment evaluated and compared two alternative methods for improving fumigation efficacy (tarping versus supplemental fumigation with metam sodium) to conventional broadcast fumigation with Telone C-35 without tarping. The second experiment evaluated cover crop management, including planting date and time of kill to break the bridge for nematode and pathogen survival from the previous raspberry crop to the new planting. These experiments were complemented with dissemination of project information through multiple methods, which shared generated information with growers.

This project was important and timely because former methods of managing soilborne pathogens in raspberry were variable and often failed to control target organisms. Poor fumigation and soilborne pathogen management leads to plantings with reduced productivity and profitability for growers. It also increases replanting costs, as growers are more likely to replant on shorter rotations because plantings are not productive. In addition, public and private scientists discovered RLN in the roots of winter wheat. This

finding lead to the suspicion that the practice of cover cropping with winter wheat can provide a green bridge for RLN between plantings. Overall, growers needed information on how to better manage soilborne pathogens, the impact of cover cropping with a winter wheat, and how to manage cover crops to reduce RLN infestations in subsequent plantings.

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

Project Approach

Briefly summarize the activities performed and tasks achieved during the project period. Whenever possible, describe the work accomplished in both quantitative and qualitative terms. Include the significant results, accomplishments, conclusions and recommendations. Describe favorable and unusual developments.

Performed activities include establishment and continued monitoring and evaluation of two experimental trials established in 2016 and outreach of project information. This entailed collecting yield and plant growth data, sampling soils and raspberry roots to assess RLN, Fusarium, and Pythium population densities (which provided proxies for *P. rubi*), and sharing project and related information on soilborne disease management via 2 field days, 2 conference presentations, 4 extension newsletter articles, and 1 scientific publication to date. A special session focused on soilborne disease management that included results from this project was also held at the Washington Small Fruit Conference in Dec. 2017.

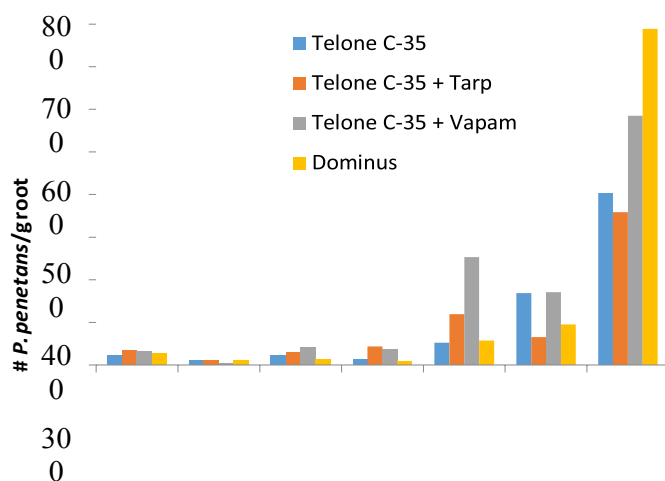
In the first experiment, conventional and alternative pre-plant soil fumigation techniques for soilborne pathogen suppression were compared. Treatments included: 1) Telone C-35 (1,3-dichloropropene + chloropicrin) deep-shanked and non-tarped (referred to as Telone C-35 control; standard industry practice); 2) Telone C-35, deep-shanked and covered with an impermeable tarp (referred to as Telone C-35 + Tarp; alternative practice); 3) Telone C-35, deep-shanked and supplemented with a shallow application of Vapam (metam sodium) (referred to as Telone C-35 + Vapam; alternative practice); and 4) Dominus (allyl isothiocyanate; another alternative practice that was not part of the original proposal but was added when the opportunity arose to test it). The experimental design was a randomized complete block with four replicates. Treatments were applied to single row plots that were a minimum of 400 ft long. Treatments were applied October 2015 and data were collected in 2016-2018. Data collected included plant growth (i.e. primocane number, height, and diameter), yield (measured in 2017 only, when the planting produced its first crop), and plant vigor. Populations of RLN in soils and roots were also collected every spring and fall until 2018. Because the experimental site did not have *P. rubi* throughout the planting, Pythium and Fusarium in bulk soil and large and small root debris were evaluated instead and served as proxies for *P. rubi*. Pythium and Fusarium were also recovered from planting stock roots.

No differences in plant growth nor yield were observed (Table 1). All of the fumigation treatments reduced population densities of RLN compared to pretreatment densities (1,242 RLN/100 g soil and 3,607 RLN/g root) ($P < 0.0001$). This would be considered a high density RLN field, demonstrating that these fumigant treatments were very effective, even at high initial population densities. The only significant effect in the repeated measure analysis was sampling date ($P < 0.001$). There were significantly more RLN in roots in the fumigation treatments at the final sampling date (September 2018) compared to previous sampling dates (Figure 1). It is important to note that these results are not translatable to all raspberry fields. The soil at this site is a sandy loam (>70%) and it has been observed RLN are more aggregated in the upper part of the soil profile (<24 inches) than deeper in the soil profile (Kroese et al. 2015). Therefore, it is possible that this field is more amenable to managing RLN with soil fumigation compared to heavier soils where RLN will reside at deeper soil depths.

Results from the Fusarium and Pythium assessments show fumigation did not reduce Fusarium in large root debris compared to prefumigation levels (Figure 2). Pythium was largely absent from large root debris before fumigation, but colonized raspberry roots in the Telone C-35 + Vapam and Dominus treatments after fumigation. Similar findings were observed in the small root debris. In bulk soil, only the Telone + Tarp reduced Fusarium soil populations, while no treatment reduced Pythium soil populations (Figure 3). Fusarium was detected at high levels on planting stock roots, while there were no Pythium on planting stock roots (data not presented). Overall, none of the fumigation treatments reduced Fusarium or Pythium in root debris compared to pretreatment colonization levels. Tarped Telone C-35 was the only treatment that was effective at reducing Fusarium in the soil (Figure 4), but this effect was gone by the time planting occurred in March 2016 (Figure 3). No treatments were effective at reducing Pythium in the soil. Tarped Telone C-35 therefore provided the best disease control against soilborne fungi or fungi-like organisms of the four fumigant treatments, but further optimization of application rates or fumigant formulations is likely needed before improvements in disease control of fungi and fungi-like diseases, including *P. rubi*, can be achieved.

Table 1. Impact of soil fumigation on ‘Meeker’ raspberry plant growth, yield, and vigor, 2016-2017.

Treatment	Primocane no.	Primocane height (cm)	Primocane diameter (cm ²)	Yield (lbs/60 ft plot) ^z	Plant vigor (1-5) ^y
Telone [®] C-35 (control)	9	52.8	0.89	205	2.78
Telone [®] C-35 + tarp	10	53.1	0.92	238	3.03
Telone [®] C-35 + Vapam [®]	10	55.9	0.91	210	3.34
Dominus [®] biofumigant	10	53	0.91	245	2.83
<i>P</i> - value	NS	NS	NS	NS	NS
^z Average determined from four machine harvests of 60 ft sections in each plot.					
^y Scale: 1=poor vigor/weak; 3=moderate vigor; 5=excellent vigor					



20

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Jun-16 Jul-16 Oct-16 Apr-17 Oct-17 May-18 Sep-18

Figure 1. Populations of root lesion nematodes (*P. penetrans*) in a ‘Meeker’ raspberry field, 2016-2018.

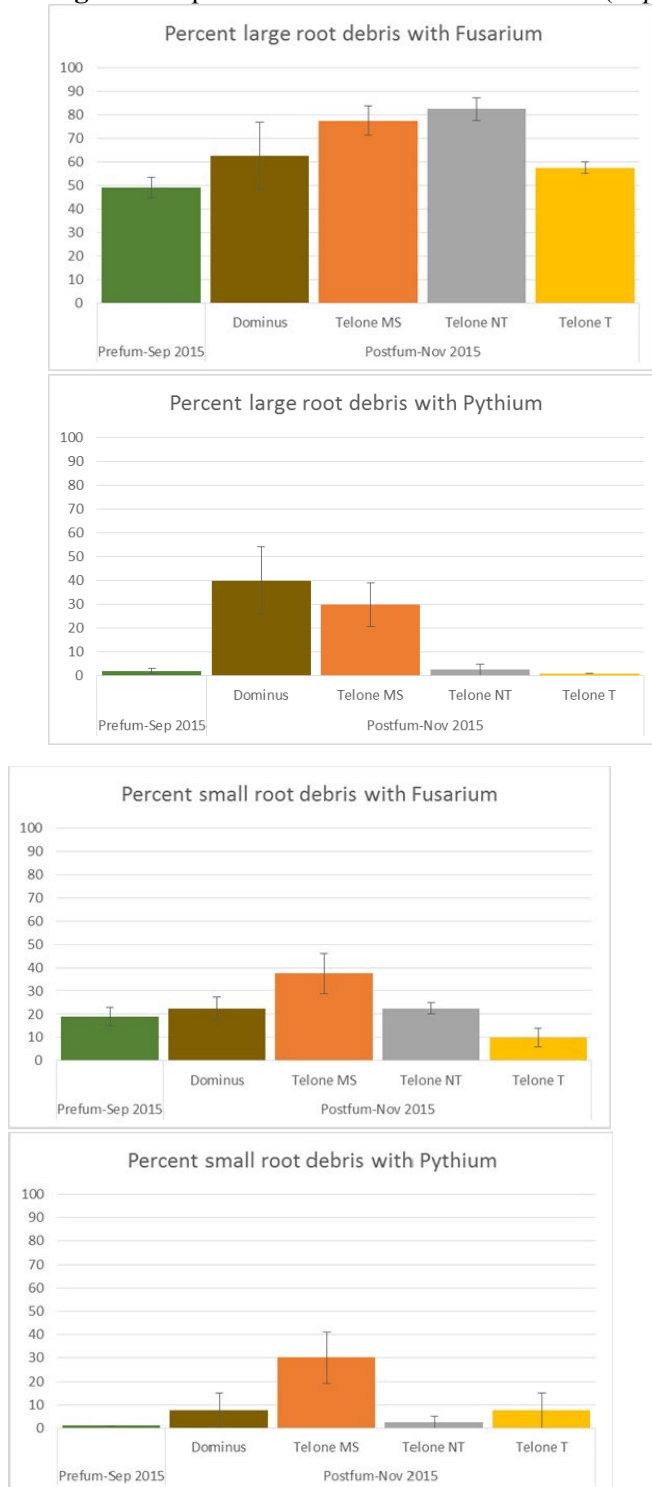


Figure 2. Colonization of ‘Meeker’ raspberry roots by Fusarium and Pythium species before and after

fumigation, 2015-2016. Note treatments correspond to: Dominus = Dominus; Telone MS = Telone C-35 + Vapam (metam sodium); Telone NT = Telone C-35, no tarp (control); and Telone T = Telone C-35 + Tarp.

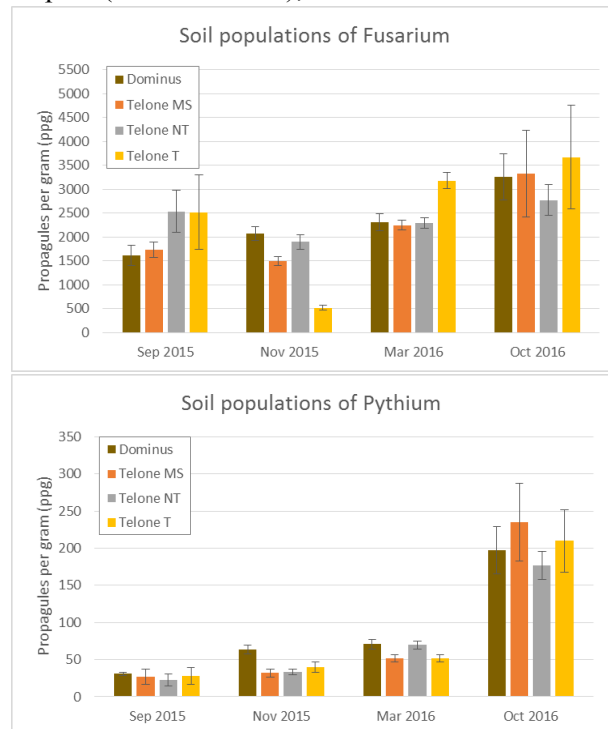


Figure 3. Soil populations of *Fusarium* and *Pythium* species before and after fumigation, 2015-2016. Note treatments correspond to: Dominus = Dominus; Telone MS = Telone C-35 + Vapam (metam sodium); Telone NT = Telone C-35, no tarp (control); and Telone T = Telone C-35 + Tarp.

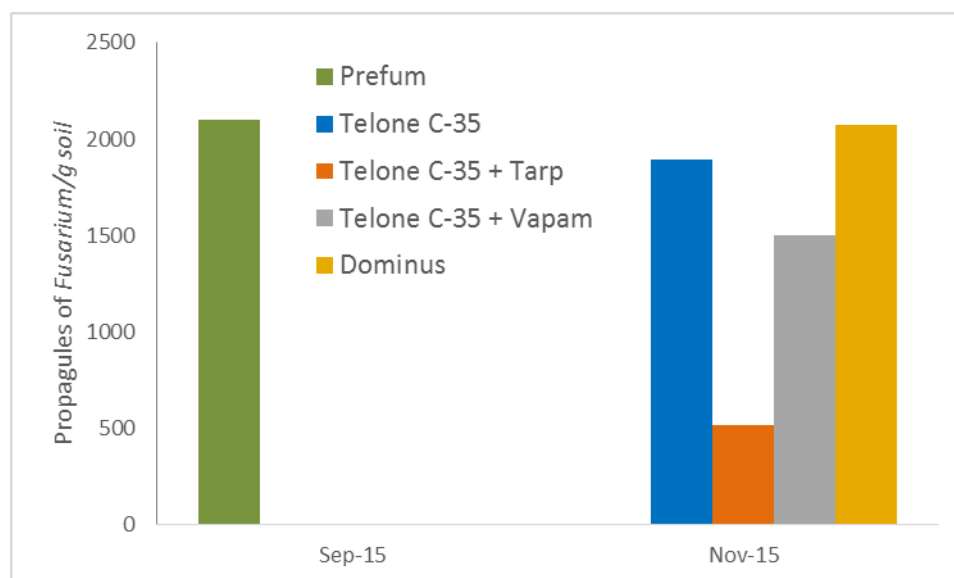


Figure 4. Soil populations of *Fusarium* species before and after fumigation, 2015. Note treatments correspond to: Prefum = prefumigation; Telone C-35 = Telone C-34, no tarp (control); Telone C-35 + Tarp = Telone C-35 + Tarp; Telone C-35 + Vapam = Telone C-35 + Vapam (metam sodium); and Dominus = Dominus.

The second experiment focused on evaluating management techniques of winter wheat cover crops established following standard fumigation with Telone C-35. Treatments included cover crop planted

immediately before fumigation (control; standard industry practice) and cover crop planting two weeks after fumigation. These two treatments were tested alone and in combination with: early destruction of the cover crop in January, late destruction of the cover crop in February, early destruction of the cover crop preceded by application of an insecticide with nematicidal properties (Lannate; methomyl insecticide); and late destruction of the cover crop preceded by application of a systemic insecticide with nematicidal properties. In total, there were 8 treatment combinations. The experimental unit was a 30-ft plot and each treatment was replicated four times in a randomized complete block design. Fumigation and cover crop planting occurred October 2015 with plant growth and nematode data collection occurring in 2016 and 2017.

The results from this experiment were recently published (Rudolph et al., 2018). There was no effect of early or late planting or cover crop termination on population densities of RLN in subsequent raspberry (Table 2). It also appears that pre-plant soil fumigation was not very effective in this field with RLN population densities in soil similar to pretreatment densities (~300 RLN/100 g soil). No treatment effects on plant growth were detected (data not presented). Although planting an RLN maintenance host of winter wheat may be of concern to growers, the advantages of reduced soil erosion and nitrate leaching associated with cover cropping outweigh the perceived risk to the subsequent raspberry crop. Also, methomyl insecticide application had no effect and it is advised that growers save money and not terminate their crop with a systemic insecticide in the attempts to reduce RLN.

Table 2. Population densities of root lesion nematode (RLN) in winter wheat and red raspberry roots surrounding the time in a trial with four replications, 2016-2018. Reproduced from Rudolph et al. (2018), which is cited below.

Treatment [†]	RLN [mean ± SE (no./g dry root)] [*]			RLN [mean ± SE (no./100 g soil)] [*]		
	Jan. 2016 (winter wheat)	Oct. 2016 (red raspberry)	Sept. 2017 (red raspberry)	Mar. 2016 (at planting)	Oct. 2016 (red raspberry)	Sept. 2017 (red raspberry)
Trial 4[‡]						
Early + Early	614 ± 406	810 ± 581	1,007 ± 164	6 ± 2	113 ± 78	125 ± 52
Early + Early + methomyl	214 ± 112	529 ± 441	2,060 ± 854	0	114 ± 92	170 ± 47
Early + Late	307 ± 149	605 ± 513	3,821 ± 1,466	0	88 ± 58	121 ± 33
Early + Late + methomyl	481 ± 177	2,161 ± 863	1,176 ± 299	4 ± 4	75 ± 16	147 ± 59
Late + Early	477 ± 93	688 ± 295	2,921 ± 793	0	249 ± 142	145 ± 63
Late + Early + methomyl	947 ± 735	588 ± 152	4,387 ± 1,590	0	136 ± 33	124 ± 56
Late + Late	907 ± 400	1,114 ± 666	3,115 ± 1,811	13 ± 9	235 ± 63	297 ± 51
Late + Late + methomyl	614 ± 83	1,190 ± 528	2,297 ± 367	0	501 ± 181	81 ± 27

^{*}1 nematode/g = 28.3495 nematodes/oz, 1 nematode/100 g = 0.2835 nematode/oz.

[†]Treatment designations are as follows: Early + Early = September (early) winter wheat planting followed by early glyphosate (herbicide) termination of winter wheat 6 weeks before red raspberry planting; Early + Early + methomyl = September winter wheat planting followed by early glyphosate (herbicide) termination of winter wheat 6 weeks before red raspberry planting with methomyl application; Early + Late = September winter wheat planting followed by glyphosate (herbicide) termination of winter wheat 2 weeks before red raspberry planting; Early + Late + methomyl = September winter wheat planting followed by glyphosate (herbicide) termination of winter wheat 2 weeks before red raspberry planting with methomyl application; Late + Early = October (late) winter wheat planting followed by glyphosate (herbicide) termination of winter wheat 6 weeks before red raspberry planting; Late + Early + methomyl = October winter wheat planting followed by glyphosate (herbicide) termination of winter wheat 6 weeks before red raspberry planting with methomyl application; Late + Late = October winter wheat planting followed by glyphosate (herbicide) termination of winter wheat 6 weeks before red raspberry planting with methomyl application.

[‡]The soil was a Lynden sandy loam from a red raspberry field in Lynden, WA. "Mecker" red raspberry was planted at this site.

One unusual development that impacted and will continue to impact the transfer of project results to commercial operations is the shortage of 1,3-dichloropropene (1,3-D). This chemical is one of the active ingredients in Telone C-35 and was the primary broadcast fumigant applied by the red raspberry industry for RLN control. The shortage of 1,3-D manifested into reduced availability of Telone. Consequently, Telone C-35 is no longer able to be applied via broadcast in red raspberry and this was a new development that occurred in 2017. It is expected that the shortage of 1,3-D will continue in future years and lead to reduced availability of this product for broadcast applications. Only bed-fumigated application of Telone C-35 are currently available to raspberry growers in Washington. This impacted the project because the treatments being evaluated in Experiment #1 are no longer directly applicable on commercial farms. However, the information from this project demonstrates what products, fumigant combinations, and

practices can lead to improved suppression of soilborne pathogens and the team will have data to back that up should these methods of application become commercially available again.

Dr. Lisa DeVetter (PI) provides project oversight, including completion of the work plan, monitoring of project outcomes, submission of performance reports, and expenditures. DeVetter led collection of yield and plant growth data, as well as soil and root sample collection for Dr. Zasada. She also organized field days and led authorship of articles that were submitted to the Whatcom Ag. Monthly extension newsletter and Growing Produce (Growing Produce article in press). Her graduate student co-advised by Dr. Zasada also published a scientific paper summarizing our results. Dr. Zasada (co-PI) is responsible for extracting, analyzing, and interpreting RLN data from her lab in Corvallis, OR. She also assisted with fall 2017 soil and root sampling, co-presented at our July 2017 field day, and contributed to extension publications and newsletter articles. Dr. Weiland (co-PI) is leading evaluation of treatment effects on soilborne pathogens (*Fusarium* and *Pythium*) from his lab in Corvallis, OR. He also assisted with field sampling, presenting at the field day, and contributed to the extension publications. Dr. Walters (co-PI) assisted with sample collection in the field, application of treatments for Experiment #2 (cover crop trial) with DeVetter, presenting and organizing the field day, and contributed to the extension publications. Grower cooperators (Northwest Berry Co-op and Maberry Packing, LLC) are hosting the field studies and manage the planting as per industry standard.

This project only focused on red raspberry, which is a specialty crop.

Goals and Outcomes Achieved

The primary **expected measurable outcome** was the development and dissemination of practical IPM tools that raspberry growers can utilize to improve management of soilborne pathogens. This was completed through two field trials and subsequent dissemination of project information through 2 field days, 2 conference presentations, 4 extension newsletter articles, and 1 scientific publication to date. A special session focused on soilborne disease management that included results from this project was also held at the Washington Small Fruit Conference in Dec. 2017. Several large growers have started to implement the alternative fumigation treatments used in this trial, particularly the use of a metam sodium cap when broadcast fumigation of Telone C-35 is permitted. Use of tarps is still limited due to costs and even use of Telone C-35 is limited for broadcast applications because of a shortage of Telone C-35. In addition, growers have continued to perform winter cover cropping both between plantings and within rows. Concerns about winter cover crops serving as a maintenance host for RLN has diminished and cover cropping is still recommended because of its benefits to soil health.

The **goal** of the project was to improve the efficacy of current soilborne pathogen management strategies available to raspberry growers, thereby leading to increased crop lifespan and productivity, as well as a reduction in the amount and frequency of soil fumigation. The **performance measures** for this project included comparing plant performance and yield of alternative treatments to the controls (i.e. industry standard practices) and measuring efficacy of the treatments in reducing RLN, *Pythium*, and *Fusarium*. This was accomplished, as described above. However, crop longevity cannot be measured in this study because it extends beyond the length of the project. Another performance measure was to enumerate growers that learned about the research. Based on field day and grower conference attendance, as well as readership of newsletter articles, it is estimated approximately 90 growers learned about the study and its results. In addition, 24 additional people learned of the project by attending a presentation at a national conference.

The benchmark for the project's outcome was set at 4 years, which is the expectancy of many raspberry fields before renovation due to high pressures from diseases. The experiments that were established in this study are still in the ground and the growers have no plans to renovate, so planting longevity is expected to

exceed 4 years. Adoption of treatments and overall increase in planting longevity combined with decreased fumigation over time, which will be monitored by DeVetter and county agents, will continue to be observed past the length of this project in order to assess achievement.

The activities proposed in this project were completed with the exception that *P. rubi* was not found in the experimental site and Fusarium and Pythium were monitored instead as proxies. Additionally, soilborne disease assessment took longer than anticipated and an extension was granted to allow completion. A student was not recruited for this project, after all, and was instead used for technical support to collect project data. The overall goal of increasing planting longevity while decreasing fumigation frequency is long-term, as perennial plants like raspberry live beyond the lengths of a project proposal. However, DeVetter and county agents will continue to observe these trials and soilborne disease management practices beyond the length of this project in order to assess achievement.

The primary **expected measurable outcome** was the development and dissemination of practical IPM tools that raspberry growers can utilize to improve management of soilborne pathogens. The **target** was to share results and recommendations for IPM of soilborne diseases with approximately 100 growers in Washington. The WRRRC reported there were 92 growers in their production statistics (WRRRC, 2018). It is known most raspberry growers attend the Washington Small Fruit Conference, including caneberry growers from Oregon and British Columbia. The anticipated attendance at the conference based on historical averages is how the baseline was set. Regarding achievements, this target was accomplished because the research team shared results and integrated them with the results from other projects to develop improved IPM for soilborne diseases. Attendance was enumerated at these outreach events. A summary of these outreach events and outputs are listed at the end of this report.

Beneficiaries

The Washington raspberry grower community, which includes growers, crop advisors, and agrichemical suppliers, directly benefited from this project through improved knowledge and IPM tools for the enhanced management of soilborne pathogens. In addition, this project was presented at the American Society for Horticultural Science (ASHS) national conference in 2017 and information was shared with other specialty crop researchers and extension specialists.

According to Galinato and DeVetter (2017), fumigation with Telone C-35 costs \$1,100/acre. Walters et al. (2013) reported Vapam (metam sodium) costs \$450/acre and tarps can cost an additional \$500/acre. This represents a significant cost to growers. If growers fumigate less because of improved soilborne disease management, they incur these costs less frequently. Furthermore, total variable costs for establishing a planting is \$6,486 (DeVetter and Galinato, 2018). This expense is reduced if growers have to renovate and replant their fields less. Although differences in yields were not detected, it is common knowledge plants afflicted with soilborne disease have reduced production and lower quality fruit. Therefore, healthy plants not afflicted by soilborne diseases will have greater productivity and this will help growers offset establishment and production costs.

According to the Washington Red Raspberry Commission (WRRRC, 2019) website, there are 83 growers in the state. Given the number of field days, conference presentations, and newsletter articles we published, I would estimate 90% of that population learned of our project and the results that we generated ($83 \times 0.90 = 75$ growers). In addition, I estimate key five crop consultants from Whatcom County learned of the research. Furthermore, we presented the information at a national conference with approximately 30 people in the audience representing extension specialists and researchers that work with small fruits like raspberry. Therefore, we estimate 110 people (growers, consultants, and research/extension specialists) benefited from this project.

Lessons Learned

Through this project and others, it was learned that soil type influences fumigation efficacy and this has been incorporated into our recommendations to growers. Also, although the investigators really wanted to directly measure *P. rubi*, this pathogen has a spotty distribution in fields and it is thus difficult to monitor how it responds to experimental treatments. This is why the investigators measured Fusarium and Pythium, which are good proxies for *P. rubi*.

Due to a shortage of Telone C-35, broadcast applications of this product are no longer widely available. This was unexpected and occurred in 2017. As such, several of the treatments investigated in the first experiment are not commercially available. This may change if/when Telone C-35 becomes more available. For the time being, growers are broadcast applying Vapam (metam sodium) and using Telone C-35 in bed fumigation settings, which has achieved good results.

As mentioned, it was difficult to find a site with consistent distribution of *P. rubi* so it's response to the fumigation treatments could be studied. This was solved by using Fusarium and Pythium instead as proxies for *P. rubi*.

The goals of this project were more long-term given the perennial nature of raspberry. Although the status of plantings can be followed by measuring soilborne pathogen populations and comparing them across treatments and alongside plant performance indicators, it is still difficult to ascertain whether the longevity of a planting will or will not be increased given the duration of these grants. Furthermore, other factors, like raspberry bushy dwarf virus, also cause growers to shorten their raspberry planting cycle. This challenge was anticipated by the researchers, which is why they also focused on dissemination of project information as another goal. This was a good approach and the recommendations were strengthened by interpreting the results of this project alongside others so growers get a better synthesis of soilborne disease management.

Contact Person

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Additional Information

The Washington Red Raspberry Commission contributed \$30,455 in direct funding for this project and \$6,500 in in-kind contributions which includes field plots and maintenance on commercial farm fields, dissemination of information at workshops, conferences, and newsletters, and project guidance through the commission research committee.

Publications (scientific and extension)

Rudolph, R., T. Walters, L.W. DeVetter, and I.A. Zasada. 2018. Contribution of a winter wheat cover crop to the maintenance of *Pratylenchus penetrans* populations in the raspberry production system with management considerations. HortTechnology. 28(2):182-188.

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Presentations

DeVetter, L.W. (presenter) and I. Zasada. 2017. Pre-plant to replant: Improving management of root lesion nematodes in red raspberry. Western Washington Berry Workshop. Mount Vernon, WA.

DeVetter, L.W., I. Zasada, T. Walters, and J.E. Weiland. 2017. Development of a decision-making tool for improved management of root lesion nematode (*Pratylenchus penetrans*) in red raspberry. American Society for Horticultural Science (ASHS) Annual Conference. Sept. 19-22. Waikoloa, HI. <https://ashs.confex.com/ashs/2017/webprogramarchives/Paper26354.html>

Field days and events

DeVetter, L.W. (organizer), I.A. Zasada, J.E. Weiland, and T. Walters. 2017 Soilborne disease management in raspberry field day. Everson, WA.

DeVetter, L.W. (organizer), I.A. Zasada, J.E. Weiland, and T. Walter. WSU 2016 Western Washington small fruit field day. Lynden, WA.

Benedict, C. and L.W. DeVetter (organizers). 2017. Soilborne disease management in red raspberries. Special session held at the Washington Small Fruit Conference. Lynden, WA.



Image 1. Co-PI Tom Walters presenting on the use of Vapam (metam sodium) as a soil fumigant in raspberry for improved management of root lesion nematode at the 2017 Washington Small Fruit Conference.



Image 2. Growers learning about Vapam (metam sodium) and the difference between rolling and tarping to improve fumigant efficacy at a field day in 2017.

Project Title: Improved disease control strategies of potato powdery scab

Project Summary

This project is to initiate control strategies for potato powdery scab disease, which in recent decades has spread in many regions including most potato production areas in Washington State. Typical symptoms are cosmetic damage on the skin of potato tubers and the formation of root galls, which reduce nutrient and water uptake. Moreover, the powdery scab pathogen vectors a virus, Potato mop-top virus (PMTV), which causes plant growth suppression and internal tuber necrosis. Most importantly, PMTV is an impediment to foreign trade. The objectives of this proposal are to develop a diagnostic method to survey powdery scab infestation on farms, and to improve grower education about the powdery scab disease. This proposed work is important because current management of the disease relies heavily on fungicides and soil fumigations that are only partially effective against powdery scab and are expensive and risky to applicators and the environment. Improved control strategies for the powdery scab disease are required for the sustainability and profitability of the state's potato industry.

Potato powdery scab disease is caused by a soil-borne pathogen, *Spongospora subterranea*, and leads to symptoms of significant cosmetic damage on the skin of potato tubers and the formation of root galls, which reduce nutrient and water uptake. *Spongospora* is also responsible for the transmission of Potato mop-top virus (PMTV), which causes significant suppression of plant growth and internal tuber necrosis. PMTV is an emerging disease that occurs in epidemics along with *Spongospora*, and is also an impediment to foreign trade, because it is a reason for rejection of shipments to some countries. Despite many research efforts, fully effective fungicides or fumigation treatments for powdery scab have not been developed. Once the powdery scab disease has infested a field, it remains infectious for many years, that is, management practices, for example, crop rotations, have little impact on this disease. There is a clear need for the development of novel pathogen management strategies. This project is important and timely because current management of the disease relies heavily on fungicides and soil fumigations that are only partially effective against powdery scab and are expensive and risky to applicators and the environment. The sustainability and profitability of the state's potato industry benefits from improved diagnostics and disease control strategies specifically targeting powdery scab.

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

Project Approach

In this project, developing a protocol for the on-site diagnosis of powdery scab (by detecting *Spongospora subterranea*) had been completed using a portable real-time PCR machine. At the same time, the on-site detection method for PMTV was also developed. Soil samples from potato field and pathogen-infected tissues were tested. The real-time PCR experiment using the portable machine was successfully performed. Capability (sensitivity and specificity) of the portable PCR machine was compared with that of a conventional standard PCR machine and found equivalent specificity and 1-10-time different sensitivity.

As part of the activities in the project, training sessions were organized for growers and allied industry for the diagnosis methods developed. Working with Matthew Blua, the Director of Industry Outreach from Washington State Potato Commission, the workshop event took place at the WA-OR Potato Conference in Kennewick, WA. <https://labs.wsu.edu/tanaka-lab/2018/01/24/diagnosis-workshop/>. Based on survey, more than 95% of attendees have evaluated the event very useful:

This project has resulted in a publication in a peer reviewed video journal, Journal of Visualized Experiments (JoVE). Citation: <https://doi.org/10.3791/56891>. The publication in JoVE is the best way for dissemination of the methods because it includes video showing a step-wised protocol to perform the methods. In addition, this was a very useful material for the training session. The outcomes from this project were highlighted in the following media: NIFA Update <https://content.govdelivery.com/accounts/USDANIFA/bulletins/1de8edd>, EurekAlert! https://www.eurekalert.org/pub_releases/2018-02/wsucst022318.php, WSU News <https://insider.wsu.edu/2018/02/28/crop-saving-soil-tests-now-at-farmers-fingertips/>.

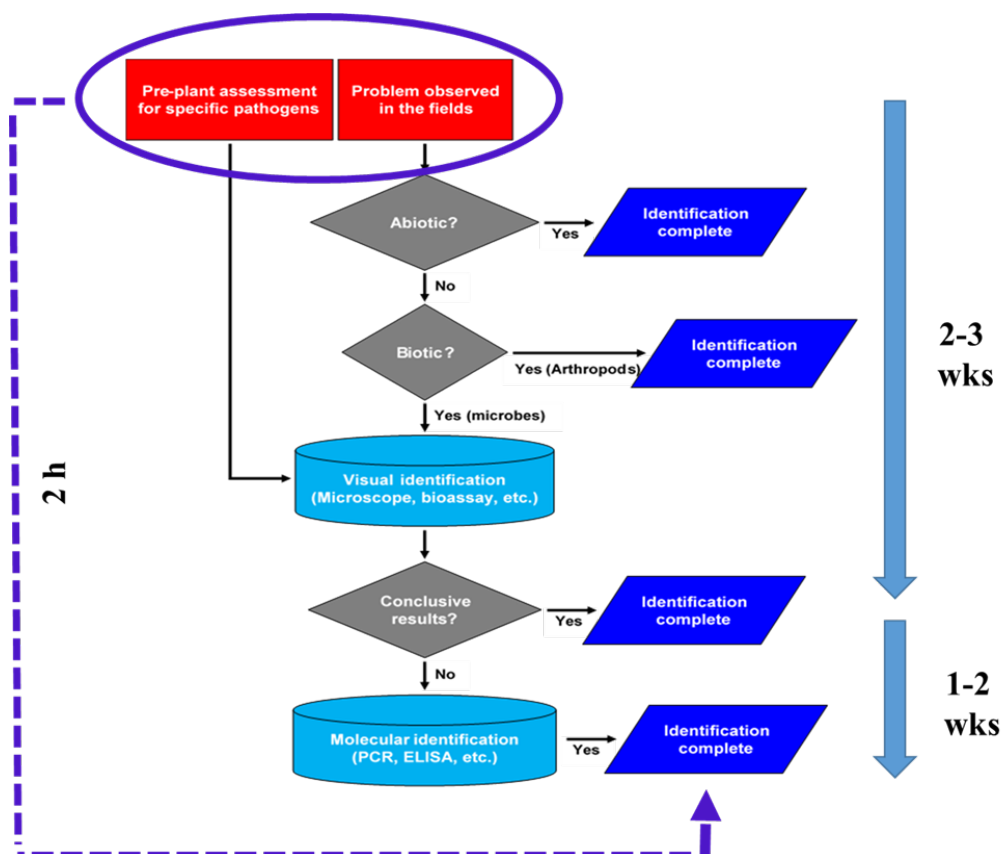
Recent technological advances in the molecular identification of pathogenic agents have increased the efficacy, accuracy, and speed of diagnosis, which have contributed to the detection of pre-symptomatic infections. Regarding on-site diagnosis, LAMP and lateral-flow methods are frequently used because they are portable and provide us with immediate results at a lower cost. However, in the case of serological methods, species specific detection can be hard to achieve. This occasionally causes misdetection of off-target microbes such as common soil inhabitants.

In the project, an optimized protocol was developed for on-site molecular detection of soilborne potato pathogens using the portable real-time PCR system by comparing its capabilities with that of a conventional lab-based real-time PCR system. The on-site method was found to specifically detect *Spongospora subterranea* and PMTV in the soil sample, although sensitivity is ~10 times lower than that of equivalent lab-based assay. It is also worth considering that in this case both the laboratory and field test did not use a biologically relevant sample size. Large sample sizes are required for use in routinely screening field soils where sample sizes of between 250 g to 1 kg are processed, although these methods require skilled operators and sophisticated equipment to extract DNA. Typically, a large scale soil DNA extract is taken from a single aggregate soil sample representative of numerous subsamples over 1 to 4 hectares. However, the protocol developed here is quick, easy-to-use for users with no prior experience in molecular diagnostics and can be used outside of a lab. As the method is rapid and relatively cheap compared to large scale soil extraction, it could be used to screen many small-scale samples taken from a similar sampling area to large scale aggregate samples. This could overcome some of the deficiencies of a small sample size and determine additional information on the spatial distribution of the pathogen in the field. In addition, the portability and speed of the method means that it can also be used in demonstration activities to growers for educational and engagement purposes.

Another consideration is that many real-time PCR assays are already published for a wide range of plant pathogens. This system can make use of these existing assays without the need to design new LAMP assays to enable in field testing. A frequent criticism of LAMP assays is that they can be difficult to design. Portable PCR therefore allows the relatively easy implementation of a wide range of readily available pathogen tests for on-site testing.

Traditional methods can often be costly, laborious, inaccurate and time-consuming. The simplicity of the on-site method developed allows growers and industry workers to perform pathogen detection by themselves and perhaps generate a result much quicker than sending to a diagnostic laboratory which could be some distance away. The promptness and sensitivity of the portable PCR method can help growers avoid potential secondary infections, which can further increase the pathogen population and inadvertent spread (via equipment or humans). In conclusion, the on-site method developed in the project enables accurate and relatively sensitive detection of important soilborne pathogens in the field. The on-site method developed in this project will contribute in a current diagnosis pipeline (see the figure below), not only by providing

quick and accurate answers to epidemiological questions about plant diseases in the field but also by providing increased understanding of the biology and epidemiology of plant pathogens.



Flowchart shows a general workflow of the phytopathogen diagnosis. Note that the traditional step, e.g., visual identification, can be omitted if on-site molecular detection is utilized, which makes the entire process of diagnosis simple and fast (as shown with a purple line).

A project partner, Co-PI Matthew Blua (Washington State Potato Commission) has been involved for organizing workshop sessions for growers and allied industry, and for conducting the survey of attendees on the pathogen detection methods established in the project. This project only benefitted specialty crops.

Goals and Outcomes Achieved

A new on-site diagnostic method was established that can contribute to building of distribution maps of powdery scab and PMTV on farms or larger regions. The method was based on handy technology easily used by everyone including growers and allied industry.

All expected measurable outcomes were completed during the duration of this grant period.

The project focused on developing on-site diagnosis methods for rapid prediction of contaminated areas in fields. However, given that the ultimate goal is to develop integrated disease control strategies, disease resistance against powdery scab has to be developed in the future and used concomitantly with the diagnostic method that has been established in the project.

An on-site pathogen detection did not exist prior to the project. It has been established and confirmed reproducibility using a soil sample from the field infested by the powdery scab pathogens. The method was introduced to growers and allied industry at the demonstration workshops. Knowledge gain about the powdery scab disease by growers was measured as a performance measure. The method can be used to create a distribution map of the pathogens on farms or larger regions.

Beneficiaries

This project has predictively impacted all of Washington State's ~115 potato growing operations, which are mostly located in the Columbia Basin, producing about 160,000 acres annually. These operations produce for all market segments including table stock, processing potatoes for frozen and dehydrated products, and chipping potatoes.

Given that management of powdery scab, and thereby PMTV, has only recently become widely recognized and important to the Washington potato industry, producers and allied industries were impacted by an increased understanding of the distribution of the highly contagious powdery scab disease and better educational efforts about *Spongospora* and its relationship with PMTV. Because no effective management techniques exist for infested fields, the project started nearly from scratch in development of management options. There was likely significant knowledge gain toward management of this nearly intractable problem. The project provided growers with the ability to understand their risk and manage their farms accordingly; for example, by planting potatoes in fields that are least infested by powdery scab or planning their export crops for those low-risk fields, for which better diagnostic methods allows growers to plant crops targeted for export in their low-risk fields, thereby reducing the costs of marketing uncertainty. At the demonstration workshop, more than 95% of attendees have evaluated the event very useful.

Lessons Learned

The major goal **was** to implement integrated disease control strategies against powdery scab. The efforts in this project focused on developing on-site diagnosis methods to predict contaminated areas in fields. Better diagnostic methods allow growers to plant crops in their low-risk fields, thereby reducing the costs of planting and marketing uncertainty. Although the outcomes contributed implementing better integrated disease control strategies against powdery scab, a complete powdery scab management scenario requires additional work that is, developing disease resistance with identification of plant defense inducers and introducing new potato cultivars.

No unexpected outcomes or results affected the implementation of this project. The project proceeded just as the PI proposed.

All activities outlined for the project were completed and the Expected Measurable Outcome was achieved.

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Additional Information

Cash match from Washington State University was in total \$165,463.92 in which a portion of PI Tanaka's salary/benefits was \$58,336.96/\$17,535.52; a portion of salary/benefits of a researcher, Joseph DeShields was \$10,624.50/\$1391.80; in-kind goods and services was \$50,003.14; and uncovered F&A as allowed by the agency was \$27,572. In-kind match from Washington State Potato Commission for a portion of Co-PI Blua's salary/benefits was a total of \$9,502. \$40,503 was provided as seed money for this research project by Northwest Potato Research Consortium.

This project included Special Purpose Equipment, specifically a portable mini-real time qPCR machine. This piece of equipment was valued at \$3,915.75 by the end of this grant.

- ☐ DeShields JB, Bomberger RA, Woodhall JW, Wheeler DL, Moroz N, Johnson DA, Tanaka K (2018) On-site molecular detection of soil-borne phytopathogens using a portable real-time PCR system. *J. Vis. Exp.* e56891 <https://doi.org/10.3791/56891>
- ☐ Tanaka K, DeShields JB (2017) A classic yet new method for diagnosis of powdery scab disease. Proceedings of the Washington-Oregon Potato Conference. p74-78
- ☐ NIFA Update <https://content.govdelivery.com/accounts/USDANIFA/bulletins/1de8edd>
- ☐ EurekAlert! https://www.eurekalert.org/pub_releases/2018-02/ws-cst022318.php
- ☐ WSU News <https://insider.wsu.edu/2018/02/28/crop-saving-soil-tests-now-at-farmers-fingertips/>



Performing the on-site diagnosis using the portable real-time PCR machine at the field.



Demonstration workshop at the WA-OR potato conference on January 24, 2018.

Project Title: Strengthening the grapevine supply chain for healthy vineyards

Project Summary

Washington State has emerged as one of the premium wine grape-growing regions in the world. With an estimated \$5 billion economic impact to the State's economy, the grape and wine industry has become a key player in the economic prosperity of Washington State. Grapes are currently ranked as the fourth largest commodity in the State. Nearly 70 different wine grape (*Vitis vinifera*) cultivars are grown in 14 American Viticultural Areas or Appellations across the State. With an anticipated 5 percent increase in wine grape acreage annually from current area of about 60,000 acres, the wine grape acreage could reach 100,000 acres within a few years. This trajectory of grape and wine industry's growth in the state, however, is threatened by viral diseases. Virus diseases are known to induce a wide range of disorders, vine growth problems, graft incompatibility, reduced yield, delayed fruit maturity and poor quality of grapes. Consequently, virus diseases are recognized as one of the most serious impediments to the long-term sustainability of Washington's grape and wine industry in *The Pest Management Strategic Plan for Washington State Wine Grape Production* (http://www.ipmcenters.org/pmsp/pdf/WA_WineGrape_PMSP_2014.pdf). Additionally, management of virus diseases impacting fruit quality and vine health was identified in a recent industry-wide survey as one of the highest research priorities for winemakers and wine grape growers (<http://www.goodfruit.com/wine-grape-revelations/>). Due to the lack of curative measures, management of virus diseases in vineyards involves a two-pronged strategy consisting of prevention by planting virus-tested planting material and implementation of post-planting disease control strategies. Thus, it is critical to strengthen the grapevine planting material supply chain from nurseries to grower vineyards and implement 'start clean, stay clean' concepts for healthy vineyards.

Strengthening the grapevine planting material supply chain from certified nurseries to grower vineyards is vital for preventing the spread of debilitating viruses via propagation materials. It is, therefore, imperative that grapevines in certified nurseries are maintained free from economically important viruses in ways that can help growers access virus-tested planting materials for establishing healthy vineyards. Additionally, monitoring young vineyards for viral diseases and roguing or removing symptomatic vines is considered an effective post-planting strategy for reducing the incidence and spread of viral diseases in newly planted vineyards. Consequently, this project was designed to implement an integrated strategy to safeguard registered grapevine mother blocks and grower vineyards from viral diseases. Since symptom-based diagnosis of viral diseases is challenging and unreliable, state-of-the-art molecular diagnostic assays, including next-generation sequencing, were utilized for reliable and high-throughput analysis of grapevine samples from nurseries and grower vineyards for the presence of economically important viral diseases; namely, grapevine leafroll and red blotch diseases. Collaborative partnerships between researchers, wine grape industry stakeholders and regulatory agencies are critically important for successful implementation of science-based "start clean, stay clean" principles for sustained growth of Washington's grape and wine industry.

This project was not funded previously by the SCBGP. However, activities of this project were carried out synergistically with on-going research activities funded, in part, by the Washington State Grape and Wine Research Program, WSDA Grapevine Certification and Nursery Improvement Program, and Washington State Commission on Pesticide Registration for efficiency and economy of scale.

Project Approach

Include the significant results, accomplishments, conclusions and recommendations. Describe favorable and unusual developments.

During the project period, activities described below were conducted to improve the sanitary status of grapevines in registered mother blocks maintained by WA certified nurseries. Collaborative approaches

were pursued with nurseries and regulatory agencies (Washington State Department of Agriculture [WSDA] Plant Services Program) to ensure that WA certified nurseries continue to maintain virus-tested vines in registered mother blocks and make virus-tested ‘clean’ planting stock available for wine grape growers within and outside Washington State. New plantings were monitored to examine grapevine planting material supply chain and strengthen the supply chain to improve the quality of planting materials used for establishing new vineyards. In addition, participatory approaches were pursued with growers to implement roguing as a post-planting management strategy for minimizing virus spread through planting materials. Outreach and education activities were conducted to showcase advantages of using virus-tested ‘clean’ planting materials and encourage growers to adopt roguing as a post-planting strategy for reducing incidence of viral diseases in young vineyards.

Activity: Project initiation and training of nursery personnel in grapevine sample collections from certified mother blocks.

Initially, the project team (Washington State University and WSDA Plant Services Program [sub-contractor of the project]) reviewed the overall project objectives. Subsequently, a meeting was organized with two large certified nurseries (Ste. Michelle Wine Estates and Inland Desert Nursery) to discuss project objectives and the role of individual nurseries in the project. These meetings established a strong foundation to pursue team-based approaches for conducting project activities. Subsequently, in-field workshops were organized to train ten nursery personnel from Ste. Michelle Wine Estates and Inland Desert Nursery for collection and transportation of grapevine samples from registered nurseries (leaf samples during the season and cane samples during the dormant season) to Prosser IAREC for virus testing.

Activity: Sample collection from certified mother blocks and processing at WSU-IAREC.

Composite sampling method was optimized for processing leaf samples during the season and cane samples during the dormant season. For testing leaf samples, six leaves were collected randomly from different parts of individual vines and leaves collected this way from four adjacent vines along each row were pooled as one composite sample. Petioles from all leaves were pooled and used for subsequent processing and virus testing. For testing cane samples, four canes of 2 to 3 internodes long were collected from individual vines. Canes collected this way from two adjacent vines in a row were pooled as one composite sample for subsequent processing and virus testing. Individual vines in each block were mapped in a XY matrix representing the planting lattice using the row number and vine position as coordinates. If a pooled sample tested positive for a virus, samples from individual vines (4 in the case of leaf-based composite sampling or 2 in the case of cane-based composite sampling) corresponding to each virus-positive composite sample were collected and retested to identify virus-positive vine(s). The results were used for spatial mapping of virus-infected vines and subsequent removal from registered mother blocks. This approach was found to be helpful in high-throughput processing of large number of samples in a cost-effective manner. This strategy was used during the project period for collecting grapevine samples from nurseries and testing by molecular diagnostic assays described below.

Activity: Testing grapevine samples using molecular diagnostic assays for viruses.

Grapevine leafroll and red blotch were recognized as economically important viral diseases in Washington State vineyards in consultation with the registered nurseries and the Foundation Block Advisory Group, a regional grapevine advisory group in the Pacific Northwest. Therefore, all samples were tested for Grapevine leafroll-associated virus 3 (GLRaV-3) and Grapevine red blotch virus (GRBV), associated with leafroll and red blotch diseases, respectively. Sample extracts were tested by reverse transcription polymerase chain reaction (RT-PCR) and PCR for the presence of GLRaV-3 and GRBV, respectively. Appropriate controls were used for reliable interpretation of test results. A limited number of samples were

subjected to next-generation sequencing (NGS) and viral sequences generated from NGS analyzed by bioinformatics software programs to identify additional viruses (besides GLRaV-3 and GRBV) as advised by WSDA Plant Services Program.

Year 1 and 2:

- i. Monticule nursery requested re-entry into the WSDA grapevine certification program. At the request of WSDA Plant Services Program, grapevine samples were tested for the presence of viruses to assess sanitary status of Monticule nursery blocks for inclusion into the certification program. Extracts from 382 composite samples (each composite sample containing leaves from four adjacent vines along each row) from nursery blocks were tested for the presence of GLRaV-3 and GRBV. Approximately 6% of the 382 composite samples tested positive for GLRaV-3. All 382 composite samples tested negative for GRBV. Total RNA was extracted from 39 composite samples (representing about 10% of total 382 composite samples) and subjected to NGS and bioinformatics analyses to identify if viruses other than GLRaV-3 and GRBV were present in these samples. The results revealed absence of GRBV in all 39 composite samples and presence of GLRaV-3 in six samples that were positive in PCR assays. These results showed good correlation between PCR and NGS indicating that PCR can be reliably used for detecting GLRaV-3 and GRBV in grapevine samples. However, 9/39 composite samples contained sequences related to Grapevine Virus B (GVB), Grapevine red globe virus, Grapevine vein feathering virus, Grapevine rupestris stem pitting-associated virus (GRSPaV). Based on these results, the WSDA Plant Services Program concluded that the Monticule nursery block do not meet 'Freedom from Infestation' rule WAC 16-402-015 and the certification program standards. Consequently, WSDA denied re-entry of this block into the WSDA grapevine certification program. ***This decision played a significant role in strengthening the grapevine supply chain, in terms of maintaining high sanitary standards in registered nurseries to provide virus-tested 'clean' planting materials to growers for establishing healthy vineyards.***
- ii. A total of 180 composite samples (each composite sample containing leaves from four adjacent vines along each row) were collected from 6 clones of Cabernet Sauvignon from a registered nursery maintained by Ste Michelle Wine Estates (SMWE). Sample extracts were tested for the presence of GLRaV-3 and GRBV. All samples were negative for both GLRaV-3 and GRBV. NGS analysis of 18/180 composite samples confirmed PCR results in the absence of GLRaV-3 and GRBV. However, the NGS results indicated the presence of viral sequences related to Grapevine fleck virus (GFkV) and GVB in clone #29, viral sequences related to GFkV in clone #33 and viral sequences related to GRSPaV in clone #39. Based on these results, samples from 237 individual vines of clones #29 and #33 were tested for GVB and GFkV and samples from four individual vines from clone #39 were tested for GRSPaV. The list of individual vines positive for GFkV, GVB and GRSPaV were shared with WSDA Plant Services Program and SMWE to remove virus-positive vines from the registered nursery block. These efforts improved the sanitary status of Cabernet Sauvignon clones maintained in SMWE Mother Block to provide virus-tested planting material for establishing healthy vineyards.
- iii. The WSDA nursery inspector collected samples from 11 vines in a registered mother blocks suspected for leafroll disease. Nine of the eleven samples tested positive for GLRaV-3 and negative for GRBV. These results were shared with the WSDA nursery inspector for follow up action with the concerned nursery to remove virus-positive vines in registered block.
- iv. A total of 120 composite samples (each sample composed of leaf samples collected from 5 individual vines) from the cultivar Chasselas Dore and 5 composite samples from the cultivar Chenin Blanc maintained in registered mother blocks of Inland Desert Nursery (IDN) were tested for GLRaV-3 and GRBV. All samples tested negative for both viruses. The results were shared with the WSDA nursery inspector and IDN continued maintaining virus-free status of vines in the mother blocks.
- v. A total of 55 composite samples (each sample composed of leaf samples collected from 4 individual vines) from cultivars Chardonnay, Marsanne and Sauvignon Blanc maintained in registered mother blocks maintained by SMWE were tested for GLRaV-3 and GRBV. All these samples tested negative

for both viruses. The results were shared with the WSDA nursery inspector and SMWE continued maintaining virus-free status of vines in the mother blocks.

Year 3:

- i. At the request of IDN, four-vine composite cane samples from two rootstock cultivars (124 composite samples from the rootstock cv.101-14AR6 and 30 composite samples from the rootstock cv. 1103PBH) were tested for the presence of GLRaV-3 and GRBV. All samples tested negative for both viruses. To further confirm these results, 10% of composite cane samples from both the rootstock cultivars were subjected to NGS and bioinformatics analyses to identify if viruses other than GLRaV-3 and GRBV were present in these samples. The results showed that none of the samples contained sequences related to GLRaV-3, GRBV and other grapevine viruses, indicating that both rootstock cultivars (cv.101-14AR6 and cv.1103PBH) are as 'clean' as they can be for propagation and grafting with virus-tested scion cultivars to produce virus-tested grafted vines. The results were shared with the concerned nursery to make contingency plans for bench-grafting (omega-grafting) of the two rootstock cultivars with preferred scion cultivars and make virus-tested 'clean' grafted plants available for growers.
- ii. Samples were collected from 6,821 grapevines from Certified Mother Blocks in IDN and SMWE registered nurseries. A composite sampling strategy, where petiole samples from five individual vines in a row were pooled, was used for processing and subsequent testing. In one nursery, petiole samples collected from a total of 5,401 individual grapevines from 25 wine and table grape cultivars and two root-stock cultivars were pooled into 1,094 composite samples. In the second nursery, petiole samples collected from a total of 1,420 individual grapevines from 13 wine grape cultivars were pooled into 284 composite samples. Extracts from each composite sample was subsequently tested for the presence of GLRaV-3 and GRBV. The results showed that all composite samples from both nurseries tested negative for GRBV. In contrast, 26 composite samples from one nursery and 2 composite samples from the second nursery tested positive for GLRaV-3. The results were shared with the two nurseries. Subsequently, samples were collected from individual vines of virus-positive composite samples and retested for GLRaV-3 to identify specific vine(s) infected with the virus. The results were shared with respective nurseries to remove only virus-positive vines from individual registered mother blocks.

Summary: Overall results obtained during the project period indicated the absence of GRBV and low incidence of GLRaV-3 in registered grapevine nurseries maintained by IDN and SMWE. Testing grapevine samples will be continued beyond the project period to ensure virus-tested grapevines are maintained in registered mother blocks in Washington certified nurseries. Thus, experiences gained and protocols established during the project period established a foundation to continue improving the sanitary status of registered mother blocks in Washington State certified nurseries.

Activity: Additional inspection of mother blocks during the crop season.

In previous years, WSDA nursery inspectors normally conduct two seasonal inspections of all certified grapevine mother blocks, with one inspection in spring and the second in fall. Based on observations during the project period, a third inspection in late October was recommended for monitoring mother blocks, especially in red fruited cultivars that show leafroll disease symptoms towards end of the season. Overall, a second inspection of red-fruited cultivars towards end of the season is an important strategy to identify late expression of virus symptoms and implement symptom-based identification of virus-infected vines followed by testing and removal of virus-positive vines from certified mother blocks. Another benefit of two fall inspections was that the nursery inspector could be able to identify problems with signage of registered grapevine blocks not found in previous inspections and notify nurseries to revise the database accordingly.

Activity: Update the PISCES database of registered vines in all certified mother blocks.

After roguing of infected vines was completed in late October each season, WSDA nursery inspector advised registered nurseries to submit an updated inventory of all registered grapevines for uploading into the WSDA PISCES database. Due to the high volume of data entry and tracking more than 200,000 vines in all registered nurseries, WSDA relied on the certified nurseries to provide updates and inventory spreadsheets. The timeframe to receive these annual updates was from November 1 to January 1 of the following year. This coincides with the annual date nurseries must reapply for the certification program on January 1. The updated data is then verified for quality controls by WSDA nursery inspections during the following spring.

WSDA has developed a generic spreadsheet for all certified nurseries to use, with common fields that will populate PISCES database. Common data fields collected from registered nurseries and uploaded to PISCES include as follows:

Row Number	Vine Number	Variety/ Selection	Year Planted	Foundation Source	G1 Source Block	G1 Source Row	G1 Source Vine
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The information gathered in this format fulfills record keeping requirements of WAC 16-462, the grape planting stock registration and certification rule of WSDA. Based on the row and vine number in a given registered block, WSDA can trace back a vine to its original source vine in the foundation block maintained at Clean Plant Center Northwest, Prosser, WA or Foundation Plant Services, Davis, CA. The database provided consolidated information about the chronological history of vines in individual registered blocks and helped to correlate diagnostic test results with roguing of virus-infected vines and replacements with virus-tested ‘clean’ cuttings. In view of growing interest in increasing the volume of virus-tested planting materials via tissue culture, the PISCES database is updated annually to track certified grapevine planting materials generated through tissue culture.

The revised PISCES database is a user-friendly reporting system. Once test results for a given season have been entered into the PISCES system, a detailed report can be generated for each certified nursery and individual registered blocks and vines. Thus, the database is an excellent system for generating comprehensive reports for each season and a valuable tool for tracking the sanitary status of registered mother blocks from season to season.

Activity: Monitor young vineyards (< 5 years old) planted with cuttings from certified nurseries and self-propagated materials and implement roguing as an early intervention strategy to reduce viral incidence.

Roguing or removing symptomatic vines has been recognized as a cost-effective post-planting strategy for managing viral diseases in vineyards. As a first step in this effort, young vineyard blocks were monitored during successive seasons to better understand pathways of viral spread and examine the effectiveness of roguing for reducing viral incidence in young plantings. For this purpose, vineyards (3 to 5-yrs old) planted with red-fruited cultivars were monitored for leafroll and red blotch diseases. In each vineyard, the location of symptomatic vines was mapped on an annual basis using site-specific spreadsheets. Samples from symptomatic vines were tested for the presence of GRBV and GLRaV-3. These activities were conducted with complementary funding from Washington State Grape and Wine Research Program.

Effectiveness of roguing for controlling red blotch disease: Vineyard blocks planted with red-fruited cultivars (cvs. Merlot, Cabernet franc, and Sangiovese) in Horse Heaven Hills, Red Mountain, Yakima Valley, Walla Walla appellations were monitored for red blotch disease. The cumulative results indicated absence of the spread of GRBV in time and space in infected vineyards. Instead, GRBV spread was observed primarily via contaminated planting materials. In view of the lack of vector-mediated spread,

roguing was pursued as an effective practice for controlling red blotch disease in vineyards. In a 10-acre vineyard block planted in 2013 with cv. Merlot (clone 15), spatial mapping showed random distribution of symptomatic vines across the entire vineyard block. The disease incidence was 15.27% and symptomatic vines tested positive for GRBV and negative for GLRaV-3. Roguing of symptomatic vines during 2017 winter and replanting with virus-tested cuttings in May 2018 helped to reduce disease incidence from 15.27% in 2017 down to 1.96% in 2018. The leftover symptomatic vines were mapped during 2018 season and will be removed in winter 2018 followed by replanting with virus-tested cuttings to completely remove red blotch in the block. Similar approaches (roguing of symptomatic vines and replanting with virus-tested cuttings) are being pursued in several vineyard blocks to reduce red blotch incidence. All these vineyard blocks will be monitored during 2019 season and beyond to assess the effectiveness of roguing for controlling red blotch disease. Based on the results obtained so far, it can be concluded that field spread of red blotch is less likely to occur in Washington vineyards and roguing can be implemented as an effective strategy for controlling red blotch disease.

Effectiveness of roguing for controlling leafroll disease: Since GLRaV-3 can be disseminated via planting materials and spread by vectors (mealybugs and scale insects), monitoring newly planted vineyard blocks on an annual basis would provide information to better understand pathways of viral spread and aid in implementing roguing for reducing viral incidence in young vineyards. For this purpose, vineyard blocks planted in three geographic locations in Yakima Valley and Horse Heaven Hills appellations were selected to test roguing as a non-pesticidal strategy for reducing virus infections in young vineyards. The results are presented below:

- i. Roguing in a vineyard block planted with compromised cuttings obtained from a grower vineyard: In spring 2015, a grower planted a 5.5-acre block with Cabernet Sauvignon cuttings obtained from a grower vineyard compromised with leafroll disease. In fall 2015, 11.88% vines showed leafroll symptoms that tested positive for GLRaV-3 and negative for GRBV. By roguing symptomatic vines in winter 2015 and replanting with virus-tested cuttings in spring 2016, virus incidence was reduced to 1.05% in 2016. The incidence was further reduced to 0.29% in 2017 by roguing leftover symptomatic vines and replanting with virus-tested cuttings. However, a few vines showed new infections in 2018 likely due to the introduction of GLRaV-3 by insect vectors. Nevertheless, the disease incidence remained below 0.5% in this block, underscoring the beneficial effect of roguing for controlling the spread of leafroll disease.
- ii. Roguing in vineyard blocks planted with cuttings brought from a certified nursery: Two Cabernet Sauvignon blocks planted, respectively, in 2013 and 2014 with cuttings purchased from a certified nursery were monitored during 2015, 2016, 2017 and 2018 seasons. Samples from a select number of symptomatic vines in both blocks tested positive for GLRaV-3, but not for GRBV. In the 13-acre block planted in 2013, roguing symptomatic vines resulted in keeping the leafroll disease incidence at sufficiently low levels (<2%). In contrast, increased incidence of symptomatic vines was observed in the 19-acre block planted in 2014, despite replacing symptomatic vines with virus-tested cuttings. These results indicated two possibilities. Firstly, symptoms expressed by apparently healthy vines during each season could represent new infections likely due to vector-mediated spread from outside sources. Secondly, slow buildup of virus titer in cuttings initially used for planting could have contributed to delayed expression of symptoms during post-planting.
- iii. Studies were conducted during the project period to assess the effectiveness of roguing for reducing the incidence of leafroll disease in additional vineyards in Yakima, Horse Heaven Hills and Red Mountain appellations. Overall, the results obtained during the project period showed encouraging results regarding the effectiveness of roguing in reducing incidence of viral diseases in these young vineyards.

Overall conclusions:

- ☐ The observed lack of GRBV spread makes roguing or removing symptomatic vines more significant than vector management in controlling red blotch disease in vineyards. Planting vineyards with virus-tested planting materials in combination with roguing as a post-planting tactic can be implemented for effective control of red blotch disease in vineyards.
- ☐ Annual monitoring of new plantings in three geographic locations in Yakima Valley and Horse Heaven Hills appellations and implementing roguing of symptomatic vines provided encouraging results in reducing GLRaV-3 incidence in young vineyards. Roguing was found to be successful in some vineyards infected with GLRaV-3 while in others, the outcomes were less successful. This calls for additional strategic research to strengthen the grapevine planting material supply chain and refine roguing and vector management for implementing integrated strategies to control leafroll disease in vineyards. Consequently, this activity (*Monitoring young vineyards planted with cuttings from certified nurseries and self-propagated materials and implementing roguing as an early intervention strategy to reduce viral incidence*) will be continued beyond the project period to comprehend the role of insect vectors and planting materials in the spread of viruses and implement effective control measures to mitigate crop losses due to viral diseases in vineyards.

Activity: Outreach & education activities for nurseries, growers, participants of WSU's V&E Certificate Program, undergraduate students in WSU's V&E program and WSDA nursery inspectors.

1). A workshop "Industry Expansion Bottleneck: Where will you get your plants?" was organized in partnership with Washington Winegrowers Association and Washington Wine Industry Foundation at Walter Clore Center, Prosser, WA on October 27, 2016. Nearly 60 members of the grape and wine industry in Washington and Idaho States attended this workshop. The following presentations were made by the project team members:

- i. **Naidu Rayapati** made two oral presentations "It spread like...a virus: How leafroll spreads from old blocks to new plantings" and "What happens if I see something fishy and I want to test my vines?"
- ii. **Cindy Cooper**, WSDA Plant Services Program, made an oral presentation "Wait.... My Vines Could be Illegal?" describing grapevine quarantines, grapevine certification and the assessment on vine sales and best management practices while sourcing plant material for new plantings.
- iii. **Aaron Paul**, WSDA Plant Services Program Nursery Inspector made a presentation "How Do I Know They Are Still Clean?" describing steps for virus testing and inspection of certified mother blocks for maintaining clean plants in registered nurseries.

2). Project outcomes were shared at the meeting "Harmonizing Grapevine Nursery Stock Certification Programs in the Pacific Northwest", The Dalles, OR on October 19, 2016, March 22, 2017, May 19, 2017 and December 15, 2017. This participatory workshop, attended by five members of the Departments of Agriculture Idaho, Oregon, Washington, ten stakeholders from WA, OR and ID, and three scientists from the three states, lead to strengthening WSDA Grapevine Certification Programs and establishing guidelines for the exchange of virus-tested planting stock across the state borders in the Pacific Northwest. ***This workshop is fostering participatory, collaborative efforts in harmonizing Grapevine Certification Programs and establishing guidelines for the exchange of virus-tested planting stock across the three states in the Pacific Northwest.***

3). Organized a field trip for 65 undergraduate students in the course PIP 300: Diseases of Fruit Crops during October 7-8, 2016, to learn different aspects of diagnostics and therapeutics at the Clean Plant Center Northwest for producing healthy plants. In the afternoon, students visited Inland Desert Nursery to learn strategies for safeguarding virus-tested grapevines in Registered Mother Blocks and production of virus-tested propagation materials for grape growers to plant healthy vineyards. The second day, students visited vineyards to study impacts of viral diseases and management strategies implemented by growers.

4) On April 7, 2017, the project objectives in advancing prosperity of Washington's grape and wine industry were explained to local Congressman Dan Newhouse (4th District of WA) and Rodney Davis (13th District of Illinois), chairman of the Agriculture Committee's Subcommittee on Biotechnology, Horticulture, and Research. This discussion included threats from viral diseases to the grape and wine industry and project activities in strengthening grapevine supply chain for healthy vineyards.

(<https://www.facebook.com/WSU.IAREC/photos/pcb.1667710926591138/1667709226591308/?type=3&theater>)

5) Showcased the value of clean plant materials and best practices guidelines while sourcing clean plant material with participants of WSU's professional certificate program in viticulture on September 10, 2017. A total of 25 attendees from the US and abroad enrolled in the Viticulture Certificate program benefited from this knowledge.

6) A tail-gate meeting was organized on October 12, 2017 to discuss grapevine leafroll disease and current sampling and testing methods in a grower vineyard near Benton City, WA. Twenty five agriculture regulatory officials from 13 western states of the USA attending the Western Horticultural Inspection Society meeting participated in this tail-gate meeting. Discussions were held on how participatory approaches between Washington State University, Washington State Department of Agriculture and grapevine nurseries in Washington State are strengthening grapevine certification programs to maintain virus-tested plant materials in registered nurseries and advancing clean plant efforts to provide 'clean' planting stock for wine grape growers.

7) An oral presentation on "The booming wine grape industry in the Pacific Northwest and threats from viral diseases" was made at The 44th Annual Hermiston Farm Fair Seminars & Tradeshow, Hermiston, OR on December 1, 2017. An estimated 45 people, including growers, crop consultants, extension agents and Oregon State University faculty attended this presentation.

8) A workshop on "grapevine viruses and clean plants" was organized for Latino Ag Education Program (LAEP) on January 19, 2018. LAEP is offered by Wenatchee Valley College and sponsored by the Washington Winegrowers and Yakima Valley College. The program is designed to equip Latino employees in viticulture with the technical expertise that will allow them to practice Vineyard Management and Integrated Pest Management strategies. This 4-hr workshop, held at IAREC, Prosser, WA on January 19, 2018, was attended by 14 students enrolled in the LEAP and provided information on virus diseases, methods available for detection and the benefits of using 'clean' planting materials for healthy vineyards.

9) Project outcomes were shared at the meeting "Harmonizing Grapevine Nursery Stock Certification Programs in the Pacific Northwest", Kennewick, WA on February 5, 2018. This participatory workshop was attended by two members of the Departments of Agriculture Oregon and Washington, three stakeholders from WA and OR, and two scientists from the two states. Discussions were held on best sampling strategy for testing grapevines in nurseries, standards to be followed for white- (asymptomatic) and red-fruited (symptomatic) cultivars and filling the gaps in grapevine certification standards. ***This participatory meeting, together with series of meetings held earlier during 2016 and 2017 (mentioned above), is fostering collective efforts in harmonizing Grapevine Certification Programs and establishing guidelines for the exchange of virus-tested planting stock across the state borders in the Pacific Northwest.***

10) In partnership with Washington State Wine Commission, a mini-symposium on "Managing Grapevine Viral Diseases for Healthy Vineyards" was organized on March 15, 2018 at WSU-Wine Science Center, Richland, WA. This is a condensed version of the Washington Advancements in Viticulture and Enology research seminar, called WAVEx, designed to share science-based research knowledge resulting from grape

industry-supported research for application in the vineyard and winery. Nearly 70 members of the wine grape industry and WSU faculty and students attended this meeting.

The following presentations were made at this meeting:

- i. Naidu, R.A. “What Grape Viruses are in WA and Why Do We Care?”
- ii. Walsh, D. “Managing Vectors of Grapevine Leafroll Disease”
- iii. Ball, T. “The Economic Impacts of Virus Diseases”

11) An oral presentation “*Viruses: What They Are, Are Not, Their Damage, And More*” was made at the workshop “Regionalizing Grape Quarantine and Certification Programs in the Pacific Northwest” on May 1, 2018, at Yakima, WA. This is an outreach effort for nurseries, grape growers, interested wineries and processors, as well as buyers of nursery products from big box stores about grapevine planting material supply chain and the importance of virus-tested ‘clean’ planting material for healthy vineyards. About 20 people (growers, nursery managers, regulatory personnel from WSDA, crop consultants and scientists) benefited from this presentation at this workshop.

12) Organized a field trip on September 16, 2018, for 25 participants of WSU’s professional certificate program in viticulture. The participants from the US and abroad learned the importance of virus-free planting materials in establishing healthy vineyards and implementing post-planting control methods for mitigating negative impacts of viral diseases in vineyards.

13) Organized a one-day field trip for 70 undergraduate students in the course PIP 300: Diseases of Fruit Crops on September 28, 2018 to showcase impacts of viral diseases in grower vineyards. Students had an opportunity to interact with growers to learn the importance of planting new vineyards with virus-tested planting materials and roguing as a cost-effective tactic to reduce viral incidence in vineyards.

Activity: Present results at industry-sponsored annual meetings

The following presentations were made at grape and wine industry stakeholder meetings and professional scientific meetings and during workshops for disseminating the project results:

- i. 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.

An article based on this presentation was published at

<https://www.washingtonwine.org/research/reports/details/hansen-certified-plants-are-only-the-first-step>. An estimated 70 growers, vineyard managers, crop consultants and researchers benefited from this presentation.

- ii. Bagewadi, B., Ocampo, C., Movva, A., Hottell, D., Garza, M., Natra, N. and Naidu, R.A. 2016. Assessing the sanitary status of certified mother blocks in Washington State. APS Pacific Division Meeting, La Conner, WA. June 28-30, 2016.
- iii. Naidu, R.A. 2016. Rational Mealybug Control Programs vs. Irrational Exuberant Programs. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
- iv. Bagewadi, B., Ocampo, C., Movva, A., Hottell, D., Garza, M., Natra, N. and Naidu, R.A. 2016. Improving the Sanitary Status of Certified Mother Blocks in Washington State. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
- v. Hottell, D., Garza, M., Ocampo, C., Bagewadi, B., Swamy, P. and Naidu, R.A. 2016. Gambling with Grafting: Do’s and Don’ts. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.

An estimated 60 growers and vineyard managers, graduate and undergraduate students, post-docs, research and extension faculty had an opportunity to read these posters and gain knowledge about the sanitary status of grapevine nurseries in Washington State and the importance of ‘clean’ plant material for healthy vineyards.

- vi. Bagewadi, B., Movva, A., Natra, N. and Naidu, R.A. 2017. Sanitary Status of Grapevine Nurseries in Washington State. The 68th American Society for Enology and Viticulture (ASEV) National Conference, June 26-29, 2017, Bellevue, WA.

An estimated 100 people (growers and vineyard managers, graduate and undergraduate students, post-docs, research and extension faculty) across the U.S.A. had an opportunity to read this poster and gain knowledge about the sanitary status of grapevine nurseries in Washington State and the importance of ‘clean’ plant material for healthy vineyards.

- vii. Naidu Rayapati made an oral presentation “Slowing the spread of grapevine viruses” at the 2017 Washington Advancements in Viticulture and Enology (WAVE) meeting at Walter Clore Wine and Culinary Center, Prosser, WA, on April 19, 2017.

Nearly 130 attendees from grape and wine industry across Washington State benefited with the knowledge derived from the project. A post-event survey conducted by the Research Program Manager of Washington State Wine Commission indicated that 100% of the attendees would apply the information learned at the meeting in their operations.

- viii. Bagewadi, B., Movva, A., Natra, N., Ryan, J., Bernal, M., and Naidu, R.A. 2017. Strengthening grapevine supply chain for healthy vineyards. Washington Association of Wine Grape Growers Annual Meeting, Convention and Trade Show, February 7-9, 2017, Kennewick, WA.

- ix. Naidu, R.A., Donda, B., Kesoju, S., Swamy, P., Bagewadi, B., Jarugula, S., Natra, N., Adiputra, J., Movva, A., and Mitra, A. 2017. The Mantra of ‘Start Clean, Stay Clean’ for Healthy Vineyards. Washington Association of Wine Grape Growers Annual Meeting, Convention and Trade Show, February 7-9, 2017, Kennewick, WA.

An estimated 50 to 60 growers and vineyard workers, graduate and undergraduate students, post-docs, research and extension faculty had an opportunity to read these posters (# iii and #iv) and gain knowledge about the sanitary status of grapevine nurseries in Washington State, pathways of virus spread through plant materials, importance of ‘clean’ plant material for healthy vineyards, and management of viral diseases through cost-effective strategies, such as roguing.

- x. The following posters were presented at the Washington Association of Wine Grape Growers (WAWGG, name changed to Washington Wine growers) meeting:

- ☐ Naidu, R.A., Jarugula, S., Swamy, P., Natra, N., Mitra, A. and Movva, A. 2018. The mantra of ‘Start Clean, Stay Clean’ for healthy vineyards. Washington Winegrowers Association Annual Meeting, Convention & Trade Show, February 6-8, 2018, Kennewick, WA. **(1st Prize under Professional Category).**

- ☐ Natra, N., Jarugula, S., Mitra, A., Movva, A. and Naidu, R.A. 2018. Strengthening the grapevine supply chain for healthy vineyards. Washington Winegrowers Association Annual Meeting, Convention & Trade Show, February 6-8, 2018, Kennewick, WA.

An estimated 80 to 90 growers, vineyard managers, vineyard workers, graduate and undergraduate students, post-docs, research and extension faculty had an opportunity to read these posters and gain knowledge about the sanitary status of grapevine nurseries in Washington State, pathways of virus spread through plant materials, importance of ‘clean’ plant material for healthy vineyards, and management of viral diseases through cost-effective strategies, such as roguing.

The project was led by WSU PI (Naidu Rayapati) and assisted by a post-doctoral research associate and other personnel in the PI’s program. The PI has coordinated project activities, conducted outreach and

educational activities and submitted quarterly and annual reports. The project personnel carried out proposed activities. The PI and his team made oral and poster presentations describing the project results at grape industry and professional scientific meetings. WSDA Plant Services Program participated in the project as a sub-contractor to perform specific activities related to the project. WSDA nursery inspector and nurseries collaborated with the project PI in sample collections and testing and to ensure implementation of certification rules in registered nurseries. Nurseries and commercial growers have provided access to vineyards for sample collections and conducted project activities.

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

Goals and Outcomes Achieved

As described under the Project Approach section of this report, proposed activities were completed during the project period. These activities included establishing collaborative partnerships with certified nurseries and WSDA's Plant Services Program, conducting 'train-the-trainer' workshops for best management practices to monitor nurseries for viral symptoms and collecting samples from nurseries and transportation to the PI's lab for virus indexing. Protocols were standardized for high-throughput sampling in grapevine nurseries. Molecular diagnostic assays combined with composite sampling strategy enabled processing of high volume of samples for reliable detection of viruses. Next-generation sequencing provided additional method for profiling viruses in grapevine samples. Participatory approaches were pursued with growers to demonstrate benefits of annual monitoring of new plantings and implementing roguing to eliminate virus-infected vines and reduce viral incidence in young vineyards. Dissemination of project results via industry-sponsored annual meetings, workshops and face-to-face interactions resulted in increased awareness of the importance of virus-tested planting materials for establishing new vineyards and to practice the mantra 'start clean, stay clean' for maintaining healthy vineyards. In summary, the project met targets and benchmarks listed in the project proposal to fulfil the project goals.

The project has achieved most of the short-term outcomes listed in the proposal. Due to their perennial nature, virus-tested grapevines in the registered nurseries can be subjected to infection from external sources. Consequently, annual monitoring of nurseries and testing suspected vines for viruses followed by removing virus-positive vines will be continued (beyond the project duration) to maintain high sanitary standards in registered mother blocks. In this regard, research experiences, collaborative partnerships and protocols established during the project period have laid a strong foundation to continue monitoring registered mother blocks. This will help WA nurseries maintain only virus-tested 'clean' vines in certified mother blocks. Efforts will be continued to strengthen the grapevine supply chain from nurseries to vineyards leading to healthy vineyards by focusing on roguing virus-infected from mother blocks, rigorous testing and inspection, and increasing grower access to clean propagation material. It is anticipated that these activities will be continued with funding support from the Washington State Grape and Wine Research Program, WSDA Grapevine Certification and Nursery Improvement Program and Washington State Commission on Pesticide Registration.

Goal: Develop an updated inventory of registered grapevines planted in certified mother blocks in Washington nurseries

Project Activity	Responsible Party	Accomplishments
Update the PISCES database of registered vines in all certified mother blocks.		As described in the Project Approach section, this activity

Additional inspection of mother blocks during the crop season.	WSDA Plant Services Program	was completed. However, this is an on-going activity and will be continued beyond the project period.
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Goal: Ensure virus-tested grapevines are maintained in all registered mother blocks of certified nurseries.

Project Activity	Responsible Party	Accomplishments
Project initiation meeting with Nurseries and WSDA.	Rayapati's team in collaboration with nursery personnel.	As described in the Project Approach section, the project team collaborated with registered nurseries and WSDA Plant Services Program to perform these activities. The project results were shared with WSDA Nursery inspector and concerned nurseries to remove virus-positive vines in registered nurseries. These efforts contributed towards maintaining virus-tested 'clean' vines in registered mother blocks. These activities will be continued beyond the project period.
Train nursery personnel in sample collections from grapevines in certified mother blocks.		
Sample collection from certified mother blocks and processing at WSU-IAREC.		
Test samples for viruses using diagnostic assays.		
Carryout lab-based molecular studies (cloning and nucleotide sequence analyses and deep-sequencing) for confirmation of viral infections in symptomatic vines that tested negative in diagnostic assays.		
Additional inspection of mother blocks during the crop season.	WSDA Plant Services Program	

Goal: Increased use of clean plants for healthy vineyards.

Project Activity	Responsible Party	Accomplishments
Outreach & education activities for nurseries, growers, participants of WSU's V&E Certificate Program, undergraduate students in WSU's V&E program and WSDA nursery inspectors.	Rayapati's team	As described in the Project Approach section, educational and outreach activities were conducted to increase awareness of viral diseases and benefits of maintaining high sanitary standards in nurseries as well as planting virus-tested clean planting stock for healthy vineyards. In addition, roguing was demonstrated as an effective strategy to reduce infection levels in newly planted
Present results at industry-sponsored annual meetings.		
Monitor young vineyards (< 5 years old) planted with cuttings from certified nurseries and self-propagated materials,		

test suspected vines for viruses at WSU-IAREC.		vineyard blocks. These activities will be continued beyond the project period.
Implement roguing in newly planted vineyards (< 5 years old) in partnership with growers to remove virus-infected vines.		
Collect data from nurseries for benchmark analysis.		

Expected measurable outcome: The overall outcome of the project is to ensure that virus-tested ‘clean’ grapevines are maintained in mother blocks in Washington certified nurseries and growers are able to use certified planting stock for raising healthy vineyards, thereby advancing sustainability of the wine grape industry in Washington State.

Outcome 1:

Benchmark: In collaboration with certified nurseries, establish 2014 data as a benchmark and compare with an updated inventory in 2018 to showcase increased number of registered mother vines.

Progress towards achieving the proposed benchmark: In 2014, WSDA data base listed 138,939 registered grapevines planted in certified nurseries. In 2018, WSDA data base showed 205,451 registered grapevines planted in certified nurseries. This represents an approximately 48% increase in number of registered grapevines planted in certified nurseries during the project period. WSDA Plant Services program has established an updated PISCES database of virus-tested grapevines maintained in registered mother blocks. In addition, the PISCES database provides updated information to track certified grapevine planting materials produced via tissue culture. This user-friendly database will provide growers a list of virus-tested grapevines maintained in registered nurseries and available from tissue culture for planting new vineyards.

Outcome 2:

Benchmark: In collaboration with certified nurseries and WSDA, build database annually on number of grapevines tested for viruses and virus-positive grapevines removed from mother blocks.

Progress towards achieving the proposed benchmark:

- i. Robust sampling protocols and high-throughput molecular diagnostic methods were established for high-throughput testing of grapevine samples towards improving the sanitary status of certified nurseries and grower vineyards.
- ii. As a consequence of testing vines during the project period (between 2014 – 2018), one certified nursery voluntarily dropped from the certification program due to poor sanitary status of registered blocks. Another nursery voluntarily withdrew 4 registered blocks from the certification program due to virus infections. Thus, about 33,306 registered vines not meeting certification standards were dropped from the certification program, thereby improving the sanitary status of certified mother blocks.
- iii. A significant outcome of the project results was the absence of Grapevine red blotch virus in grapevine samples tested so far from registered nurseries in Washington State. In contrast, Grapevine leafroll-associated virus 3 continues to be a major concern for grapevine nurseries.
- iv. Symptom expression in red-fruited wine grape cultivars is influenced by seasonal climatic conditions. Therefore, an additional inspection of registered nurseries towards end of the crop season (in addition

to two visits/season, one in spring and another in fall) was found to be effective in symptom-based monitoring of red grape cultivars and implementing roguing of infected vines.

- v. Combining visual inspection with testing by molecular diagnostic assays was found to be effective in removing virus-infected vines in red grape cultivars and maintaining high sanitary standards in registered nurseries.
- vi. Symptom-based diagnosis was not reliable for monitoring white-fruited wine grape cultivars and juice/table grape cultivars, since these cultivars do not express visual symptoms. Thus, it is essential to use molecular diagnostic assays for reliable testing of white grape cultivars and juice/table grape cultivars in nurseries and remove virus-positive vines from certified mother blocks.

Outcome 3:

Benchmark:

- ☐ The project will establish sale of planting stock in 2014 from Inland Desert Nursery as a benchmark.
- ☐ Wine grape acreage planted as of 2014 by Ste. Michelle Wine Estates will be established as a benchmark.

Progress towards achieving the proposed benchmark:

- i. Annual sale of ‘clean’ planting stock (own-rooted and grafted vines) from Inland Desert Nursery has increased between 2015 and 2018 as shown below.

Year	Total sale of vines (million)	% virus-tested ‘clean’ vines/total sale of vines
2015	4.25	32
2016	3.05	39
2017	3.15	42
2018	2.00	69

- ii. Ste. Michelle Wine Estates planted a total of 327.92 acres between 2015 and 2018 with virus-tested planting materials obtained from registered mother blocks maintained by Inland Desert Nursery and Ste. Michelle Wine Estates. This acreage includes four red-fruited varieties (50.94 acres of Cabernet Sauvignon, 4.79 acres of Cabernet franc, 8.35 acres of Malbec, and 6.68 acres of Syrah) and four white-fruited varieties (56.93 acres of Chardonnay, 156.75 acres of Sauvignon Blanc, 5 acres of Chenin Blanc and 5 acres of Semillon).
- iii. An estimated 75 growers (within and outside WA) have used virus-tested ‘clean’ planting materials (own-rooted and grafted vines) sourced from WA certified nurseries for planting new vineyards.
- iv. Implementing roguing or removing symptomatic vines benefited an estimated 25 growers in reducing viral incidence in young vineyards.
- v. Advantages of roguing as a preventive tactic showcased to about 50 growers through industry-sponsored meetings, educational workshops and face-to-face meetings.

Beneficiaries

Outcomes of the project benefited the following:

- i. An estimated 1,000 members of the Washington Winegrowers Association (consisting of grape growers, wine makers, crop consultants, vineyard managers and farm workers) benefited with science-based information shared via educational and outreach presentations. These efforts increased awareness of virus diseases and encouraged grape growers, wine makers, crop consultants, vineyard managers and farm workers to practice roguing for removing infected vines in new plantings and plant new vineyards with virus-tested ‘clean’ planting materials.

- ii. The project has contributed to the creation of a regional approach for grapevine certification to harmonize quarantines and regulatory programs in Idaho, Oregon, and Washington. This would establish guidelines for Departments of Agriculture in Washington, Oregon and Idaho to harmonize grapevine nursery certification programs in the Pacific Northwest for seamless exchange of virus-tested planting stock across the three states.
- iii. The project results have contributed to the amendment of WSDA's phytosanitary rules, WAC 16-462, the Grape Planting Stock Registration & Certification and 16-483, grape pest quarantine. These revisions, once approved, are expected to strengthen WSDA's quarantines and regulatory programs to ensure better protection of vineyards from alien pests and diseases.
- iv. Research and extension faculty working on grapes, and research associates, graduate students and undergraduate students specializing in Viticulture & Enology Programs at Washington State University and in community colleges.

Note: More details about beneficiaries of the project are provided in the Project Approach section, under the Activity: *Outreach & education activities for nurseries, growers, participants of WSU's V&E Certificate Program, undergraduate students in WSU's V&E program and WSDA nursery inspectors* and Activity: *Present results at industry-sponsored annual meetings*.

As detailed in the Project Approach and Beneficiaries sections of this report, dissemination of results of the project benefited the grape and wine industry that is currently contributing an estimated \$5 billion to Washington State's economy. Since managing virus diseases affecting vine health and fruit yield and quality is recognized by the grape and wine industry as one of the highest priorities, the project outputs have contributed to implementation of science-based best practice guidelines to manage viral diseases in certified nurseries and grower vineyards for long-term sustainability of the wine grape industry. Additionally, the project contributed to the WSDA SCBGP priority "Controlling Pests and Diseases" impacting Washington State's agriculture. 'Train-the-trainer' collaborations with regulatory agencies strengthened Washington State grapevine certification program (Rule #4 in WSDA section WAC 16-462-025) and established guidelines for inter-state exchange of virus-tested planting stock in the Pacific Northwest.

Lessons Learned

Collaborative partnerships with certified nurseries and regulatory agencies are extremely vital for implementing science-based "start clean, stay clean" principles to advance sustainable growth of Washington's grape and wine industry. Complementary funding from Washington State Grape and Wine Research Program, Grapevine Research Funding (Grapevine Grower Assessment) from WSDA and Washington State Commission on Pesticide Registration provided synergistic approaches to conduct project activities in a holistic manner.

Virus indexing of grapevines in certified mother blocks during the project period indicated that (i) wine grape cultivars can show differences in symptoms for the same viral disease leading to misleading conclusions, (ii) some grape cultivars may express symptoms 2 or 3 seasons after infection in the field in a climate-responsive manner, and (iii) white-fruited cultivars do not express symptoms and hence escape symptom-based diagnosis. A significant outcome of these observations is that Certified Mother Blocks need to be monitored on a regular basis to maintain high sanitary standards and freedom from viral infections.

It is also noteworthy that all samples tested to date from mother blocks were negative for GRBV, indicating the absence of GRBV in grapevines maintained in certified nurseries. This outcome has enhanced nation-wide reputation of Washington State nurseries for the quality of plant material supplied to growers.

Since GLRaV-3 and GRBV produce fairly similar symptoms in red-fruited cultivars, accurate virus identification provides clues as to how each virus spreads in vineyards. Conversely, white-fruited cultivars remain symptomless and reliable identification of GLRaV-3 and GRBV is critical. Thus, accurate diagnosis

is the first step for implementing preventive and integrated strategies to control leafroll and red blotch diseases in both red- and white-fruited cultivars.

In the longer term, the project outputs will improve the sanitary status of certified nurseries and growers are able to use virus-tested planting material for establishing new vineyards. Overall, outcomes of this project will advance grapevine clean plant programs in the Pacific Northwest with spillover benefits to allied programs across the U.S.A.

The efficacy of a roguing strategy is constrained due to the natural variability in symptom expression displayed by different wine grape cultivars. Therefore, future studies should involve examining the correlation between symptoms and presence of specific virus(es) to improve visual diagnostics as a reliable identifier of viral infections in red-fruited cultivars and support roguing as a practical and cost-effective approach. A lack of foliar symptoms makes visual diagnosis of infected vines unreliable in white-fruited cultivars. Therefore, diagnostic methods are critical to support roguing in vineyards planted with white-fruited cultivars.

The observed lack of GRBV spread in vineyards makes roguing or removing symptomatic vines more significant than vector management in controlling red blotch disease. Planting vineyards with virus-tested planting materials in combination with roguing as a post-planting tactic can be implemented for effective control of red blotch disease in vineyards.

Since GLRaV-3 can be disseminated via planting materials and spread by vectors, monitoring vineyard blocks provides information to better understand pathways of viral spread in young vineyards. Roguing was found to be successful in some vineyards infected with GLRaV-3, while in others the outcomes were less successful. This calls for strategic research to strengthen the grapevine planting material supply chain and refine roguing and vector management for implementing integrated strategies to control leafroll disease in vineyards.

Team work between project personnel and productive collaborations with wine grape growers and regulatory agencies (WSDA Plant Services Program) were found to be essential for successful completion of the project activities and making tangible impacts benefiting the grape and wine industry. Keeping the WSDA SCBGP management apprised of challenges and soliciting advice as needed during the project period is critical for successful implementation of the project activities.

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Additional Information

Total cash or in-kind match utilized for the project: \$176,287.00. This includes (i) Salaries (\$90,492.49), Employer contributions (\$24,902.84) and Facilities & Administrative costs (\$39,661.67) from Washington State University and \$21,230.00 from stakeholders as in-kind match from Ste Michelle Wine Estates (contribution of \$10,730 as wages and \$500 for travel) and Inland Desert Nursery (contribution of \$8,000 as wages and \$2,000 for travel). Thus, the project has met cash and in-kind obligations for the project. Outputs of this project will be part of research and extension publications in future. The funding from SCBGP will be acknowledged in these publications.

Project Title: Identification, distribution, and management of needle cast diseases on noble fir

Project Summary

A complex of needle cast diseases is causing significant reductions in the production and quality of noble fir boughs and some Christmas trees in the Pacific Northwest (PNW). The southern Cascade Mountains of Washington State represent the geographic center of noble fir bough production in the PNW. Noble fir occurs naturally at high elevation sites above 3000 ft and most boughs are harvested from extensive noble fir plantations on public and private lands that came about, in part, as a result of reforestation efforts after the eruption of Mt. St. Helens in 1980. In recent years the demand for noble fir boughs and Christmas trees has increased markedly. The PNW leads the nation in the production of Christmas trees, and noble fir represent about 45% of the production. The increased production of noble fir by Christmas tree growers has resulted in a significant increase in bough harvests from low elevation noble fir Christmas tree plantations that have been converted into bough production stands.

Applications of fungicides during shoot elongation has been a very effective approach to manage needle cast diseases. Growers typically apply fungicides to control interior needle blight (INB), a disease that is caused by several other pathogens, but these failed to control the “Purple Needle Eater” (PNE) disease that occurs in high elevation noble fir bough production stands. The difficulty growers had in controlling needle cast on noble fir is due in part to a lack of understanding of the identity of what diseases are present, differences in the efficacy of fungicides against specific pathogens, and uncertainty about their timing.

Noble fir boughs are harvested from a variety of sources, ranging from large public (USDA Forest Service and WA DNR) and large private landowners, such as Weyerhaeuser, that manage extensive high elevation stands of noble fir, to an increasing number of smaller Christmas tree growers that are managing and harvesting noble fir for boughs and Christmas trees from low elevation sites. In 2014, an estimated 45% of the 16 million pounds of noble fir boughs that were harvested came from low elevation Christmas tree sites, a \$3,024,000 value. Historically, noble fir boughs from high elevation sites have been considered to have superior postharvest quality compared to boughs from low elevation sites and it is unclear what, if any effect the increased utilization of low elevation sources of boughs will have on the overall quality of greenery production.

The goals of this project are to confirm the identity of pathogens causing needle cast diseases on noble fir, determining the prevalence and distribution of these pathogens, identifying fungicides or mixtures of fungicides that are effective in controlling these diseases, and determining the impact the increased reliance on low elevation boughs will have on the postharvest quality of greenery products.

1. Establish the motivation for your project by presenting the importance and timeliness of the project. During the past few years, high elevation bough stands near Mt. St. Helens have been severely impacted by a needle cast disease that landowners and bough harvesters refer to as Purple Needle or Purple Needle Eater (PNE). This disease is characterised by a purple coloration of the blighted new growth during the summer. In 2014, a similar looking disease appeared at a number of low elevation sites that were producing noble fir boughs and Christmas trees. In some sites, symptoms varied, consisting of a reddish brown, brown, or yellow-banding of the needles. Disease samples were collected and examined at a number of high and low elevation noble fir bough and Christmas tree sites in 2014 in an effort to identify what was causing the damage. This revealed that there was a complex of pathogens that were attacking needles at both the high and low elevation bough sites and some Christmas tree stands. DNA sequence data from fruiting bodies on material with the PNE symptom matched *Delphinella abietis*. This pathogen is known to cause severe shoot blight on *Abies* spp in Canada and Europe. It has been observed on noble fir in Europe, but not the PNW. Attempts to control *Delphinella* in Canada with fungicides has only had limited success and fungicides that are used to control this pathogen in Europe are not currently available in the U.S.

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

Project Approach

Activity 1: Identification of fungi associated with needle cast on noble fir at high and low elevation production sites.

WSU worked with growers and landowners to obtain samples of diseased boughs from high and low elevation stands of noble fir. Samples were brought/shipped to WSU Puyallup and used to identify the fungi associated with the symptomatic needles. Symptomatic noble fir boughs were collected from a total of 31 sites representing low and high elevation stands in WA and OR during this project (Figure 1). Bough material from each of the 15 sources used in the post-harvest study (Activity 5) in 2016 and 4 sources in 2017 was examined as well as additional samples from other growers.

Symptomatic foliage was examined and fungi present were identified from symptoms and signs when possible. Symptoms were characterized, examined in the dissecting microscope, and photographed. Spores from fruiting bodies were examined in the compound microscope and measured. Foliar fungi were also isolated from symptomatic material and DNA from pure cultures were sequenced.

DNA was extracted from representative isolates and the ITS region of the rDNA was amplified and sequenced to confirm the identity of the isolates to species. Sequences were analyzed using BLAST (<https://blast.ncbi.nlm.nih.gov/Blast.cgi>). ITS sequences of voucher specimens of known species were downloaded from Genbank. A maximum likelihood tree was constructed with known species and ITS sequences obtained from noble fir isolates for each of three fungal classes Dothideomycetes, Leotiomycetes, and Sordariomycetes (Figures 2, 3, 4). These three classes contained the majority of isolates. Table 1 contains a summary of the fungi identified from noble fir foliage.

Foliar symptoms and fungi associated with them are given below:

Damage associated with noble fir needle cast diseases in 2014



Purple needle eater (PNE)

Delphinella abietis associated with tip dieback and "Purple Needle Eater" (PNE) symptoms (Figure 5) was isolated from dead flushes and current year needles. This fungus was most common at one of the high elevation sites.

Interior needle blight (INB)

Rhizosphaera spp. associated with interior needle blight (INB) symptoms (Figure 6) was found at all the sites, as was *Sydowia polyspora* (an endophyte thought to be involved in current season needle necrosis, CSNN). This fungus and *Rhizosphaera* spp. were also isolated from asymptomatic needles from new flushes, current year, and 2 year old foliage.

Fungi that have been reported to be associated with INB on *Abies* sp. include *Mycosphaerella* spp., *Phaeocryptopus nudus*, *Phyllosticta* spp., *Toxosporium* spp., and *Rhizosphaera* spp (Hansen et al. 2018). It is possible that *P. nudus* is the sexual stage of *R. pini*, but further research needs to be done to confirm this (Kobayashi 1967). *Mycosphaerella*, *Phyllosticta* spp., or *Toxosporium* spp. was not detected.

The ITS sequences of *Dephinella abietis* and *Sydowia polyspora* were only different by 6 out of 551 bp, or 1%), although it was possible to distinguish the two fungi in culture. In addition to these isolates, 10 other fungi were isolated that had similar ITS sequences and morphology but could not be identified to species. Additional genes of these isolates will be sequenced to further identify these fungi.

Lirula needle blight

Lirula spp. was observed on symptomatic needles (Figure 7), mainly at high elevation sites. It was not possible to isolate this fungus into culture. Noble fir needles with black lesions consistent with *Lirula* fruiting bodies were placed in a petri dish with moist filter paper. Once the lesion burst open, the whitish mass (asci and ascospores, Figure 7C) was photographed and sampled with a sterile needle for diagnostic sequencing of the ITS region of ribosomal DNA. The closest match of the sequence was a 91% (456/503 nucleotides) similarity to *Lirula yunnanensis* in the GenBank database. Only three *Lirula* species have sequences in GenBank. These are *L. macrospora*, *L. exigua*, and *L. yunnanensis*. Although many identifications of *Lirula* sp. by morphology have been made from symptomatic material, this represents the first successful sequence of *Lirula* in this lab. Morphological measurements of the asci and ascospores are similar to *L. abietis-concoloris* except that the ascospores are narrower in width (Table 2). Asci and ascospores on herbarium specimens of *Lirula abietis-concoloris* were observed but attempts to get a DNA sample and/or DNA sequence (using direct PCR method) from the herbarium *Lirula* were unsuccessful. Work on this fungus is ongoing.

Needle rusts

Needle rusts caused by *Pucciniastrum goeppertianum* (alternate host *Vaccinium* spp.) and *Uredinopsis pteridis* (alternate host *Pteridium aquilinum*) were found on symptomatic noble fir needles. Noble fir needles with rust symptoms (Figure 8) were sampled by direct PCR and the ITS region sequenced. The closest match in GenBank to the resulting sequence was to *Pucciniastrum goeppertianum* with 99%

similarity (650/656 nucleotides). *Uredinopsis pteridis* was identified based on spore morphology (Ziller 1959).

Other needle symptoms

A large number of other fungi associated with spots, isolated dead needles, or other needle blight symptoms were isolated (Figure 9). These included *Allantophomopsis* spp., *Pyrenophora leucospermi*, *Sirococcus* spp., *Phomopsis* spp., and *Pleospora* spp. Many of these fungi have been reported to cause foliar blight or leaf spot symptoms on angiosperm hosts. *Sirococcus* spp. are known to cause shoot blight on conifers. *Phacidium* sp. were isolated from symptomatic needles of various types. These fungi cause snow mold on conifers and are also endophytes. Several *Diaporthe* spp. (anamorph *Phomopsis* spp.) were isolated from needles of all symptom classes. The most common were *D. eres* and *D. rudis*. These fungi are likely to be endophytes, although their ability to cause disease under certain conditions is unknown.

Saprophytic fungi identified from noble fir foliage included *Cladosporium* spp., *Alternaria* spp., *Epicoccum nigrum*, *Aureobasidium pullulans*, *Penicillium* spp., *Thysanophora penicillioides*. *Cladosporium* spp. cause sooty mold. Some of these fungi are associated with leaf spots on other hosts. Decomposer fungi isolated from noble fir foliage included *Graphostroma* sp., *Hypoxylon rubiginosum*, *Mollisia cinerea*, and *Pestalotiopsis microspora*. The ambrosia fungus *Raffaelea montetyi* was also isolated.

Research will continue to examine the fungal community of noble fir foliage, with special attention to fungi in the Dothideomycetes, a closely related group of fungi that contains *S. polyspora*, *D. abietis*, *Rhizosphaera* spp., *A. pullulans*, and others.

Activity 2: Pathogenicity trials.

Pathogenicity trials using several of the fungi isolated in Activity 1 were done on emerging foliage of potted noble fir seedlings. In the first trial, mycelium of *Delphinella abietis* and *Rhizosphaera kalkhoffii* isolated from noble fir were ground in sterile water and applied to new foliage in May and June. The inoculated plants were placed in chambers (plastic buckets), sprayed with water, and incubated with a tightly sealed lid. After 48h the lids were removed and the plants placed outdoors under shade cloth. There was visible free moisture evident when the lids were removed. Only a few seedlings (n=2) showed symptoms and both had been treated with *Rhizosphaera*.

In the second and third pathogenicity trials, potted plants were placed under inoculum branches that were used in the fungicide trials (Activity 4). None of the plants got infected. This took place after two fungicide trials were conducted using these branches for inoculum and it is possible that fruiting bodies on the needles were no longer able to produce sufficient levels of inoculum needed for infection.

A fourth trial using ground mycelium of *Delphinella abietis* (2 isolates), *Rhizosphaera kalkhoffii*, *Phacidiopycnis* sp., *Allantophomopsis lycopodina*, and *Pyrenophora leucospermi*, all isolated from noble fir, was conducted using the bucket method used in Trial 1 with five plants per treatment. In this trial, symptoms were seen on emerging foliage treated with *D. abietis* (3 plants), *R. kalkhoffii* (1 plant), and *P. leucospermi* (all 5 plants). Identity of the fungi was confirmed by re-isolation and sequencing. Symptoms on inoculated foliage were identical to those seen on naturally infected material. The team was unable to re-isolate *D. abietis* from infected foliage, but both *R. kalkhoffii* and *P. leucospermi* were reisolated from symptomatic inoculated foliage.

A set of 6 trials was started in 2018 using ground mycelium and/or conidial suspensions of 6 additional fungi that were isolated in 2017-2018 (Table 3) and repeating 3 of the fungi that were tested in 2016. Inoculations were done on emerging foliage in June 2018 using the bucket technique described above, and

applying inoculum suspensions in a fine mist with a spray bottle. Inoculum was also sprayed onto PDA plates to check viability. The plants are being monitored for symptom development.

The results of the pathogenicity tests so far indicate that *R. kalkhoffi* is important in interior needle blight and *P. leucospermi* may cause a needle blight. Symptoms associated with *P. leucospermi* are shriveled attached needles (Figure 10). This is a new host/pathogen combination not previously reported.

Activity 3: Determine the distribution of specific needle cast pathogens on noble fir.

Throughout the duration of this project, surveys of high and low elevation stands of noble fir were done to obtain a better understanding of distribution of needle cast pathogens. Sites sampled were based on feedback from industry partners, as well as samples sent from growers. Samples were labeled according to location and date collected and processed at WSU Puyallup. Pathogen identification was based on a combination of morphological methods and DNA sequencing described under Activity 1 above.

Noble fir bough material was collected from sites in OR and WA over a range of elevations, from 165 ft to 3000 ft (Figure 1). Details of these sites are shown in Table 4. This material was examined for symptoms of needle blight and other foliar diseases in Activity 1. Seven diseases or disease complexes were seen (Table 5).

Delphinella abietis (PNE) was found throughout the range, with less PNE seen on the low elevation samples. Needle rusts were most common at the high elevation sites, but may be more related to the presence of the alternate hosts at these sites as opposed to low elevation Christmas tree sites where herbicides are frequently used to control weed growth. High elevation sites had a higher incidence of *Lirula* needle blight, and there was more interior needle blight, which has been associated with *Rhizosphaera* spp., at lower elevations.

A more rigorous examination was done on sites that were sampled in spring (March-June) and fall (September-November) in both years of the project. Presence or absence of each of the 7 symptom categories was noted at two low elevation sites (site 15 and 16) and two high elevation sites (sites 7 and 10) sampled in spring and fall of 2016-2018 (Figure 11). The high elevation sites had an equal or higher incidence of all diseases than the low elevation sites ($p < 0.001$, Wilcoxon signed-rank test). There was no significant difference in observed disease incidence between the spring and fall sampling times. This is due to the persistence of symptomatic needles on trees for more than one season before being shed.

Data from nearby weather stations was examined for these sites for years 2014-2018. Total precipitation in June, the month when budbreak occurs and noble fir foliage is most susceptible to infection, was compared for the years 2014-2018 (Figure 12). The high elevation weather station (Elk Rock, EKRW1) had the most rainfall, and the year with the highest rainfall was 2014. The years with the highest rainfall at the low elevation site WSUP (site 15) were 2016 and 2017. Foliar diseases on conifers are known to increase with higher levels of summer precipitation (Woods et al. 2016) because of the moist conditions needed for fungal spore release, germination, and infection, and the presence of susceptible host foliage. There was an inverse relationship with average daily temperature, with wetter years having cooler temperatures. Temperatures between 10-15C and high moisture levels are thought to favor the development of foliar diseases (Woods et al. 2016).

When climate data for June 2014-2018 was examined for weather stations closest to where the remaining samples (Table 4) were collected, there was a trend for high elevation weather stations to have more precipitation. 2017 was the wettest year, followed by 2014 and 2016 (Figure 12). The driest year was 2015.

Although there were differences in rainfall among the sites, high humidity in a closed canopy or crowded stand will result in more foliar disease than in an open stand at the same location. However, the higher moisture levels at the high elevation sites will contribute to the development of foliar diseases, even in an open stand since periods of leaf wetness are extended due to lower temperatures and less rapid evaporation than at low elevation sites.

Activity 4: Determine the effectiveness of fungicides and application timing to control needle cast diseases.

2015-2016 tests

Dry conditions during spring 2015 resulted in insufficient infection of new growth on trees to evaluate the effectiveness of fungicides in controlling *D. abietis* in two preliminary fungicide trials (Data not shown). Because of this, the team modified how the fungicide trials were conducted in 2016. Noble fir seedlings in 4" treepots were placed in an inoculation structure in an effort to create conditions that were favorable for infection. In both the pathogenicity (see Activity 2 above) and fungicide trials, the experiments were carried out on seedlings with newly emerging foliage. Two trials that included 16 fungicide treatments and one control treatment (water, no fungicide) were conducted in 2016 (Table 6). Plants were treated with fungicide and allowed to dry for 24h, then placed into a structure where noble fir branches with *D. abietis* PNE symptomatic 2015 needles that were collected from a growers site were placed over the seedlings and overhead irrigation was applied. High humidity was maintained in the structure, where the plants were irrigated 4x/day for 48h. After exposure to inoculum the plants were removed from the structure and placed under shade cloth. Symptoms were assessed and reisolation and sequence ID of fungi from symptomatic needles was done to confirm that infection by *D. abietis* occurred. In both trials there was only a low rate of infection, even on the untreated control plants. No *D. abietis* was isolated from symptomatic needles.

An additional two fungicide trials on emerging noble fir foliage were done using ground mycelial inoculum of *D. abietis*. A slurry of ground mycelia was applied to emerging foliage using the same technique as in the pathogenicity tests described above (Activity 2). Also, detached branches of noble fir with PNE symptoms were fastened onto the inside of the lid of each bucket and moistened in an effort to provide a source of spore inoculum. Infection frequency was greater than on the previous two trials where the seedlings were placed only under naturally infected branches. However, disease severity or percent of shoots infected per tree, was still low, with most of the infected plants only having one or two infected shoots, despite inoculum being applied to all emerging shoots. This may relate to the life cycle of the fungus and the mycelial stage being ineffective at colonizing the host. Results for Trial 3 are shown in the appendix (Figure 13).

2017 tests

Fungicide control trials were conducted at two high and one low elevation site in 2017 (Table 7).

Two techniques were used:

1. Seedling exposure trials
2. Branch spray trials

In addition, an operational fungicide trial was done at one of the high elevation sites.

Seedling exposure trials

Working with industry partners, fungicide trials were established using treated seedlings set out in noble fir stands with high levels of infected needles. These trials were started in June 2017 during budbreak at low and high elevation sites. Sites were selected that had trees with needle casts caused by *Rhizosphaera* sp., *Delphinella*, *Lirula* and/or needle rusts. Disease type and severity was assessed on the trees under which fungicide treated seedlings were placed.

Two trials using fungicide treated seedlings were done at the low elevation site, which consisted of a noble fir stand at WSU Puyallup with severe interior needle blight caused by *Rhizosphaera* sp. Two high elevation sites were selected near Mt. St. Helens that had *Delphinella*, *Lirula*, and needle rusts. Weather stations measuring air temperature, rainfall, and leaf wetness at 15 minute intervals were installed at the sites.

Branch spray trials

At the two high-elevation sites branches on trees were sprayed with the same fungicides used on the seedlings in June 2017 (Table 6). Data was collected on branches to be sprayed with fungicides, including length and condition (closed, partially open, fully expanded) of the terminal bud, and compass bearing for each branch.

Helicopter spray trial

One branch on each of 25 trees was bagged before aerial application of fungicide (88 oz/acre chlorothalonil) and the bags were removed after spraying at one high-elevation site that has a heavy infestation of *Lirula* needle blight. These seedlings and branches are being monitored for symptom development. Figure 14 shows a bough on one of the trees at this site with a heavy *Lirula* infection on 2014 foliage.

Photos of all three fungicide trials are in Figure 15. Since symptoms of *Rhizosphaera* and *Lirula* appear more than a year after infection, the trees are being monitored into 2018.

Results

Delphinella disease data on the sprayed branches and seedlings at site 10 were collected during 2017 - 2018. There were fewer symptomatic seedlings than sprayed branches on the trees. Overall, disease incidence on the branches ranged from 30% to 80%. Two symptom categories were observed, individual needle necrosis and blighting of the entire new flush. Needle symptoms were observed the most often and only a few of the branches had shoot blight. The condition of the terminal bud had no significant effect on disease incidence ($p=0.25$, t-test, two-tailed), so results from branches of all bud categories were combined for each fungicide treatment. Overall, severity of disease symptoms was very low on both the seedlings and the branch sprays when assessed in October 2017, four months after treatment, and the differences in the amount of infection between treatments was not statistically significant (seedlings, X-squared = 9.5746, $df = 14$, $p\text{-value} = 0.7926$, branch sprays, X-squared = 3.75, $df = 14$, $p\text{-value} = 0.9968$).

Although treatments had no significant effect on disease incidence on the branches, branches treated with chemicals in FRAC group 11, the strobilurins had limited symptom development. These include the active ingredients azoxystrobin, pyraclostrobin, and trifloxystrobin.

All seedlings were assessed again in September 2018. There was heavy mortality due to a period of excessive heat in summer 2018 and these seedlings were removed from the analysis. The remaining seedlings were rated for the percentage of 2017 shoots that had foliar symptoms (Figure 16). The sprayed branches on trees at sites 7 and 10 were rated in October 2018. The diseases present on 2016, 2017 (sprayed), and 2018 age classes of foliage on each tree were noted, and the percent of branches with

symptoms for each age class and fungicide treatment. Figure 17 shows results of branch spray tests for PNE at site 10. High levels of PNE were seen on 2018 foliage at site 10, and *Lirula* on 2016 foliage at this site. Because the untreated control branches only had 20% infection on 2017 foliage it is difficult to draw conclusions about fungicide efficacy. There were very low levels of all disease types on 2017 and 2018 foliage at site 7, and high levels of *Lirula* on 2016 foliage at this site (data not shown). Monitoring on these trees will continue.

The results of 2018 assessments of branch sprays and seedling exposure treatments at sites 10 and 7 were examined using Pearson correlations for PNE (site 10) and *Lirula* (site 7), as well as leaf spot caused by a variety of fungi (both sites). There was no significant correlation between the percent of branches with disease symptoms when sprayed with fungicides on 2017 foliage and disease rating on the fungicide treated seedlings exposed to inoculum for these diseases, meaning that the fungicides had no effect on disease control or possibly other confounding factors such as site conditions, were present.

Other studies on fungicides for controlling needlecast disease on conifers have had mixed results, from almost complete control of *Delphinella* on balsam fir using 11 fungicides in Quebec (Bedford et al. 2016) to variable control of *Rhizosphaera* on different sites in Ontario and Nova Scotia (Jotcham 2015). No studies have demonstrated control of *Lirula* with fungicides, possibly because of the extended period between infection and symptom expression, and also timing of fungicide applications. Chlorothalonil is the industry standard for treating needlecast diseases of conifers and is recommended for most sites, although control of these diseases is not adequate. Recommended fungicides among those tested for needlecast diseases in this study are shown in Table 8.

Activity 5: Compare the postharvest quality of decorative greenery products made from high vs. low elevation boughs.

In collaboration with industry partners, noble fir boughs were harvested from high elevation and low elevation sites in 2016 and 2017. Boughs were transported to WSU Puyallup and held in cold storage under simulated commercial conditions. During early November, wreaths were made from each of the bough sources. Wreaths were displayed for 2 weeks in the WSU Postharvest Display room maintained at 68F. The moisture status of the boughs was determined at harvest, when the wreaths were constructed, and during the display trial. Needle loss was also assessed during the display period. Statistical analysis was conducted to assess any differences in the postharvest moisture and needle retention between the sources of bough material. Two trials were done in each year of the project. In addition, a consumer survey of wreath quality was done during the second display trial of each year.

Year 1 – compare high and low elevation sites, cold storage vs immediate display

Bough material was obtained from 5 growers at a total of 15 sites in October 2016, ranging from 33 to 4255 ft in elevation (Figure 18). Wreaths were constructed from these materials in November 2016 by two workers, referred to here as Worker 1 and Worker 2. There was a highly significant effect of the worker on percent wastage and consumer ratings on the quality of the wreaths. It was observed that Worker 1 tended to cut the material into smaller pieces and trim the edges to make a more symmetric wreath, while Worker 2 tended to use bigger pieces and leave more uneven edges on the wreaths (Figure 19).

Two display trials were done. In the first trial, wreaths were displayed right after they were made. In the second trial, wreaths were held in cold storage at 34°F (1°C) for 3 weeks before they were displayed in order to determine the effect of cold storage on wreath quality and drying rate. Wreaths were weighed and needle loss data was collected three times per week. At the end of the two week display period they were

placed in a drying oven at 98°C for 24 hrs and the resulting dry weights were used to calculate changes in the moisture contents of the wreaths.

There was no significant difference between workers for the average initial wreath weight ($p = 0.4143$, t-test, two-tailed). There was a trend that wreaths made from high elevation material weighed more than wreaths made from low elevation material, but this was not significant ($p = 0.1932$). Percent wastage for each source of bough material was determined. There was a significant difference in wastage between high and low elevation sites, but the difference between workers was highly significant and this may have influenced the results. When examined separately for each worker, there was no significant difference in wastage between high and low elevation material, although there was a trend for more wastage from the high elevation materials.

A single value for drying was calculated from the area under the drying curve (AUC), which includes the sum of all measurements over the 15 day display period. Cold storage at 34°F (1°C) for 3 weeks had no effect on drying for noble fir wreaths from all sources ($p = 0.33$, t-test). Therefore, the AUC data from both cold-stored and immediately displayed wreaths was pooled for further analysis. There was a significant difference in wreath drying rate, initial wet weight, and final dry weight between the two workers ($p < 0.001$, t-test), so data for each worker was analyzed separately. The initial wreath weight was greater for wreaths made by worker 2 than by worker 1. However, wreaths made by worker 2 dried faster than those made by worker 1. There was no relationship of elevation with drying rate ($p = 0.90$, worker 1; $p = 0.54$, worker 2, t-test). There was negligible needle loss from any of the noble fir bough sources during the display period. Needle loss during the rapid initial drying period of days 1-3 was less than 1% and ranged from 0.030% - 0.603%.

Wreath quality was rated on a scale of 1-5, with a rating of 1 = unacceptable and 5 = excellent. Quality ratings for each wreath were done at the beginning, middle, and end of each two week display trial. Mean quality rating and percent moisture was examined for each of the three rating intervals (Figure 20). As expected, both quality ratings and moisture content decreased during the two week period. The moisture contents of the wreaths that were in cold storage for 3 weeks had a small, but significantly lower moisture content than the wreaths that were displayed shortly after construction. Although this trend occurred throughout the display period, there was no difference in the rate of drying between the two sets of wreaths. Overall, the cold-stored wreaths also had slightly, but significant lower quality ratings than those that were displayed immediately. Based on regression analysis, the difference in quality rating was not correlated to the moisture content of the wreaths (data not shown).

In addition to the wreath measurements, an event was held where the public could assess representative wreaths from each source and provide feedback about their preferences. Nineteen people took the survey. A scale of 0-3 was used to rate wreaths from each bough source, with 0 = not desirable, 1 = limited desirability, 2 = moderate desirability, 3 = highly desirable. In the consumer survey, there was no significant difference in overall wreath quality score between workers ($p = 0.21$, t-test), although wreaths made by worker 1 (mean quality score = 2.07) had a higher average score than those made by worker 2 (mean quality score 1.72). There was no difference in consumer ratings between high elevation and low elevation sources ($p = 0.6843$, t-test, two-tailed) and between wreaths made by each worker ($p = 0.2097$, t-test, two-tailed). The wreath with the highest rating was from source #17 (Figure 21). This material was obtained from trees at the lowest elevation site, at 33 ft above sea level.

Overall, the differences in quality of bough material appears to be related to characteristics such as the age of the tree, the location of the bough on the tree (sun-exposed vs shaded), needle orientation on the shoot, and color more than elevation. The team examined some of these factors in the second post-harvest trial.

Year 2 –Compare high and low elevation sites, early vs late harvest

A second postharvest keepability trial was conducted in November and December 2017. This trial examined the postharvest keepability of wreaths made from bough material that was collected from two high and two low elevation sites (Table 9). A bundle of boughs was collected from one tree at each site, and five trees per site were sampled. There were two harvest times to compare the effects of early (October 5-10) and late (November 9-14) harvests on wreaths made from the same trees. One wreath was made from each bundle. One of the wreath makers (Worker 1) from 2016 made all the wreaths, so the effect of worker was not an issue in this trial. An event for consumers was held to rate their preferences in wreath color, needle orientation, and overall quality.

The wreaths were displayed in a temperature (68F) controlled room and changes in the moisture status of the wreaths, needle loss and overall quality were assessed. Quality was rated on a 1 to 5 scale, where 5 = excellent, 4 = very good, 3 = good, 2 = fair, and 1 = unacceptable. As in the previous trial, elevation had very little effect on the rate of drying or quality ratings of the displayed wreaths, and harvest date was not significant (data not shown). Needle loss was not evident on any of the wreaths.

The wreaths from the late harvest were displayed and consumers were invited to come and rate them on the second day of the display period. Twenty-six people took the survey. They were asked to rate their first, second, and third choice of wreaths based on quality. The number of first, second, and third choices per wreath was summed and a value based on consumer preference was generated for each of the 20 wreaths. Consumers were also asked to rate wreath color on a 1-6 scale, from light green to very blue-green.

When scores for the wreaths from each of the four sites were compared, wreaths from site 10 scored the highest for quality and color (Figure 22). The correlation between consumer quality rating and color rating was positive ($r = 0.7168$, $p = 0.002$), and suggested that with all other things being equal, consumers preferred wreaths that have a darker, blue-green color to those that are a lighter green. The wreaths made from material at the highest elevation site were scored the lowest for both quality and color. There was a great deal of variation in quality rating among wreaths from an individual site, and sites were not significantly different ($p = 0.2915$, ANOVA). There was a significant difference among sites for color rating ($p < 0.001$, ANOVA) with wreaths from site 10 having the highest color rating and no difference in color rating among the remaining sites.

The results of the post-harvest trials suggest that for noble fir foliage, the elevation, harvest time, and time in cold storage do not affect wreath quality, and that consumers prefer wreaths with a darker blue-green color than lighter green.

Activity 6: Develop a noble fir needle cast identification and management guide, and industry updates.

A comprehensive 224 page Compendium of Conifer Diseases, which includes information on the identification and management of Armillaria root rot, Annosus root rot, Lirula needle cast, interior needle blight, needle rusts, and purple needle eater (Delphinella shoot blight) on noble fir was coedited and published by APS Press (Hansen, Lewis, and Chastagner 2018).

Industry updates:

Report on this project were made to 150 growers at the 2018 Pacific Northwest Christmas Tree Association Short Course in OR, 200 growers at the 2017 PNWCTA Short Course in OR, 20 growers at the IECTA Spring Meeting in ID, and 200 growers at the 2016 PNWCTA Annual Short Course (March) and Tree Fair (September) in OR.

An update on this project were also presented at the 2017 Annual Western International Disease Work Conference in BC, 2017 IUFRO 7.02.02 Foliage, shoot and stem diseases of forest trees working party meeting in Niagara Falls, Ontario, Canada, 2016 WSDA Christmas Tree Advisory Committee fall meeting, WA and the 2016 Region 6 Forest Health Protection annual technical meeting in OR.

In addition, the following stories and media interviews were conducted.

Interview and edit story

- Mitch Lies, Editor Christmas Tree Lookout, Needle blight back in the spotlight.
- Mitch Lies, Editor Christmas Tree Lookout, Delphinella appears to be rearing its head in the Pacific Northwest.

Press Release and subsequent interviews and stories

- Sylvia Kantor, Science Writer, CAHNRS, Washington State University. Purple needle eater threatens noble fir holiday boughs, trees. December 1, 2015. http://article.wn.com/view/2015/12/01/Purple_needle_eater_threatens_noble_fir_holiday_boughs_trees/
- Mary Anne Barga, RFD-TV Senior Producer, Rural Media Group INC. Nashville, TN December 4th
- Herb Weisbaum, Midday Anchor & Consumer Reporter, KOMO Newsradio, Seattle. December 10, 2015. consumer@comcast.net
- Bellevue Business Journal. December 1st. <http://www.bellevuebusinessjournal.com/search/label/Purple%20Needle%20Eater> (do a search for purple needle)
- Kevin Rounce, Reporter Washington Ag Network, Cherry Creek Radio. December 2nd
- Greg Martin, News Director/VP of Programming, Ag Information Network of the West, <http://www.aginfo.net/AginfoReportView.cfm?reportid=32700>
- Shanon Quinn, Education Reporter, Moscow-Pullman Daily News, December 16, 2015 – Purple needle eater attacks noble fir
- Leah Messinger Smithers: Independent Journalist and Editor, The Guardian. December 7th
- @WSUPuyallupREC research - Purple needle eater threatens noble fir holiday boughs, trees

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Anna Leon, Brian Bradac, Yazmina Venegas, and John Browning, Weyerhaeuser, have provided access to bough sites for surveys and sample collection, fungicide trials, boughs for postharvest studies, and seedlings for fungicide and pathogenicity trials. Ben Carlsen and Darrin Kasteler, St. Helens Noble Farm, have provided access to bough sites for surveys and sample collection, fungicide trials, and bough material for post-harvest studies. Other growers have provided bough material for disease ID and sources of inoculum for use in inoculation studies, material for post-harvest studies, and access to sites. David Barrett of I.E.F. Corporation provided workers and materials to make wreaths for the post-harvest study.

These foliar diseases cause economically-important effects on noble fir, which is used for Christmas tree and bough production. No non-specialty crops benefitted from this project.

Goals and Outcomes Achieved

- Progress has been made towards Goal 1: Characterizing foliar pathogens of noble fir. This has been done in activities 1, 2, and 3.
- Progress towards Goal 2: Information on the identification and management of diseases on noble fir was included in a Compendium of Conifer Diseases, which was published by APS Press in 2018. (See Activity 6).

The target of identifying foliar diseases of noble fir has been partially achieved. Continued sampling of symptomatic foliage and pathogenicity testing will provide more information on the roles of these fungi in needle cast diseases of noble fir. Because some of the pathogens that have been found on boughs have an extended incubation period between infection and symptom development it was not possible to determine the effectiveness of the 2017 fungicide treatments and complete the 2017 pathogenicity trials with these pathogens by the termination date on this project. Information was obtained relating to *Delphinella*, because symptoms appear during the same growing season as infection occurs. That is not the case with *Rhizosphaera* and *Lirula* where symptoms show up the year after infection.

Activities 1 and 3: Provided the beginning of a good understanding of the fungal community on noble fir foliage and its distribution. It is clear that years with increased June precipitation resulted in more foliar disease symptoms on noble fir, and that high elevation sites had longer periods of leaf wetness due to higher precipitation and lower temperatures. There was a difference in disease prevalence with elevation, where more interior needle blight was found at lower elevation sites, and *Delphinella* and *Lirula* needle blights at high elevation sites.

Activities 2 and 4: There were some difficulties with obtaining symptoms on the host plants in the pathogenicity and fungicide trials. This will improve with additional information about life cycles

and conditions for growth and sporulation of the individual pathogens, and their interactions with organisms, such as endophytic fungi, that may be suppressing symptom expression.

Activity 5: Additional information was obtained from the postharvest survey on consumer preferences for noble fir wreath foliage characteristics. This was related to the data collected as originally planned on the differences in elevation, storage time, and harvest time.

The target of identifying foliar diseases of noble fir has been partially achieved in Activity 1, and disease distribution in Activity 3. Continued sampling of symptomatic foliage and pathogenicity testing will provide more information on the roles of these fungi in needle cast diseases of noble fir. Information relating to this project was presented to an estimated 570 growers at regional Christmas tree conferences.

The target of creating noble fir bough needle cast disease identification and management guide was achieved in Activity 6: A comprehensive 224 page Compendium of Conifer Diseases, which includes information on the identification and management of Armillaria root rot, Annosus root rot, Lirula needle cast, interior needle blight, needle rusts, and purple needle eater (Delphinella shoot blight) on noble fir was coedited and published by APS Press (Hansen, Lewis, and Chastagner 2018). This publication is available at: <http://my.apsnet.org/ItemDetail?iProductCode=45973s>. To date 202 copies have been purchased. The proceeds from the sale of the publication goes directly to the American Phytopathological Society to support the cost of the publication, so this would not be considered program income.

Beneficiaries

Currently there are about 500 growers that are members of the Pacific Northwest Christmas Tree Association. Given that noble fir accounts for almost 45% of the Christmas tree production and virtually all of the bough harvest, I would estimate that 300 to 400 growers have benefited from this project's research/accomplishments. As indicated in the project's final report, presentations were made to 570 producers at regional grower meetings during the course of this project.

This research will provide growers and land managers with critical information that is needed to control needle cast diseases and information to assure that the increased use of boughs from low elevation sites does not adversely affect the postharvest quality of WA holiday greenery products.

This project provides information to beneficiaries on identifying the specific pathogens causing needle cast diseases that are impacting noble fir bough and Christmas tree production, determining the prevalence and distribution of these pathogens, identifying fungicides or mixtures of fungicides that are effective in controlling these diseases, and determining the difference in postharvest quality of low and high elevation bough material.

The owner of Sherwood Forest stated that "Gaining a further understanding of the needle cast diseases on noble fir is critical not only to Sherwood's ability to continue in its business enterprise, but also for the health and vitality of the holiday evergreen business in the PNW". In this project, information about diseases, such as the pathogens present and timing and conditions for infection at high and low elevation bough sites was generated that will help growers manage these diseases.

The sale of boughs and Christmas trees is a multimillion dollar industry in the Washington and Oregon. Bough prices depend on grade, volume, and type of buyer. In 2012 wholesale prices to wreath makers ranged from \$0.25-\$0.37/lb, while prices paid by wholesale florists ranged from \$0.95-\$1.20/lb. Prices for value-added products, such as wreaths and swags can be up to 100 times higher than the raw product. Boughs represent an important source of supplemental income for small forestland owners and harvesters and can cover the costs of other forest management activities such as planting and pre-commercial thinning. The presence of needle cast diseases on boughs potentially impacts all stages of the decorative greenery

products industry. Greenery companies and independent contractors often submit bids on the harvest of boughs from large public and private high elevation land owners. These diseases reduce the marketability of boughs and thus eliminate or reduce the numbers of bids for specific stands of noble fir. They also impact small private landowners who are harvesting boughs and Christmas trees. Even at low levels, needle cast diseases can increase the cost of harvesting and processing bough material because of the need to grade-out infected material.

Historically, noble fir boughs from high elevation sites have been considered to have superior postharvest quality compared to boughs from low elevation sites. In this project, no difference in postharvest quality between high and low elevation material was found, and consumer preference was based on foliage color.

Lessons Learned

A better understanding of the life cycle, infection biology, and environmental conditions needed for infection is necessary to develop protocols for pathogenicity assays and fungicide trials in this host/pathogen system. In addition, the role of endophytic fungi in disease development or suppression should be studied further. Some progress was made on these goals in this study but more research needs to be done.

Some important conclusions of this project are the following:

- The most damaging foliar diseases on noble fir are Purple needle eater (PNE), caused by *Delphinella abietis*, Interior needle blight (INB), associated with *Rhizosphaera* spp., *Lirula* needle blight, caused by a *Lirula* species similar to *L. abietis-concoloris*, and needle rusts caused by *Pucciniastrum goeppertianum* and *Uredinopsis pteridis*.
- The distribution of these diseases varies with elevation, with INB being more prevalent at low elevation sites and PNE, *Lirula*, and rusts at high elevation sites.
- Disease incidence and severity is related to increased June precipitation. In general, disease problems can be more severe at high elevation sites because of longer leaf wetness periods due to lower temperatures and higher humidity.
- Emerging foliage should be treated with fungicides to prevent infection, particularly at high-risk sites or in wet years.
- There is no difference in postharvest quality of noble fir bough material from low and high elevation sites. Furthermore, there was no difference in quality between material in cold storage for 3 weeks and displayed immediately, and no difference in quality between material harvested early and late in the season.
- Consumers preferred wreaths made from boughs that had a very blue-green color to boughs with a light green color.

The lack of differences in postharvest quality between low and high elevation sites was unexpected. This information will benefit Christmas tree growers at low elevation sites that want to use older trees for bough production. Additional consumer surveys should be done to further determine what characteristics are desirable in noble fir bough material.

The screening for fungicides for their effectiveness in controlling foliar disease was limited because of the low levels of disease that developed during the trials. This was likely due to the inability of producing spores of the pathogen in culture and the complex interactions between environmental conditions and inoculum levels associated with infection of needles. Different inoculation techniques were attempted to improve infection rates on newly emerging foliage. These included

fungicide trials where treated seedlings were exposed to natural sources of inoculum by placing them under infected trees during 2017.

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Additional Information

Cash Support: The PNWCTA provided a total of \$10,000 in support of this.

In-Kind Support: (See No. 5 above for specific names of collaborators)

Weyerhaeuser has provided \$6,973.50 worth of in-kind support consisting of access to bough sites for surveys and sample collection, fungicide trials, boughs for postharvest studies, and seedlings for fungicide and pathogenicity trials. The St. Helens Noble Farm have provided access to bough sites for surveys and sample collection, fungicide trials, and bough material for postharvest studies. Holiday Tree Farm and Hupp Farm provided bough material for postharvest studies. South Tree Farm provided several hundred PNE-infected noble fir boughs for use in the inoculation and fungicide studies. The I.E.F. Corporation provided workers and materials, valued at \$207.20 to make wreaths for the postharvest study.

Project Title: Cosmic Crisp: Training system and orchard management

Project Summary

The Washington State University (WSU) apple breeding program recently released a very promising variety, WA 38 (marketed as Cosmic Crisp[®]) characterized by an unusually firm, crisp and juicy texture and excellent storability. There are almost 5 million trees already planted and another 5 million will be planted by 2019. The first planting started in 2017 and current growers demand for this variety greatly exceeds the tree production supply and it is clear the variety has been and will be widely planted throughout the state over the next five years. Washington apple producers will require critical information on horticultural management issues and possible solutions coming from this project. The main goal was to evaluate the horticultural performance of the variety using innovative 2 or 3-axis training systems. In addition, the horticultural and economic aspects of orchard establishment of WA38 were analyzed using a top grafting approach, which can bring an orchard into commercial production much faster than the usual practice of planting young trees coming from the nursery. Planting a new apple variety requires high investment costs. In this scenario, offering alternatives to the industry that could represent lower initial investment costs, are important in order to contribute to the adoption of the new cultivar.

The embracement of a new cultivar is an expensive and risky decision for growers to take, and horticultural practices for each new variety must be optimized years in advance to minimize that business risk. This project ends the year before the first fruit of WA38 will be sold on the market in WA for the first time. All the data collected in this project are meaningful for the growers. Evaluations of vegetative, productive and quality data before the variety will hit the market can really help the apple industry to optimize the orchard design and determine the quality standard of the fruit. High investment costs could deter adoption of the promising WA38 cultivar. The motivation of the project is to demonstrate likely profits to be earned under two different alternatives, planting from scratch a block of WA38 and top grafting WA38 over a Granny Smith block.

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

Project Approach

a) Top graft an existing orchard at the Sunrise Research Orchard near Wenatchee, WA – The Granny Smith orchard was top worked to WA-38 in March 2016 (Figure 1). It was trained and maintained throughout the project, and in 2018 it entered into production.

Out of 1,433 grafted trees, 1,140 were successful and 20% of the grafts failed. Throughout the summer, lateral branches were pruned to remove tip competition (Figure 1).

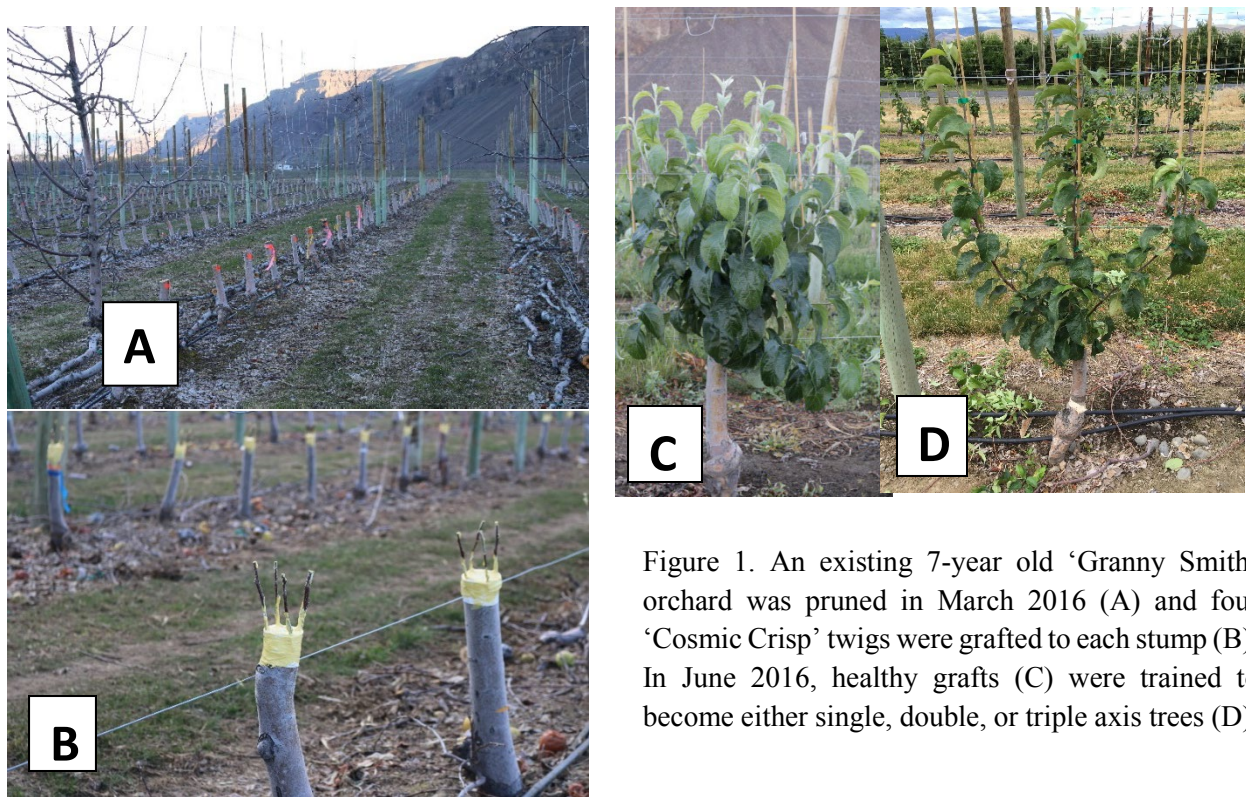
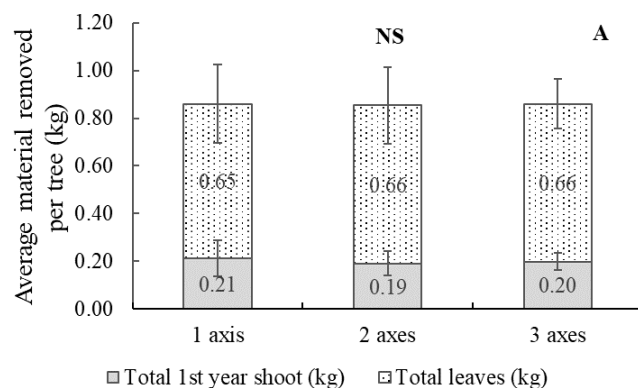


Figure 1. An existing 7-year old ‘Granny Smith’ orchard was pruned in March 2016 (A) and four ‘Cosmic Crisp’ twigs were grafted to each stump (B). In June 2016, healthy grafts (C) were trained to become either single, double, or triple axis trees (D).

The vegetative parameters of the top graft trial were measured to compare training systems with one, two or three axes. This was measured by trunk cross-sectional area, 1st year wood length and count, weight of winter wood pruned from the trees, number of flowers and subsequent fruit set, and weight of summer wood pruned from the trees. The trees were mechanically pruned in 2017 to reduce the shoot growth and enhance flower buds’ formation. Photosynthesis and stress measurements were taken as well.

The team found that the overall vigor per tree was similar between the three training systems (Fig. 1a.) and a significant trend that vigor was reduced per axis in trees with more than one axis (Fig. 2b). Also, there were significantly more blossoms and subsequent fruit set on tree with three axes than spindle (Table 1).



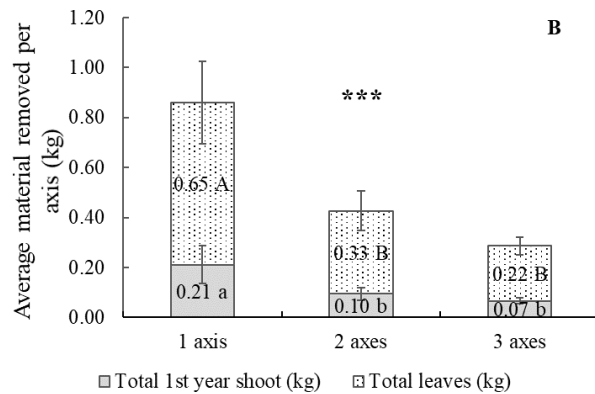


Figure 2: The weight of 1st year shoots and leaves removed per tree (A) and per axis (B) from the Cosmic Crisp grafts during summer pruning 2017. Bars represent standard deviation from the mean. *

= $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, NS = not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant.

Table 1: Blossom count, fruit set, and percentage of fruit set over total flowers per axis in Cosmic Crisp grafts. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, NS = not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant.

Top graft Cosmic Crisp 2017	Blossom cluster per axis		Blossom cluster per tree		Fruit set per axis		Fruit set per tree		Percentage of fruit set per flower per axis		Percentage of fruit set per flower per tree	
Trainin systems												
Spindle	3		3	B	0.1		0.1	B	0.30		0.30	
Biaxis	4		9	B	0.2		0.3	A B	0.71		0.66	
Triaxis	6		17	A	0.3		1.0	A	0.84		0.89	
Significance	N S		***		N S		*		N S		N S	

b) Measure vegetative and productive parameters in the experimental orchard already existing

(pruning weight, bloom, fruit set and yield).

Vegetative parameters

For vegetative vigor in 2017, the Sunrise combination with the highest amount of wood pruned in winter was Spindle, G41, Bending while it was Spindle-Nic29-Click in Roza (Figure 3 A,B). The Roza and Sunrise combinations with the least amount of wood pruned was V-Nic29-Click. For Sunrise, the combination on average with the the highest number of flower clusters was Spindle, G41 Bending, but Spindle-Nic29-Click and Bending combinations, statistically similar, reported the highest percentage of flowers set to fruit (Table 2).

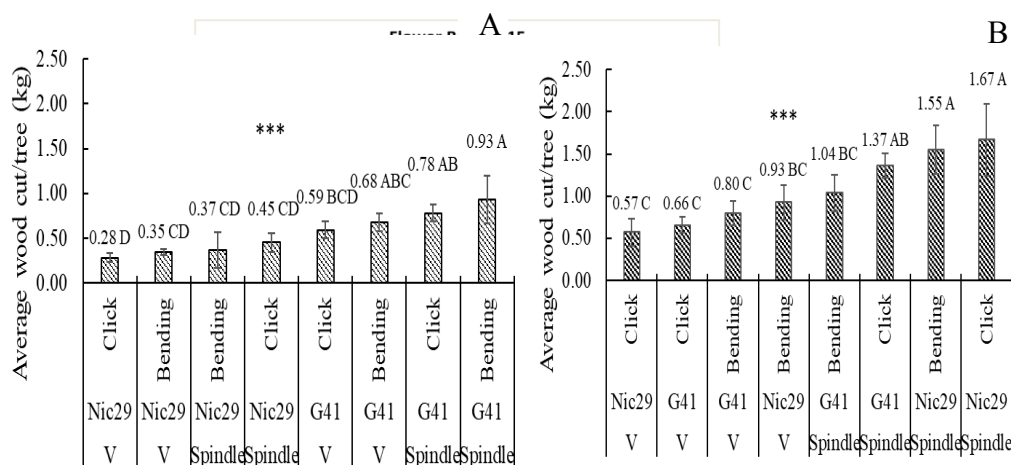


Figure 3: The weight of wood removed per tree in Wenatchee Sunrise orchard (A) and Prosser Roza orchard (B) from the Cosmic Crisp during winter 2017. $P < 0.05$, *, $p < 0.01$, **, $p < 0.001$, ***, NS, not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant. Bars represent standard deviation from the mean.

Table 2: Flower cluster count, fruit set counted in August, and percentage of fruit set over total flowers in Cosmic Crisp by training and pruning combinations in Cosmic Crisp at 5th leaf in 2017. $P < 0.05$, *, $p < 0.01$, **, $p < 0.001$, ***, NS, not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant.

Traini ng	Rootsto ck	Pruni ng	Average count of flower clusters		Average fruit set		% of flower set to fruit	
Spindl e	Nic29	Bendin g	20 5	B	115	A	9	A
Spindl e	G41	Bendin g	27 3	A	90	B	5	B
Spindl e	Nic29	Click	16 4	BC	89	B	10	A
Spindl e	G41	Click	19 1	BC	69	BC	6	B
V	Nic29	Bendin g	12 4	C	46	CD	6	B
V	G41	Bendin g	22 9	AB	47	CD	3	C
V	Nic29	Click	13 5	C	54	CD	7	B
V	G41	Click	13 0	C	37	D	5	B
Significan ce			** *		***		** *	

Spindle-G41-bending had the total highest flower buds count in 2015 (Fig. 4) but in 2016 Spindle-Nic29-click had the highest number of total flower buds (Fig. 5).

Figure 4: Flower buds of planted Cosmic Crisp at Sunrise orchards 2015. $P<0.05$, *, $p<0.01$, **, $p<0.001$, ***, NS, not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant.

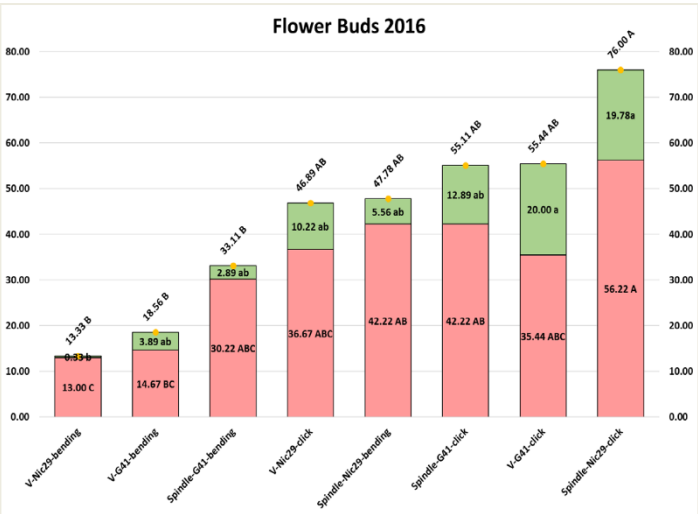


Figure 5: Flower buds of planted Cosmic Crisp at Sunrise orchards 2016. $P<0.05$, *, $p<0.01$, **, $p<0.001$, ***, NS, not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant.

**Assess fruit
quality after
harvest and
after storage –**
There was not

enough fruit in 2017 in the top graft block to have a comprehensive fruit quality assessment. Some preliminary data about young fruit (harvest 2017) are reported in Table 3. Not very many differences except for the apples produced on the 3-axis tree were on average more red than the others from other systems. In 2018, fruit was harvested, and fruit quality is currently being assessed after storage.

Table 3: Fruit quality assessment carried out one month after harvest 2017 on the few fruit produced per each training system. Top part of the table shows Ripening index (IAD), average fruit weight, red overcolor percentage, Average red intensity and maximum red intensity, and specific color parameters (Hue and Chroma) for red overcolor and background. In the bottom part of the table the internal quality parameters such as firmness of the outer part of the flesh, predicted dry matter % and traditional destructive dry matter % assessment, starch index (1-6 scale), pH, titratable acidity and exogenous ethylene concentration measured by injecting in a gas chromatograph the gas released in a jar headspace from apples sealed inside for an hour. $P<0.05$, *, $p<0.01$, **, $p<0.001$, ***, NS, not significant for Type III sum of squares model. Student-Newman-Keuls post hoc test to assign letter group to arithmetic means where model was significant.

Axes(#)	IAD @ harvest	Weight (g)	Overcolor (%)	AverageRed	MaxRed	Background Hue	Background d Chroma	Overcolor Hue	Overcolor Chroma			
1	0.65	A	250.8	86.4	2.8	B	4.1	81.2	38.7	26.3	A	34.7
2	0.50	AB	290.2	85.1	2.9	B	4.2	83.1	39.9	23.4	AB	34.8
3	0.44	B	282.3	87.9	3.2	A	4.5	72.9	38.4	20.3	B	34.3
sign.	ns	ns	ns	***	ns	ns	ns	ns	**	ns		

Axes (#)	Firmnes s M1 (Kg)	pDM % @ harvest	DM %	SSC (Brix %)	Starch	ph	Tit. Acid. Malic Acid (%)	Ethylene (nL h-1 g- 1 FW)
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1	9.5	16.4	17.3	15.4	3.7	3.5	0.95	9.1
2	9.2	16.0	17.0	15.3	3.7	3.5	0.85	9.3
3	9.3	16.2	16.9	15.0	3.6	3.6	0.89	10.1
sign.	ns	ns	ns	ns	ns	ns	ns	ns

Photosynthesis measurements – Photosynthesis and water potential measurements were made throughout the 2017 and 2018 seasons to characterize WA38 thresholds for irrigation and typical photosynthetic values for the cultivar. This will help guide irrigation practices for the industry and irrigation research in these plots in the future.

From October 2016 to September 2017, Dr. Kalcsits completed the described activities in the timeline from the original proposal. In addition to participation in pruning, training, and bloom and shoot measurements activities for the project, the photosynthetic rates of one, two, or three-leader WA38 top grafts were measured in the middle of June prior to mechanical pruning and again after mechanical pruning to assess leaf photoinhibition in leaves for the three training approaches. Additionally, an experiment was conducted with 15N isotope tracer, rubidium (a potassium analog tracer), and strontium (a calcium analog tracer) to measure differences in uptake and distribution of these elements in the different training system over the course of the growing season (from June to September). The samples were analyzed using a portable x-ray fluorometer and will be analyzed for nutrient analysis in winter 2018. However, fruit will be analyzed for elemental concentrations to see if there is a connection between vigor and nutrient composition in WA38. This data combined with the root monitoring data from 2016 will provide information on how re-grafting affects nutrient redistribution and movement in the developing tree canopy and provide information on nutrient management of top grafted orchards.

Obtain physiological stress measurements – Summer pruning substantially increased photooxidative stress in leaves that were previously located in the inner canopy and were then exposed to full light from the removal of outer branches. Photosynthesis was significantly lower.

Evaluate sunburn incidence – Sunburn incidence including spectral reflectance characterization, sunburn typing, and colorimeter measurements were made on harvested fruit in 2018 and the data is currently being compiled.

c) Economic activities:

Activity 1: The project compared the costs and returns of an existing Granny Smith block top-grafted with WA38, with those of an existing Granny Smith block. Data on top-grafting costs was gathered by interviewing growers who had experience with the activity. Data on licensing and royalty fees associated with WA38 delivered trees, propagation wood, and fruit sold were obtained from Proprietary Variety Management and WSU CAHNRS Office of Research. The production costs and returns associated with the existing ‘Granny Smith’ block was estimated with input from growers.

Significant results:

It is assumed that Granny Smith trees have a productive life beyond 20 years. It is further assumed that a grower will renovate the existing Granny Smith block in year 21 by top-grafting with WA38. This means that Year 21 of existing trees will correspond to Year 1 of the top-grafted block. Figure 1 shows the estimated production costs and total revenues for both options. In the top-grafted block, during the first year, there are no costs associated with soil preparation or planting but there are top-grafting costs. During the first two years of establishment there are no revenues. For years 3 to 5, the top-grafted block has lower total variable costs compared to the existing Granny Smith due to the lower cost of harvest activities and lower warehouse packing charges.

In a top-grafted block, total revenues in Year 3 offset all production costs. In the existing Granny Smith

block, the revenues (in year 21 and onwards) also cover all the production costs albeit they are lower than the revenues of the top-grafted block. Without considering the forgone revenues, the discounted payback period of the top-grafting investment is 3.1 years.

Yr1_TG
Yr2_TG
Yr3_TG
Yr4_TG
Yr5_TG
Yr6-Yr10_TG
Yr11-Yr20_TG
Yr21-Yr30_G
Yr31-Yr40_G

Figure 6. Gross returns and production costs of ‘Granny Smith’ top-grafted with WA38 (TG) compared to existing and established Granny Smith (G).

Considering the foregone revenues, Figure 7 shows the spread or difference in the profits between Granny Smith top-grafted with WA38 and existing Granny Smith block. For Years 1 and 2 (or Years 21 and 22) the difference is negative, that is, the foregone net revenues of the existing block are higher than the net revenues of the top-grafted block. The net revenue in Year 1 of a top-grafted block is -\$9,176/acre compared to \$1,075/acre on Year 21 of the existing block— a difference of \$10,251/acre. In Year 2, the net revenue of the top-grafted block is -\$4,498/acre compared to \$1,075/acre on Year 22 of the existing block, difference of -\$5,573/acre. In Year 3 and onwards, the difference is positive indicating that the net revenues from the top-grafted block offset any forgone revenues of the existing block.

Considering the foregone revenues of the ‘Granny Smith’ block, the discounted payback period of the top-grafting investment is 3.5 years.

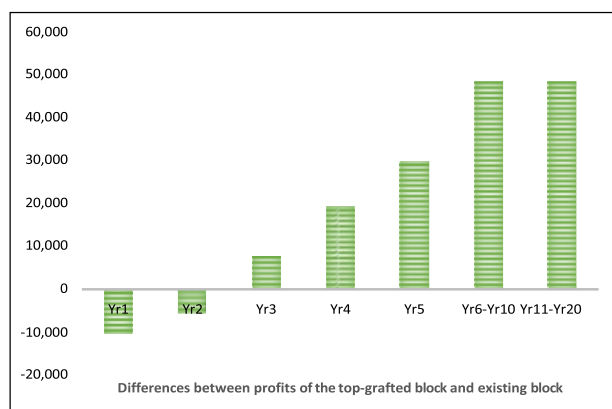


Figure 7. Spread of profits between Granny Smith top-grafted with WA38 (TG) and existing ‘Granny Smith’ (G). Note that the years correspond to the TG block (i.e., Year 1 of TG corresponds to Year 21 of an existing G block, Year 2 TG corresponds to Year 22 of an existing G block, and so on.

Activity 2: The costs and returns of establishing a block with new plantings of WA38 was compared, relative to top-grafting an existing Granny Smith with WA38, where both alternatives use a spindle trellis system. The analyses for the new planting of WA38 block are based on data collected from an experimental field trial of WA38 in the WSU Sunrise experimental field, under a spindle system with different treatments – two pruning techniques (bending, clicking), and two types of rootstock (G41 and M9-NIC29). Also, the data from the field trial are for Years 1-5 of establishment in the Sunrise block.

Significant results:

The comparison of the production costs and total revenues of a WA38 new planting with those of a Granny Smith top-grafted with WA38 are presented in Figures 8a. and 8b. given G41 rootstock and bending (8a.) and clicking (8b.) pruning techniques, respectively. Figures 4a. and 4b. show the comparison given M9-NIC29 rootstock and the two different pruning techniques.

The total variable costs of new plantings of WA38 are higher than those of a Granny Smith top-grafted with WA38. For a new planting of WA38, there are establishment costs incurred like soil preparation and tree planting in Year 1, and horticultural management activities like pruning, training and thinning until the trees become mature; also, the capital investments are still being paid. In the top-grafted block, there are no establishment costs and the fixed capital investments are assumed to have been fully paid.

However, the total revenues of new plantings of WA38 (across all treatments in a spindle system) are much higher than the production costs during the crop-producing years starting Year 3. Comparing across 4 treatments, the one with highest net revenues in Year 5 is the M9-NIC29 and clicking. Note that the estimated revenue on Year 4 is higher than Year 5 in new WA38 plantings that use a clicking technique (see S-G41-C_Y4 and S-G41-C_Y5 in Figure 8b.; and S-M9-C_Y4 and S-M9-C_Y5 in Figure 9b.). The revenues are higher in Year 4 because there were more large-sized fruits or yields relative to Year 5, and these sizes sell for a higher price than smaller ones, at the Sunrise WA-38 field trial. When comparing the two methods of orchard renovation, the total revenues of a top-grafted block are higher than those of the new plantings.

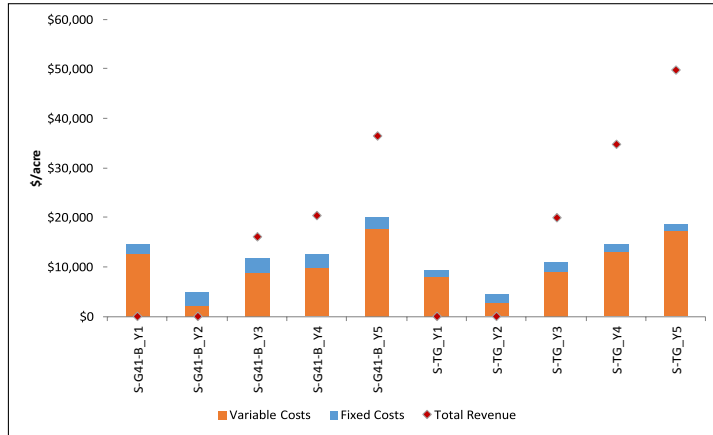


Figure 8a. New plantings of WA38 using spindle trellis system (S), G41 rootstock and bending (B) technique vs.

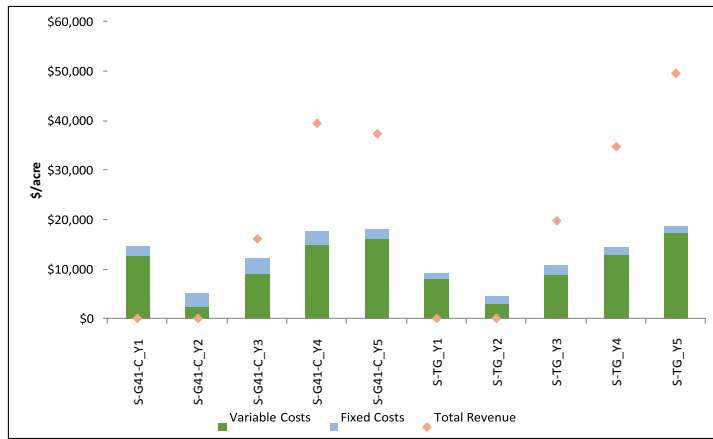


Figure 8b. New plantings of WA38 using spindle trellis system (S), G41 rootstock and clicking (C) technique vs

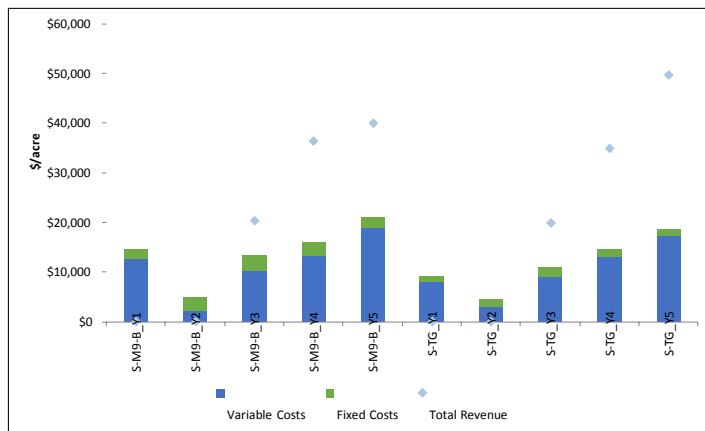


Figure 9a. New plantings of WA38 using spindle trellis system (S), M9-NIC29 rootstock and bending (B) technique vs Granny Smith top-

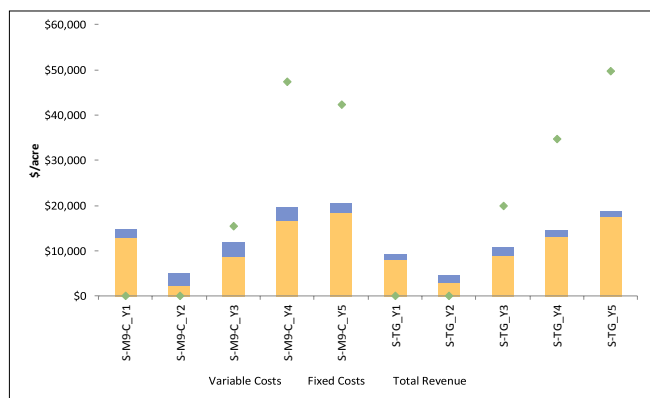


Figure 9b. New plantings of WA38 using spindle trellis system (S), M9-NIC29 rootstock and clicking (C) technique vs Granny Smith top-

Activity 3: The costs and returns of establishing a block with new plantings of WA38 under a V trellis system were compared, relative to top-grafting an existing Granny Smith with WA38 under a spindle system. Data for the new WA38 block are collected from an experimental field trial of WA38 in the WSU Sunrise experimental field, under a V system with two pruning techniques (bending, clicking), and two types of rootstock (G41 and M9-NIC29). Also, the data from the field trial are for Years 1-5 of establishment in the Sunrise block.

Significant results:

The comparison of the production costs and total revenues of a WA38 new planting using a V trellis system with those of a Granny Smith top-grafted with WA38 using a spindle trellis system is presented in Figures 10-11. Figures 10a. and 10b. show the comparison given G41 rootstock and two pruning techniques, bending and clicking. The comparison given M9-NIC29 rootstock and different pruning techniques are shown in Figures 6a. and 6b.

The total variable costs of new plantings of WA38 during the establishment years are higher than those of a Granny Smith top-grafted with WA38. Given the clicking technique in new WA38 plantings, the estimated revenue on Year 4 is higher than Year 5 (see V-G41-C_Y4 and V-G41-C_Y5 in Figure 10b.; and V-M9-C_Y4 and V-M9-C_Y5 in Figure 11b.). The lower revenues on Year 5 are caused by lower net yields relative to Year 4, and more small sized fruits that sell for a lower price than bigger ones, according to Sunrise WA38 field trial.

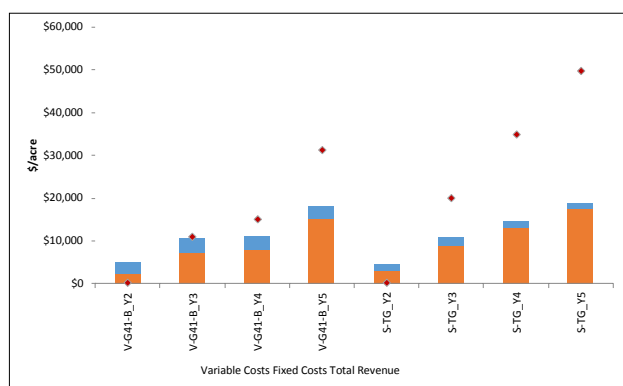


Figure 10a. New plantings of WA38 using V trellis system (V), G41 rootstock and bending (B) technique vs Granny Smith top- grafted with WA38

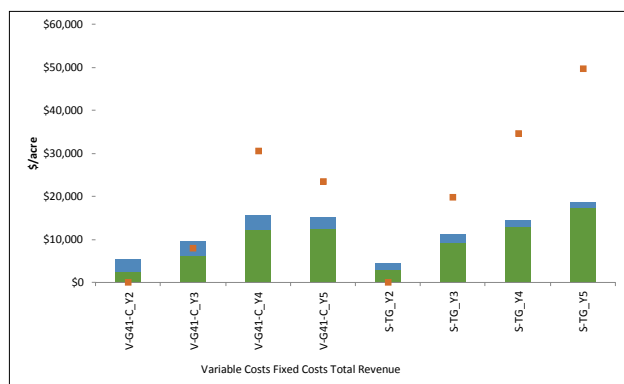


Figure 10b. New plantings of WA38 using V trellis system (V), M9-NIC29 rootstock and clicking (C) technique vs Granny Smith top-grafted with WA38 (TG) using spindle system (S).

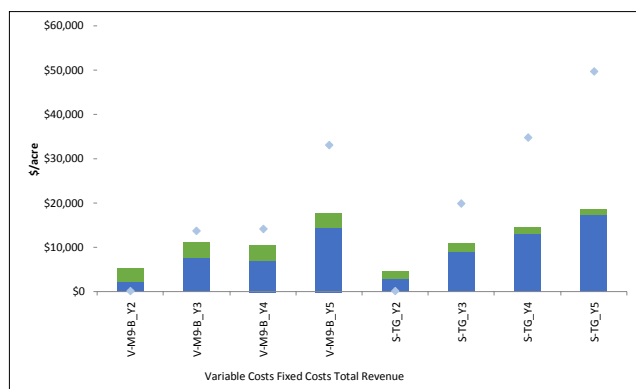


Figure 11a. New plantings of WA38 using V trellis system (V), M9-NIC29 rootstock and bending (B) technique vs Granny Smith top-grafted with WA38 (TG) using spindle system (S).

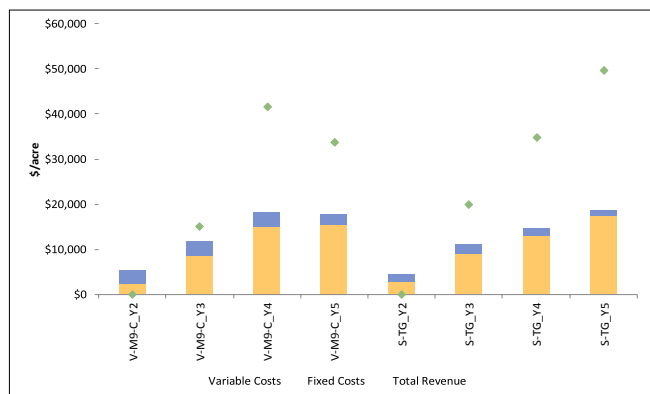


Figure 11b. New plantings of WA38 using V trellis system (V), M9-NIC29 rootstock and clicking (C) technique vs Granny Smith top-grafted with WA38 (TG) using spindle system (S).

The overall picture shows revenues that are higher for the top-grafted block as compared to new WA38 plantings regardless of the combination of rootstocks and pruning techniques.

Activity 4: Estimate the breakeven price and the payback period of both blocks, Granny Smith top-grafted

with WA38 and newly planted WA38. Different levels of breakeven prices according to the costs to be covered (i.e., variable costs, cash costs, cash costs plus opportunity costs) were estimated, using the method of discounted net returns to estimate the payback period. A discount rate of 5% is used in these analyses. This is based on the average annual effective interest rates on non-real estate bank loans made to farmers in the past 8 years (2010 to 2017), which is between 4% and 6% according to the Federal Reserve Bank of Kansas City (2018). A lower breakeven price and shorter payback period are better.

Significant results:

Breakeven return. Table 4 shows the breakeven prices for different levels of cost recovery on Year 5 of production. The breakeven prices in the first row are the prices required to cover total variable costs – soilpreparation costs for a new WA38 block, or costs to top-graft an existing Granny Smith with WA38; and for both blocks, the costs of pruning, training, green fruit thinning, harvest and packaging, maintenance and repairs, royalty fees, crop insurance, interest on operating capital and overhead. For instance, the breakeven return over variable costs for the top-grafted block is \$435/bin.

The breakeven return in the second row is the amount needed to cover total cash costs (i.e., sum of total variable costs, land and property taxes, insurance, and miscellaneous supplies), assuming there are no outstanding loans or land rent. The breakeven return in the third row is the amount required to cover total cash costs and depreciation costs of fixed capital. This value must be realized to stay in business over the long run. The fixed costs should be covered in the long run so that reinvesting in capital like machinery, equipment and buildings is possible, otherwise, existing capital stock will be at risk of depletion (Missouri Extension 2011). Note that in WA38 production, variable costs might not be strictly variable. Once the field is established, a farmer can consider the establishment costs as fixed costs and will continue to produce even if profits appear as negative in the first three years.

Table 4. Breakeven return^[1] (\$/bin) at different levels of enterprise costs - Year 5.

Levels of Production Cost	Top-Grafted, Spindle System	New 'WA-38' Plantings, Spindle System				New 'WA-38' Plantings, V System			
		G41-B	G41-C	M9-B	M9-C	G41-B	G41-C	M9-B	M9-C
1. Total Variable Costs ^[2]	\$435	\$578	\$550	\$522	\$497	\$583	\$652	\$516	\$537
2. Total Cash Costs ^[3] = Total Variable Costs + Land & Property Taxes + Insurance Cost + Miscellaneous Supplies	\$444	\$590	\$563	\$532	\$507	\$597	\$671	\$530	\$550
3. Total Cash Costs + ^[4]									

Depreciation Costs	\$459	\$608	\$581	\$547	\$522	\$622	\$704	\$552	\$572
4. Total Cost									
= Total Cash Costs + [5]									
Depreciation Costs + Interest Costs + Management Cost	\$467	\$661	\$622	\$581	\$555	\$705	\$791	\$625	\$616
Net yield (bins/acre) =	40	30	29	36	37	26	19	28	2
Price per bin (baseline) =	\$1,241 ¹⁰¹	\$1,197	\$1,273	\$1,103	\$1,148	\$1,214	\$1,226	\$1,174	\$1,175

Notes:

[1] Breakeven return is calculated as cost divided by yield.

[2] If the return does not cover total variable costs then apples are uneconomical to produce.

[3] The second breakeven return allows the producer to stay in business in the short run.

[4] The third breakeven return allows the producer to stay in business in the long run.

[5] The fourth breakeven return is the total cost breakeven return. Only when this breakeven return is received can the grower recover all out-of-pocket expenses plus opportunity costs.

[6] For new 'WA-38' plantings, a weighted average price / bin is used. It is calculated considering the yield distribution according to fruit size resulting from field trials, and the 'Honeycrisp' price corresponding to each fruit size.

The final breakeven return in the fourth row covers the total cost of production. It is only when this breakeven return is received that the grower is able to recover all cash costs, depreciation, and opportunity costs. Not obtaining the final breakeven price means the grower will not receive a return on capital contributions equal to what could have been earned through an alternative investment. On the other hand, receiving an actual price greater than the estimated total cost breakeven price means that in addition to covering all cash and opportunity costs, the grower will receive a return for management and the financial risk assumed in producing WA38.

Results show that the breakeven prices at different cost recovery levels of Granny Smith top-grafted with WA38 are lower than those for new plantings of WA38. For instance, the estimated breakeven price given total costs is \$479/bin for a top-grafted block compared to \$661/bin for new WA38 plantings that include a spindle system, G41 rootstock and bending technique. Generally, a lower breakeven return is more desirable because the target point at which revenues equal production costs is lower.

Factors impacting breakeven prices. As discussed previously, breakeven prices are determined by the levels of production costs and net yield. To determine the effects of the production costs and net yields on the breakeven prices a regression analysis was conducted: $BBB_i = \alpha + \beta_1 TTTT_i + \beta_2 NNN_i + \beta_3 TTTT_i * NNN_i + \varepsilon_i$, where i = different treatments (top-grafted spindle, or new block with different trellis systems, rootstocks and pruning techniques); TC = total cost; NY = net yield; and TC*NY = interaction term; and ε_i = random disturbance term. Using the average of net yield (29.30 bins/acre) in the above equation, the impact of TC on the breakeven return can be derived as follows: $\beta_1 + \beta_3 \cdot 29.30 = 0.02$. This value implies that, given the average net yield, a \$1 increase in total production cost will lead to an increase in breakeven return by \$0.02.

On the other hand, using the mean total production costs (\$18,532 /acre) in the first equation, the impact of NY on the breakeven return is derived by: $\beta_2 + \beta_3 \cdot 18,532 = -17.37$. This means

that for 1 bin increase in net yield, the breakeven return decreases by \$17.37.

Payback period. The estimated discounted payback period will vary depending on the costs included in the calculation. The cumulative discounted net returns from Years 1 to 5 for each treatment are plotted in Figures 12-13 below. The payback period in these figures is the point at which the line intersects with the horizontal axis.

If total cash costs are considered, which is the sum of total variable costs, miscellaneous supplies, land and property taxes, and farm insurance, the discounted payback period is 3.06 years for a top-grafted block and 3.92-4.52 years for new WA38 plantings depending on the treatment (Figures 12a. and 12b.).

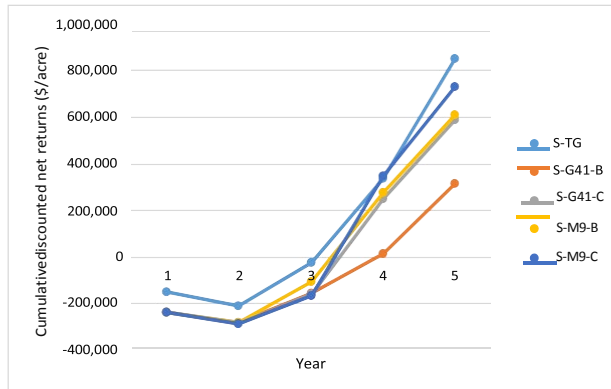


*Figure 12a.
Cumulative discounted
net returns, given total
cash costs, of Granny
Smith top- grafted with
WA38 (TG) using
spindle system (S)
compared with those of
new plantings of WA38
using the same trellis*

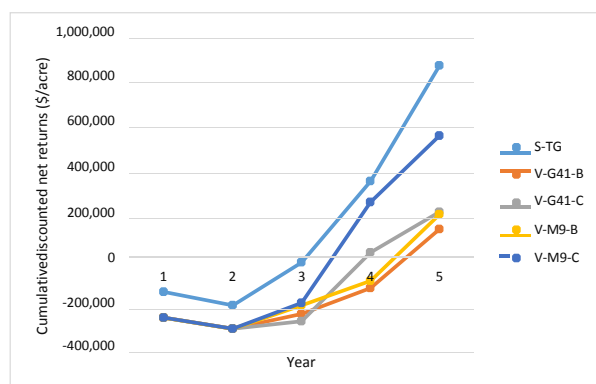


Figure 12b.
Cumulative discounted net returns, given total cash costs, of Granny Smith top-grafted with WA38 (TG) using spindle system (S) compared with those of new plantings of WA-38

If all production costs are included, which is the sum of total cash cost and fixed capital investment, the discounted payback period is 4.9 years for a top-grafted block. For new WA38 plantings, it is 3.11 years in S-G41-C, 4.48 years in S-M9-B, and 4.2 years in S-M9-C (Figure 13a.); and 4.8 years for V-M9-C (Figure 13b.). Recall that S and V refers to spindle and V trellis systems respectively, G41 and M9 (stands for M9-NIC29) are rootstocks and, B and C are bending and clicking pruning techniques.

For the other treatments – S-G41-B (Figure 13a.), and V-G41-B, V-G41-C, and V-M9-B (Figure 13b.), the discounted cumulative net returns as of Year 5 are negative. Since the data from field trials of all treatments for new WA38 plantings are available only up to Year 5, it is not yet known when the cumulative returns of these four treatments will become positive. Hence, their respective payback periods cannot be calculated.

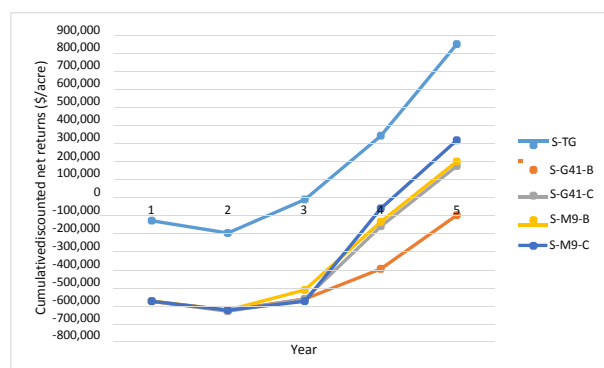
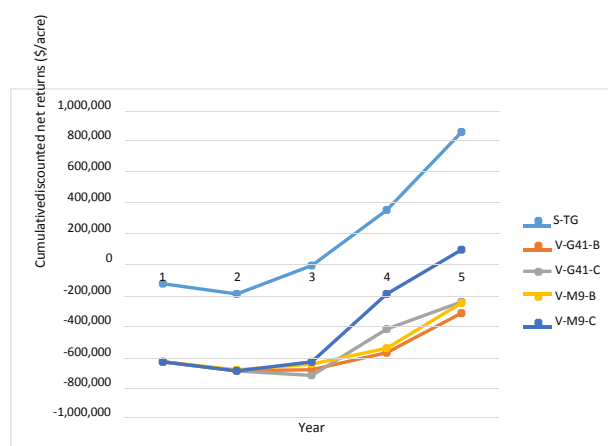


Figure 13a.
Cumulative discounted net returns, given total costs, of Granny Smith top-grafted with WA38 (TG) using spindle system (S) compared with those of new plantings of WA38 using the same trellis system, and different rootstocks, and pruning techniques.



Stefano Musacchi (Professor & Endowed Chair of Tree Fruit Physiology and Management at WSU) has been coordinating all the project activities and the data collection in all trials. He personally participated in the pruning and harvest activity during 2016-2017. He also participated at the field day organized in 2016-

17-18 and in the report writing.

Sara Serra (Assistant Professor at the Dept. of Hort.) was involved in the main activities of the trials: pruning, harvest, and fruit quality assessments and data analyses.

Lee Kalcsits (Assistant Professor) was involved in experimental planning, establishment, maintenance, and data collection for the regrafting portion of the project. Data collected included root growth information, nutrient uptake and remobilization, xylem functionality characterization of WA38 during fruit development, photosynthesis and leaf fluorescence before and after summer pruning, sunburn and disorder characterization, yield and productivity data, and bloom and fruit set information. In the next year, some additional extension information as well as a peer-reviewed publication are expected to be derived from the data collected during the project period.

Karina Gallardo (Associate Professor Extension Specialist at the School of Economic Sciences-WSU), and Suzette Galinato contribution was to estimate and compare the costs and benefits of establishing a new WA38 block with a Granny Smith top-grafted with W-38 block.

Desmond Layne (Professor & Endowed Chair Tree Fruit Extension Program Leader) participated in the organization of the field days with Tianna Dupont (WSU Extension tree fruit specialist). From the extension side of the project, a realignment of duties occurred because Dr. Desmond Layne has left his position. Therefore, the surveys using iClickers and the articles written for the American Fruit Grower, Capital Ag Press and the interview with AgInfo.net (radio program at 6:00 am on statewide radio) has been removed from the extension plan. However, the team anticipates a continued strong extension component to this project with the help of the entire project team with Tianna Dupont and Karen Lewis (New WSU Extension Leader). The team created an online and dynamic publication that is regularly update and available to growers.

The project benefitted only specialty crops, specifically apples.

Goals and Outcomes Achieved

Activities completed in order to achieve the performance goals and Expected Measurable Outcomes for the project include:

Minimizing orchard management problems and optimizing fruit quality.

The team classified WA38 as a type IV tree, with upright and spreading limbs of high vigor, with tendencies for “blind wood”, vegetative growth void of branching and flower buds. This kind of wood indicates a need for contextualized and proper training and pruning practices. Prof. Musacchi developed a pruning system called ‘click’ able to minimize this negative effect. Growers estimate an increase of yield around 20-30% with the adoption of this pruning technique combined with girdling.

WA38 achieved an important level of yield with 41 MT/acre in the V system. Information about its potential for biennial bearing has been provided, as well as the impact of crop load on fruit quality. For each cultivar, especially new released ones not fully understood yet, there is a need for contextualized research to aid the industry in producing high yields of premium quality fruit.

Compare establishing new WA38 orchards to top working an existing ‘Granny Smith’ orchard.

All the meaningful data collected so far is summarized in the report. The tree canopy growth has almost filled up the space in the second year. The first consistent crop of the top worked orchard was harvested in 2018 and full production in 2019.

Evaluate the economic benefits of management practices.

It is expected that growers will adopt the WA38 cultivar in the long term. Progress made is in terms of the cost-benefit analysis conducted under the project, which demonstrated the economic feasibility of WA38 cultivar either by top-grafting or planting new trees.

The difference in break-even prices for a newly planted ‘WA-38’ compared to an established old ‘Granny Smith’ ranges from \$116 - \$352 / bin; being the median \$234 /bin. So yes it is correct to conclude that the grower income will increase by at least \$200 /bin. The ‘WA-38’ apple will not be available in the marketplace until the fall of 2019.

Initial list of activities

Project Activity	Accomplished
Top graft an existing ‘Granny Smith’ orchard at the Sunrise Research Orchard near Wenatchee, WA	Yes
Measure vegetative and productive parameters in the experimental orchard	Yes
Prune the two experimental ‘Cosmic Crisp’ orchards in Wenatchee and Prosser (WA)	Yes
Assess fruit quality after harvest and after storage	Yes
Count flower buds to estimate bloom return	Yes
Measure the vegetative response of the top graft tree trained with 1-2-3 axes	Yes
Photosynthesis measurements	Yes
Obtain physiological stress measurements	Yes
Evaluate sunburn incidence	Yes
Hold field days in Wenatchee and Prosser (WA) before harvest to highlight preliminary results	Yes
Work with stakeholders to implement orchard design guidelines and cultivar-specific practices for sustainable tree fruit production	Yes
Present results at the state horticultural society meeting and publish in international peer-reviewed journals	Yes

Collect data on establishing and producing a commercial ‘Granny Smith’ block	Yes
Collect data on establishing and producing a field trial ‘Cosmic Crisp’ block	Yes
Develop partial budgets to compare and contrast establishing costs of ‘Granny Smith’ versus ‘Cosmic Crisp’	Yes
Develop simulation scenarios to assess potential industry benefits of grafting ‘Granny Smith’ or other cultivars with ‘Cosmic Crisp’ apples	Yes

The estimated revenues of a Granny Smith block top-grafted with WA38 offset all foregone revenues of the existing Granny Smith block.

Planting new trees of WA38 across all treatments (i.e., different trellis systems, rootstocks and pruning techniques) produce higher gross revenues than top-grafting existing trees.

Two companies in Washington have begun to implement “click” pruning and girdling technique on 1,600 acres of newly planted orchards of high value cultivars (\$500-\$800 per bin). Potentially, these techniques can increase crop value by \$16-\$25 million yearly. The economic impact for WA38 is estimated to be even higher.

During 2016-2017 a total of 5 field days were organized at two different locations with 520+ participants, 1 video was produced, 4 articles were published, and data was presented at 3 events.

Beneficiaries

Expected beneficiaries are WA state apple growers contemplating adopting the WA38 cultivar. The successful development of this variety and recommendations about training systems are a great benefit to the Washington apple industry.

With 9 million trees on the market in the next 5 years and an average planting density of 1,500 trees per acre, 6,000 new acres of WA38 will likely be planted. Assuming an increase in production of up to 20 bins per acre using these pruning techniques, the increase in value is estimated to be \$60-\$96 million yearly depending on the selling price of WA38.

Beneficiaries are the 1,450 apple growers in Washington State that have all been exposed to the results of this project.

Lessons Learned

There have been no obstacles encountered that have prevented the completion of objectives described in the proposal. The first crop of the top worked plot occurs in 2018 and required an extension of the time line of the project of 6 months. The team learned that top graft practice can delay the crop at the third year after the graft execution and that the first year of full production is the fourth after top grafting the old orchard. The orchard located in Roza has been decommissioned and no more data has been collected there in 2018. There were no unexpected outcomes or results that effected the implementation of the project.

The expected measurable outcomes of the project were achieved.

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Email: stefano.musacchi@wsu.edu

Additional Information

The WTFRC provided \$54,139 in cash match. The existing orchards cost of establishment and conversion is valued at \$50,000. WSU contributed \$49,723 in indirect charges. The total matching funds of the project are \$153,862.

Field day:

1. WA 38 Fall Field Visit –Rock Island - September 27, 2017 (Stefano Musacchi, Ines Hanrahan, Kate Evans, Sara Serra, Karen Lewis and Tianna Dupont). 102 people attended the field day.
2. WA38 Pruning Demos – WSU SRO & Roza December 13, 2017- December 14, 2017. Over 200 people participated.
3. WA38 Summer pruning tour – July 20, 2018 – Naches/Yakima/Prosser. Over 120 people attended the field day.
4. WA 38 Fall Field Visit – Roza (Prosser) and Sunrise (Rock Island) - September 11, 2018 (Stefano Musacchi, Ines Hanrahan, Kate Evans, Sara Serra, Karen Lewis and Tianna Dupont). 100 people attended the field day.
5. Several tours with growers and colleagues from all over the world.

Web articles

1. Living online documents about how to grow Cosmic Crisp (<http://treefruit.wsu.edu/web-article/wa38-horticulture/>)
2. <http://treefruit.wsu.edu/wa-38-characteristics-and-horticulture/>
3. <http://treefruit.wsu.edu/wa38-faqs/>

Professional presentations/conferences

1. Washington State Tree Fruit Association 112th annual meeting – Wenatchee, WA- December 5 to December 7, 2016. Stefano Musacchi presented “WA 38 Horticulture: Planting, Growing, Harvest and Storage.”
2. Apple Commission Review – Wenatchee, WA – January 27, 2017. Poster presented, “WA38: Rootstocks and Training Systems (Update 2016).”
3. American Society for Horticultural Science annual meeting – Hawaii – September 18 to September 22, 2017. Stefano Musacchi presented “Cosmic CrispTM optimization of rootstock, training system and pruning technique.”
4. American Society for Horticultural Science annual meeting – Hawaii – September 18 to September 22, 2017. Brendon Anthony (graduate student) presented the poster “Crop Load Effect on Fruit Quality in Cosmic Crisp”.
5. Fruit Day Chelan – January 15th, 2018. WA38 Horticulture Update. Stefano Musacchi, Karen Lewis and Sara Serra
6. Wilbur-Ellis meeting – Wenatchee, WA – February 26th, 2018. WA38 Horticulture Update. Stefano Musacchi

Scientific articles:

1. Knerl, Angela, Brendon Anthony, Sara Serra, and Stefano Musacchi. "Optimization of Leaf Area Estimation in a High-Density Apple Orchard Using Hemispherical Photography." HortScience 53, no. 6 (2018): 799-804.

Project Title: Deep sub-surface micro-irrigation to increase water use efficiency in vineyards

Project Summary

The Columbia Basin of Washington State is one of three areas within the United States capable of producing more than 300 different crops. This ability stems from irrigation from river systems that traverse through the major growing regions and provide irrigation to lands that would otherwise support native desert vegetation typical of the intermountain west. Underground aquifers are limited and not capable of supporting the current level of agricultural production derived from surface water. Additionally, ground water quality is often lower than the surface water, but varies by locale. Most importantly, most irrigation water has been adjudicated and water is demanded by many competing interests, including fisheries, energy production, and domestic use.

Against this backdrop scenario has emerged a profitable crop with an 8 percent annual growth in acreage, winegrapes, which has placed Washington State in second place only to California and quickly achieving an enviable recognition for high quality premium wines. The only factor currently threatening continued growth of this phenomenal industry is availability of water <https://www.washingtonwine.org>. Therefore, use of water must become more efficient, and new, cost-effective methods must become available for use by growers. Alternatively, acreage now committed to current crops may need to be converted to wine grape production to maintain expansion of this new industry.

Irrigation is typically applied to wine grapes as surface drip which is considered an efficient and effective method. However, in the hot, dry region of Washington State, water is lost to both soil surface evaporation and weeds. Additionally, vine root systems become mostly concentrated in the upper 18-20 inches (0.5 m) of the soil profile under current irrigation strategies (Stevens and Douglas, 1994; Bauerle *et al.*, 2008; Davenport *et al.*, 2008). This condition is compounded by the fact that wine grapes in this region are mostly own-rooted from varieties that typically develop shallow to medium depth root systems (Keller *et al.*, 2012). These growth patterns may be more susceptible to both cold intolerance and drought during infrequent, short-term climatic perturbations such as experienced in 2010 and 2015.

Deficit irrigation is known to enhance a number of compounds related to production of premium red wines and substantial literature has been published on this topic that is summarized in detail by Chaves *et al.* (2010). Likewise, subsurface drip irrigation has emerged as an effective water saving strategy in a number of row crops (Lamm *et al.*, 2012; 2015). Some growers in Washington had attempted to use subsurface micro-irrigation applied through buried lines and many reported that this system failed their expectations because of soil clogging of emitters and chewing damage by burrowing rodents. Therefore, a newer form of subsurface water delivery was developed in the lab during 2013-2014 which was labeled direct root-zone (DRZ) micro-irrigation.

To investigate opportunities for increasing water use efficiency, a coordinated, trans-disciplinary research effort in 2014 was initiated with three broad objectives: 1) determine the potential and feasibility for use of a new form of sub-surface drip irrigation which might improve water conservation while improving the use of deficit irrigation in the production of high quality premium red wine grapes; 2) gain a better understanding of the potential advantages of developing deeper root systems of vines to obtain moisture from the available soil profile in the rhizosphere; and, 3) evaluate the potential of remote sensing to monitor water stress on the whole vineyard scale when applying direct root-zone micro-irrigation at rates much lower than used to meet commercial wine grape production goals.

This project did not build on a previous SCBGP project.

Project Approach

Direct root-zone (DRZ) subsurface micro-irrigation treatments (see detailed description below) were installed in a commercial block of Cabernet Sauvignon wine grapes located on Kiona Vineyards, Block 2 (46°16'59" N, 119°26'33" W) in the Red Mountain American Viticulture Area (AVA) near Benton City, WA in early 2015. Soil on the experimental site is of the Aridisol order and classified as a Hezel loamy fine sand (Xeric Torriorthents) on a terrace landform with parent materials being eolian sands over silty glacio-fluvial sediments deposited at the end of the most recent ice age. These soils are well-drained, subject to wind erosion, and relatively infertile, containing very low amounts of organic matter. Depth to nearest water table is more than 80 inches (>2 m). Normal annual precipitation is 8.83 inches (224 mm) and occurs mainly as rainfall during the dormant growing season. Summer temperatures average 70°F (21°C)

with mid-day temperatures reaching 90°F (32°C) or higher and cooling during the night, typical of a desert climate. These conditions favor the development of high quality red wine grapes under irrigation. The research site was planted to Cabernet Sauvignon (Clone 2) of own-rooted vines on a spacing of 8' (2.5 m) between rows and 6' (1.8 m) between vines. The vineyard was 8 years old at the beginning of the 2015 growing season.

Experimental Design: During the Proof-of-Concept phase of the study (2015-2017), a randomized complete block with two main effect treatments, irrigation rate and depth of delivery sub-surface was used with a split plot super-imposed to compare pulse irrigation and constant delivery. Each treatment plot involved 15 vines (5 vines x 3 rows) with the center-most 3 vines designated for physiological measurements while being buffered by other vines receiving the same treatment. Each of 18 treatment plots was replicated 3 times (810 vines) and yields were compared with 12 plots (180 vines) receiving full commercial rate of irrigation via surface drip. Irrigation scheduling was determined by the vineyard manager according to long-standing guidelines used to meet commercial production goals. In 2017, pulse irrigation was discontinued and some of those plots were repurposed to allow direct comparisons of surface drip and DRZ (subsurface drip) delivery at equal rates on grape yield, vine stress levels, and fruit quality. Since no consistent differences in yield or grape quality were related to DRZ delivery depth during the first two years of the study, all DRZ treatments were delivered at the 2-ft. depth for the new phase of the project. Additionally, rates of water application to the treatments were raised to 80, 60, and 40 percent of full commercial rate. This modification to the original design permitted direct measurements between surface and subsurface (DRZ) and allowed relative water use efficiencies to be determined for grape production (yield) and grape quality (phenolic and other chemical components).

Direct root-zone delivery device. DRZ is designed to deliver water deep within the root zone vertically through PVC pipes. This approach was used to avoid the two most common problems associated with use of buried driplines – clogging of emitters in contact with soil and chewing damage of buried lines. An additional advantage was the ease of installing within established plantings of perennial crops such as grapes.

To install this system, a 1 inch (25.4 mm) diameter hole was bored vertically to a depth of 1, 2, or 3 foot (30, 60, and 90 cm respectively) about 1.5 foot (45 cm) either side from the base of each vine and beneath the trellis wire and suspended irrigation dripline. A length of PVC tube was inserted into each hole. Each section of PVC pipe was previously cut to length to reach the desired depth while extending above ground for a given distance and then split about 6 inches (15 cm) from the lower end with a band saw to allow sufficient water passage to move into the soil to reduce the backing of water up the tube. A PVC cap, previously drilled to allow passage of a one foot (30.5 cm) length of ¼ inch (6.35 mm) diameter micro-tubing through the hole prior to attaching one end to a barbed connector and inserted into the main horizontal water line, and attaching a pressure compensating drip emitter at the other end of the feeder tube before placing the emitter snugly into the top of the PVC tube beneath the drilled out cap. Emitters were

selected to deliver 0.5 gallon (2 liter) per hour, thus delivering approximately 1.2 gallon (4 liters) per vine per hour.

Installation of all treatments involving 990 vines was completed prior to beginning of the 2015 growing season. Additionally, soil moisture access tubes containing electron capacitance sensors were installed in designated plots to monitor soil water dynamics both temporally and spatially across depths within the top 6.5 feet (2.0 meters). This technique measured soil moisture content (data not shown) continuously when using the SynTek EnviroSCAN <https://www.sentek.com.au> or by supplemental spot reading when using the SynTek Diviner. Irrigation events were monitored by data transmitted from the EnviroSCAN probes via cellphone transmitters to a base server AgriNET <http://www.grovision.com>.

Monitoring of plant water stress. Vine water stress was determined by periodically sampling the center three vines of direct root-zone treatments and control vines by measuring mid-day xylem water potential using the pressure bomb method (Scholander *et al.*, 1965). Leaves were selected on the east side of vines (most sun drenched prior to sampling), then covered with a plastic bag inside an aluminum foil exterior envelope and allowed to equilibrate for about an hour prior to sampling. The encased leaf was detached from the vine by severing the petiole with a razor blade, then quickly removed from the bag and inserted into the pressure chamber, while shielding the leaf from direct sunlight, then pressurized with nitrogen gas to the point of water movement from the cut petiole. Pressures were measured in pounds per square inch (psi), then converted to mega-pascals. These data were correlated with multi-spectral digital images obtained through aerial and ground-based platforms during both growing seasons as described and reported by Zuniga *et al.* (2017; 2018). Visual observations of plant condition were documented with digital photos to document phenological impacts on vines from treatments as described by Keller (2005). Additionally, periodic measurements of gas exchange were taken with a field portable auto-porometer to gauge vine physiological activity.

Determination of grape production and quality. In 2015, grape clusters from designated vines were collected to determine estimates of production, as well as number and size of berries in each treatment and control block. Sampling was executed during two stages of maturity, early-*veraison* and mid-*veraison*. At the 2015 harvest date (September 26), all grapes were harvested at end of growing season from replicated rows of each treatment and weighed by individual vine. In 2016, cluster sampling was not repeated, but all vines in the treatment plots and a sample of commercially irrigated vines were harvested on September 24 and weighed. Samples of grapes from specific treatments were collected two weeks prior to harvest and submitted to a private commercial laboratory for analytical determination of a number of characteristics associated with quality red wines. Samples of clusters from each treatment were also taken at the date of harvest and submitted to the same commercial lab for juice and phenolics analyses. A similar sampling procedure was used in 2017 and 2018 to directly compare DRZ delivered at the 2-ft. (60 cm) depth with surface drip treatments, both applied at equally reduced rates in replicated plots during the second phase of the study.

The multi-disciplinary composition of the project team proved valuable to achieving the overall goals of the project. The application of lower amounts of water created differential levels of stress on the vines, and Drs. Sindhuja Sankaran and Lav Khot - the engineering partners of the team - were able to demonstrate the ability of remote sensing from unmanned aerial vehicles (UAV) to monitor the levels of stress on the vines. This research aspect of the project has produced two peer reviewed journal articles to date from a Ph.D. student (Dr. Carlos Zuniga Espinosa) and another journal paper under review produced by a M.S. graduate student (Ms. Momtanu Chakraborty). Another Ph.D. graduate student (Xiaochi Ma) who was advised by the lead PI has submitted a manuscript for review. These peer reviewed journal articles (listed below) discuss the potentials of remote sensing applications for monitoring stress levels to ensure vine health, as

well as subsurface irrigation for water conservation and production of high quality grapes leading to premium red wines. Two additional manuscripts are anticipated to be submitted for publication during 2019 and reporting additional research results.

This research project received matching funding from the Washington State Grape and Wine Research Program (\$90k) and the Washington State Concord Grape Research Council (\$56k). Additional support was provided by Rick Hamman of Hogue Ranches vineyards, Prosser, WA (1.2 acres of planted vineyard with irrigation and maintenance) and by Scott Williams of Kiona Winery and Vineyards of Benton City, WA (1.2 acres of planted vineyard with irrigation, maintenance, and harvesting labor).

The project benefitted only specialty crops, specifically, winegrapes.

Goals and Outcomes Achieved

a. Goal: Sub-surface irrigation applied deep within the soil profile will save half or more of the water used currently to achieve commercial levels of grape production.

Activities involved establishing research treatments within a commercial vineyard. Two sites were secured through collaborative agreements with vineyard owners/managers. Treatments were established (see previous section) and impacts on vines and grape yields were observed during the 2015 growing season. During the first year, commercial water use was determined to be 16.25 gallons of water per vine during each irrigation set. Intervals between sets were reduced as temperatures increased during July and August, then were lengthened in September and October. Electronic water controllers were used to reduce the amounts of water to 60, 30 or 15 percent of the commercial rate received in the subsurface treatment plots.

Yields in both commercial and treatment plots found that 90 percent of the commercial grape yield was achieved with the 60 percent subsurface treatment, while reductions to the 30 and 15 percent levels produced 75 and 70 percent of commercial yield, respectively.

b. Goal: Evaluate proof of concept for deep sub-surface irrigation to be accessed vine root systems.

Activities are described in previous sections. Results to date have confirmed that direct root-zone (DRZ) delivery at the 2-ft. depth has the ability to produce grape yields equal to or slightly about the same rate of water applied as surface drip or at the commercial rate of surface drip irrigation. During both 2017 and 2018 growing seasons, grape yields for DRZ irrigation exceeded those for commercially irrigated plots within the same vineyard while saving from 20 to 60 percent of the water. Grape quality analyses also confirmed that grapes irrigated with DRZ improved in quality with decreasing water rates compared to those receiving either equivalent rates of surface drip irrigation or the full commercial rate.

Water use efficiency increased in direct relationship with decreasing amounts of water applied through DRZ irrigation delivery. Rates of production efficiency (tons of grapes/acre ft. of water) were approximately 2.5 times that of commercial surface drip irrigation in both 2017 and 2018.

Both field and greenhouse studies showed that grapevines developed their root systems into the zones of subsurface irrigation in order to maintain vine health and satisfy water status requirements.

c. Goal: Evaluate utility of remote sensing to help guide irrigation scheduling for meeting commercial production goals.

As stated earlier in this report, remote sensing was proven effective in monitoring levels of vine water status or stress compared with on-plant measurements. These data, published by Zuniga *et. al*, 2017;2018, provide a clear path for use of remote sensing to guide irrigation scheduling for conserving water and improving water use efficiency in wine grape production.

Long-term goal: Growers will adopt use of deep subsurface irrigation by project end.

This long-term goal was not met by the end of the project, but is continuing to be pursued. Reasons for this goal not being achieved relate to the fact that the DRZ irrigation system components are not currently available for growers to purchase and install. The project PI has completed a course offered through an NSF grant (WSU I-Corps) designed to guide the process for developing a licensing agreement between WSU and a company with production and sales infrastructure to make this system commercially available to the public.

The activities and goals changed little during the term of the project. Most of the critical activities and goals originally established were continued through the 2018 growing season. One change that was made during 2017 was to make direct comparisons of equal, albeit reduced, rates of surface and subsurface irrigation. Another change that was made in 2017 was to raise rates from 60, 30, and 15 percent of commercial (applied during 2015-2017) to 80, 60, and 40 percent of commercial irrigation rate. The 15 percent rate was determined too low and was creating unnecessary stress on the vines.

Direct root-zone (DRZ) is a system of sub-surface micro-irrigation that delivers water directly into the plant root zone via plastic pipe placed vertically into the soil to depths of 2-feet (60 cm) or more. Field trials were initiated during 2015 in commercial vineyards to determine: 1) ability of DRZ to sustain grape production at or near commercial production goals with reduced irrigation throughout the growing season; 2) identify lowest rate of irrigation needed to achieve production goals; 3) determine ideal depth at which to deliver the water; and 4) determine advantage of applying water in interrupted pulses versus continuous application. In 2016, the team began to analyze grapes for quality attributes. After four years, it has been concluded that: 1) DRZ can sustain grape production near full production levels with water amounts reduced to 60 percent of full production rate; 2) grapes receiving reduced amounts of water (deficit irrigation) had progressively higher sugar content (% Brix), reduced levels of acidity, and higher total anthocyanin with decreasing rates of water delivery; 3) no consistent advantages were found for any specific depth beyond the 2-foot depth of water delivery; and, 4) no advantages were found to justify pulse delivery over continuous delivery.

Additionally, remote sensing obtained from small unmanned aerial vehicles or ground-based imaging proved effective for decision support for accurately timing irrigation needs of vines. The multispectral images obtained from these two platforms were processed to extract normalized and green normalized difference vegetation index images to access water stress levels in specific portions of the vineyard containing reduced watering contrasted with the remainder of the commercially irrigated vines.

Beneficiaries

Beneficiaries of this project are the 5,350 producers, laborers and processors of wine and juice grapes. Growers of winegrapes and researchers around the globe are becoming aware of these technologies and the potential benefits they provide to conserve irrigation water and to provide higher quality fruit as the results of this project are becoming published in international peer reviewed articles and presented at international meetings.

The quantitative data clearly verify that DRZ subsurface irrigation can save half or more of the water normally used to achieve commercial production goals and also enhance the overall quality of the winegrapes produced.

A secondary effort is now being advanced to conduct an in-depth economic cost: benefit analysis to assess the economic feasibility for installing the DRZ system for use on a commercial scale. A proposal has been submitted to the research committee of the WA Wine Commission for funding consideration. If funded, this

proposed economic study will support other efforts led by the lead PI to commercialize the DRZ system for widespread sale to growers in WA and elsewhere.

Lessons Learned

As this study was launched to determine unknown potential of a new type of subsurface irrigation strategy that had not been previously investigated, there were some assumptions concerning correct rates of irrigation to be used in the experiment. Reduced rates were anticipated to be possible based on other forms of subsurface irrigation used in studies on other crops and in other regions outside of the Pacific Northwest. The lead PI was advised of certain problems to expect, but none of those materialized during the study.

One lesson learned during the project concerned the placement of a pressure compensating emitter. The location will be relocated to reduce loss of pressurized water in the case of damage to the small line that delivers water into the vertical delivery tube. Another lesson learned concerned the proper depth for water delivery. Since no specific advantages were found for any particular depth, the two-foot will be recommended for future DRZ installations in winegrapes.

The project confirmed after three years of study that DRZ subsurface irrigation has potential to conserve water and to improve wine grape quality.

To date, there have been few unexpected outcomes or results. The potential use of pulse irrigation to enhance grape production did not materialize.

The project did not anticipate the need to perform an economic analysis during the last year of study. When this study was conceived, abilities for this system to exceed original expectations was not known. Economic studies are now warranted in order to seek commercialization of the DRZ system and will be proposed through additional grants.

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Additional Information

A total of \$175,000 was contributed in match by the following sources:
WSU CAHRNS matched \$32,250.

WSU matched 20% indirect charges totaling \$49,994, as well as \$55,167 in instruments and field equipment.

Washington State Grape and Wine Research Program matched \$23,000.

Washington State Concord Grape Research Program matched \$14,589.

Peer Reviewed Publications

Ma, X.C., K.A. Sanguinet, P.W. Jacoby. 2018, Performance of direct root-zone deficit irrigation on *Vitis vinifera* L. cv. Cabernet Sauvignon production in southcentral Washington. *Agric. Water Manage.* (in review).

Chakraborty, M., L.R. Khot, S. Sankaran, and P.W. Jacoby. 2018. Evaluation of mobile 3D light detection and ranging-based canopy mapping system for tree fruit crops. *Computer and Electronics in Agriculture* (in review).

Zuniga, C.E., A. P. Rathnayake, M. Chakraborty, S. Sankaran, P.W. Jacoby, and L.R. Khot. 2018. Applicability of time-of-flight-based ground and multispectral aerial imaging for grapevine canopy vigour monitoring under direct root-zone deficit irrigation. *Int'l. J. Remote Sensing*. DOI: [10.1080/01431161.2018.1500047](https://doi.org/10.1080/01431161.2018.1500047) (Impact Factor: 1.724).

Zuniga, C.E., L.R. Khot, S. Sankaran, and P.W. Jacoby. 2017. High resolution multispectral and thermal remote sensing based water stress assessment in grapevines to evaluate subsurface irrigation technique effects. *Remote Sensing* 9(9):961-976; <http://www.mdpi.com/2072-4292/9/9/961/html> DOI: 10.3390/rs9090961. [(ISSN 2072-4292) Impact Factor 3.244].

Non-peer Reviewed Publication

Jacoby, P.W. and X.C. Ma. 2018. Introducing direct root-zone deficit irrigation to conserve water and enhance grape quality in the Pacific Northwest. *Crop and Soils Magazine* Sept.- Oct.: pp. 34-37, 58. doi:10.2134/cs2018.51.0510

Pictures:



Dormant season – Kiona Blk. 2, Red Mountain AVA, Benton City, WA 2017



Summer 2017 Hogue Ranches Blk.112, Prosser, WA



Summer 2017 Kiona Blk. 2, Red Mountain A

Project Title: Evaluations of Arbuscular Mycorrhizal Fungi of onions and carrots

Project Summary

Onions are an important specialty crop in Washington State. Onion bulb crops were planted on 24,000 acres in this state in 2017, earning a farmgate value of \$130 million (USDA National Agricultural Statistics Service). The majority of Washington onion production takes place in the Columbia Basin, where growers typically fumigate the soil the fall prior to planting, and apply soluble fertilizers at medium to high rates of application. Carrot production, for which Washington State has the second-largest fresh market acreage in the nation after California, and the largest processing acreage in the nation, is associated with similar intense production practices. These practices may decrease fertilizer use efficiency because of potential negative impacts on crop-beneficial soil mycoflora such as arbuscular mycorrhizal fungi (AMF). AMF form associations with the roots of many plant species (>80% of plant species) and can help plants access soil nutrients and water. Evidence also exists that AMF help hosts plants limit infection by some pathogens as well as damage by some pests and abiotic stresses such as drought and heat stress.

Published scientific studies which informed this project have demonstrated that onions are responsive to the presence of AMF because of the relatively unbranched root structure with very few root hairs compared to most plant species.¹ It is also known, however, that high application rates of soluble fertilizers, especially phosphorus (P) fertilizers, inhibit the association of most AMF with plant roots.^{2, 3}

In recent years, several manufacturers have developed commercial AMF inoculants designed to promote colonization of crop roots with AMF species that have been selected to enhance crop performance. There are liquid, powder, and granular formulations of these inoculants, which can be applied as seed coatings, in-furrow at seeding, or banded or broadcast over the soil and incorporated. By using AMF inoculants, onion growers in the Columbia Basin could potentially increase AMF colonization of onion roots, particularly following soil fumigation, which may improve resistance to some soilborne pathogens and pests, and increase yields and quality of onion bulb crops while also reducing the rates of fertilizer applications. These effects would benefit long-term soil health. The project team members were being informed increasingly by onion growers in the Columbia Basin of the use of AMF inoculants. However, there was very little independent information available regarding the efficacy of these inoculants under typical production practices for onion and carrot crops in the Columbia Basin, including interactions of these AMF products with pesticides commonly used in onion and carrot crops (e.g., seed treatments and soil applications of fungicides with potential efficacy against AMF, and fertilization practices that potentially have adverse effects on AMF colonization of plant roots).

A preliminary (2013-14) study conducted by Dr. Lindsey du Toit's program at Washington State University (WSU), funded by the WSU BIOAg program, demonstrated that the commercial AMF inoculant BioTerra Plus enhanced onion growth and eliminated stunting caused by the soilborne fungus *Rhizoctonia solani* when evaluated in growth chamber trials using pasteurized soil sampled from the Columbia Basin (du Toit et al. 2014a, 2014b, 2014c; Sharma-Poudyal et al. 2014). However, the effects were negated by fungicide seed treatments used widely by onion growers in the Columbia Basin. Furthermore, the formulation of this and other AMF commercial products evaluated were incompatible with most onion growers' equipment, because of the predominance of direct-seeding of onion bulb crops and carrot root crops in this region (>99% of crops are direct-seeded, and <1% are planted using transplants), preventing effective evaluation of these products in onion and carrot grower-cooperator trials.⁴

¹ Brewster, J. 2008. Onions and Other Vegetable Alliums. Crop Production Science in Horticulture No. 15. CAB International, Wallingford.

² Charron, G., Furlan, V., Bernier-Cardou, M., and Doyon, G. 2001. Response of onion plants to arbuscular mycorrhizae. 1. Effects of inoculation method and phosphorus fertilization on biomass and bulb firmness. Mycorrhiza 11:187-197.

³ Charron, G., Furlan, V., Bernier-Cardou, M., and Doyon, G. 2001. Response of onion plants to arbuscular mycorrhizae. 2. Effects of nitrogen fertilization on biomass and bulb firmness.

Mycorrhiza 11:145-150.

⁴ du Toit, L.J., Paulitz, T., Sharma-Poudyal, D., and Knerr, A.J. 2014. Impact of arbuscular mycorrhizal fungi on P use efficiency and root diseases of onion crops in the Columbia Basin. 2014 Report for the Washington State University.

This WSDA SCBG project was developed to identify AMF inoculants compatible with onion and carrot growers' equipment as well as their production practices typical for the Columbia Basin, and to test the efficacy of these products in the context of commercial, direct-seeded onion and carrot production in the Columbia Basin. The primary objective was to generate independent data on the efficacy, compatibility, and economic viability of AMF inoculants under growers' field conditions. To provide insight into interpreting results from the field trials, the project also included growth chamber trials in which AMF inoculants were tested using pasteurized soil that had been sampled from the Columbia Basin. The growth chamber trials facilitated greater control than the field trials of the many factors that might interact with AMF inoculants (e.g., temperature, soil moisture, soil fertility, and soil microflora). Both the field and growth chamber trials included evaluation of fertilizer treatments in an attempt to quantify the interaction of fertilizers on AMF and the relative effects of AMF inoculants and soluble fertilizers on onion bulb and carrot root production that are representative of grower practices in the Columbia Basin.

Regulations on soil fumigation and nutrient management in agriculture are becoming increasingly strict, putting pressure on farmers to find alternative practices for managing crop health and productivity. A growing understanding of the importance of soil health and quality also is motivating action among agricultural stakeholders within Washington State. Internationally, 2015 was declared the 'Year of Soil' by the United Nations' 68th General Assembly. These factors, together with the increasing promotion of adoption of AMF inoculant use by commercial companies, and published literature on onion responsiveness to AMF, encouraged the exploration of AMF inoculants as a potential tool for reduction of fertilizer rates of application and pesticide applications in onion and carrot production in the Columbia Basin. The primary emphasis was on onion production because of anecdotal evidence that several larger onion production operations in this region had begun using AMF inoculants, partially in an effort to rebuild beneficial soil microflora following soil fumigation prior to planting onion bulb crops.

A further motivator for this project was anecdotal evidence received by the project team from farmers and agronomists in the Columbia Basin who were using AMF inoculants that there was a lack of independent, objective data on the agronomic or economic impacts of these inoculants in the various means by which they were being applied, potentially eroding already-slim profit margins. Growers in the Columbia Basin (and elsewhere) are inundated with promotional materials and products from agricultural product manufacturers, but the independent data needed to assess the manufacturers' claims is scarce or lacking, particularly for direct-seeded onion and carrot crops in the Columbia Basin.

This project is not a direct continuation of a previous SCBGP project but was inspired by a recent WSDA SCBGP project from the FY10, also led by Dr. Lindsey du Toit. That project investigated stunting in onion and pea crops planted in the Columbia Basin caused by *Rhizoctonia* spp., soilborne fungal pathogens which can severely limit crop yield and quality in the region. Field trials conducted during that project elucidated the etiology and epidemiology of the pathogens in onion bulb crops grown following cereal cover crops, and highlighted the need for effective management strategies. The study helped develop highly effective recommended management practices, including managing the 'green bridge' from cereal cover crops, and pre-plant, banded and incorporated application of the fungicide azoxystrobin. Additional experiments with AMF inoculants towards the end of that study showed suppression of *Rhizoctonia* stunting in onion seedlings, suggesting that AMF inoculants could provide an effective and environmentally-sound management tool for Columbia Basin growers seeking to control *Rhizoctonia* in onion crops. Dr. du Toit received an additional year of funding from the BIOAg program of the WSU Center for Sustaining Agriculture & Natural Resources to examine AMF inoculants in further detail for management of *Rhizoctonia* and promotion of onion growth. The results served as the foundation for this proposed SCBGP project.

Project Approach

This project included numerous field trials conducted on grower-cooperator farms in the Columbia Basin, and growth chamber trials carried out at the WSU Mount Vernon Northwestern Washington Research & Extension Center (NWREC) in Mount Vernon, WA. In total, eight commercial AMF inoculants were tested along with one mycorrhizal stimulant (Table 1). Interested grower-cooperators were given a list of commercial products and formulations at the start of the project, from which to select the product and formulation they thought would be most compatible with their equipment and interests. After the first field season (2016) and accompanying growth chamber trials, it was evident that the liquid formulations did not result in any AMF colonization of onion roots. Therefore, none of the liquid formulations was used in field trials in the second season (2017).

Table 1. Arbuscular mycorrhizal fungi (AMF) products tested in this WSDA SCBGP study.

Product	Manufacturer
AGTIV Specialty Crops Granular	PremierTech Ag, Quebec, Canada
AGTIV Specialty Crops Liquid	PremierTech Ag, Quebec, Canada
AGTIV Specialty Crops Powder	PremierTech Ag, Quebec, Canada
BioTerra Plus Dry Mix	Plant Health LLC, Corvallis, OR
MycoApply Endo Liquid	Mycorrhizal Applications LLC, Grants Pass, OR
MycoApply Ultrafine Endo Powder	Mycorrhizal Applications LLC, Grants Pass, OR
Myconate AS Mycorrhizal Stimulant ¹	Plant Health Care, Inc., Pittsburgh, PA
Mykos Gold Specialty Crops Granular	RTI-Ag, Gilroy, CA
Mykos Gold Specialty Crops Liquid (also known as “Mykos Gel”)	RTI-Ag, Gilroy, CA

¹Does not contain AMF but contains isoflavonoids that stimulate mycorrhizal fungi in the soil to colonize plant roots.

Field trials

From 2016 to 2018, 18 individual field trials were carried out for this project to test the effects of nine AMF products (Table 1) on crop growth, health, and productivity in three different onion market types (storage [13 trials], dehydration [two trials], and sweet onions [two trials]) and for fresh market carrots (one trial). Six grower-cooperators in the Columbia Basin served as the hosts for these trials. In the majority of the trials, AMF products were distributed from gandy boxes into the seed furrow at planting. The exceptions were the dehydration onion trials and the carrot trial, in which the AMF inoculants were applied to the seed by certified commercial seed conditioning operations, and the treated seed shipped to Drs. du Toit or Waters or the grower-cooperator for planting. The trials were all set up in the growers' crops, and each grower used their standard practices including, in most cases, planting fungicide-coated (pelletized) seed, insecticides, fungicides, and soluble fertilizer applications with a few exceptions in the trial to fit the specific treatments being evaluated.

Field trial evaluations typically included early season stand counts; mid-season sampling for aboveground

dry biomass of plants, leaf length, and foliar nutrient concentration; and sampling of the mature crop close to when the grower harvested the surrounding crop, for grading and yield quantification. Disease was also assessed mid-season or on mature crops: severity of pink root was evaluated on the roots of bulbs in all the storage onion trials and the dehydration onion trials, and both pink root severity and white rot incidence were evaluated in the sweet onion trials in Walla Walla. Carrot roots were evaluated for cavity spot and other diseases in the carrot trial. In four of the field trials, onion bulbs were stored for one month following harvest and tested for firmness using a modified penetrometer. Bulbs harvested from the two dehydration onion crops were tested for total dissolved solids (Brix) using a refractometer. To evaluate the direct efficacy of inoculants at inducing root colonization by AMF, root colonization was quantified in nine of the onion field trials. This was not completed for all of the trials because of the extremely time-consuming, tedious microscopic work required to quantify root colonization effectively. For each trial in which this was completed, roots cut off at least five plants sampled from each plot mid-season were then stained according to the method of Verheilig et al.⁵ and examined microscopically (10 to 20x magnification). The number of AMF arbuscules and/or vesicles was counted in 40 root sections, using a modified gridline intersection method.⁶ At least five plants per plot were evaluated in this manner.

All the field trial results showed no to minimal effects of the AMF inoculants on all measured indicators of crop health, growth, or productivity. Statistically significant ($p < 0.05$) results were limited to the following:

- 1) In 2016 trials near Paterson, WA (storage onions), Mykos Gold Granular was associated with a reduction in onion stand count relative to the control plots without AMF inoculant (443 vs. 461 plants per 40 ft of bed), and similar results were observed with AGTIV Granular (456 vs. 471 plants per 40 ft of bed), although this did not translate to a difference in bulb yield for either product compared to control plots.
- 2) In a 2017-18 overwintered sweet onion trial near Walla Walla, plots inoculated with Mykos Gold Granular had significantly greater stand count than the control plots (49 vs. 45 plants per 10 ft of double-row).
- 3) In a 2017 trial near Othello, WA (storage onions), plots inoculated with MycoApply and AGTIV Granular had significantly reduced yield of medium grade bulbs relative to the control plots (2.5 lb for MycoApply and 2.6 lb for AGTIV Granular vs. 4.4 lb in the control plots), though this was also associated with a trend (not significant statistically) towards greater yield of jumbo grade bulbs in plots with these two AMF inoculants compared to control plots.

A trend of reduced stand counts in AMF-inoculated plots was observed in several trials although this was only significant statistically in two of the trials. This may have been due to inadvertent reduction in seeding rate caused by placing AMF granules alongside seed in the furrow. Future trials could address this issue by using granules of an inert substance as a control treatment. Similar results were reported by Dr. Thaddeus Gourd from Colorado State University at the 2016 National Allium Research Conference in Savannah, GA, for large-scale, grower-cooperator field trials evaluating AMF inoculants in onion crops in the San Juan Valley of Colorado.

In four of the field trials in which root colonization was quantified, there were no significant differences in root colonization levels between inoculated plots and control plots. In one storage onion trial near Othello, WA in 2016, the inoculant MycoApply was associated with 30% AMF colonization of roots of the onion cv. Arcero vs. 18% in the non-inoculated control plots of that cultivar ($p < 0.05$). A 2017 field trial in a spring-planted sweet onion crop near Walla Walla revealed an average 70% AMF colonization of onion roots in plots inoculated with Mykos Gold Granular vs. 59% root colonization in the non-inoculated control plots ($p < 0.05$). Both MycoApply and Mykos Gold Granular were tested in multiple trials, and yielded non-significant results in all the field trials except the cases noted above.

An important observation in the 18 field trials was that AMF root colonization was observed in all the non-inoculated control plots, despite many of these fields having been fumigated with metam sodium the fall prior to planting. Onion roots generally showed 40-50% AMF colonization in non-inoculated plots, indicating the presence of endemic root colonizing fungi in the soil of these commercial production fields in

⁵Verheilig H., Coughlan A.P., Wyss U. and Piché Y. 1998. Ink and vinegar, a simple staining

technique for arbuscular-mycorrhizal fungi. *Applied and Environmental Microbiology* 64 (12): 5004-5007.

⁶Giovannette M., and Mosse B. (1980) An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infections in roots. *New Phytol* 89:489-500.

Metam sodium typically is applied either by chemigation through center pivots or injected into the ground with tractor-mounted shanks. Prior to completing the BIOAg proposal that preceded this WSDA SCBG, this result would have been unexpected. However, a survey of organic and conventional onion fields for prevalence of AMF and AMF community diversity, followed by a survey of fumigated and non-fumigated conventional onion fields, revealed no differences in prevalence of AMF root colonization in organic vs. conventional onion crops, and in fumigated vs. non-fumigated conventional onion crops.

For 12 of the 18 field trials, fertilizer treatments were included to examine the potential effects of rates of fertilizer application on AMF inoculants. Onion and carrot growers in the Columbia Basin make multiple fertilizer applications during the crop cycle. Most growers broadcast fertilizer over the field the fall prior to planting, e.g., in the form of composted manures. In addition, almost all onion growers make a pre-planting or at-planting application of ‘starter’ fertilizer banded over the bed (usually in a 6- to 8-inch-wide band over the bed), which is then incorporated into the soil with a rototiller. Additional side-dress or top-dress fertilizer applications may be made during the season by center-pivot chemigation or other application methods. In the 12 field trials in this study in which two factors were tested (AMF inoculant as one factor and fertilizer treatment as the second factor), a pre-plant, banded fertilizer application was tested with and without AMF inoculant, in addition to no pre-plant, banded fertilizer application with and without AMF inoculant. In two trials in 2016 near Paterson, WA, the grower-cooperator also included a half-rate of the pre-plant, banded fertilizer application, with and without AMF inoculant.

Results showed no evidence of interaction between pre-plant, banded fertilizer application and AMF inoculant effects. Pre-plant, banded fertilizer treatment effects were generally greater than AMF treatment effects. One or more measures of crop growth and productivity showed a statistically significant positive response of onion crops to the pre-plant, banded fertilizer application in five of the 12 trials that included fertilizer treatments (one trial near Paterson, WA in 2016; and two trials near Paterson, WA and two trials near Irrigon, OR in 2017). The lack of a significant pre-plant, banded fertilizer application response in the other seven field trials in which this was tested suggests that the pre-plant, banded fertilizer application may have exceeded the crop demand in these other onion fields. If so, this represents an opportunity for farms to cut back on fertilizer application rates, which will reduce input costs and, potentially, environmental impacts.

Perhaps the most distinct result from the field trials was the negative impact of the pre-plant, banded fertilizer applications on onion root colonization by AMF. Whether in AMF-inoculated or non-inoculated plots, the degree of root colonization by AMF typically was several percentage points less in plots that received a pre-plant, banded fertilizer application compared to plots in the same trial that did not receive this fertilizer application (Fig. 1). As described above, crop performance was more responsive to this pre-plant, banded fertilizer application than to AMF inoculants in these trials, indicating that the potential benefit offered by a pre-plant, banded fertilizer application outweighs the potential benefit of AMF root colonization in the few mildly nutrient-limited situations encountered in this study in growers’ fields in the Columbia Basin.

⁷ Knerr, A.J., Wheeler, D., Schlatter, D., Sharma-Poudyal, D., du Toit, L.J., and Paulitz, T.C. 2018. Arbuscular mycorrhizal fungal communities in organic and conventional onion crops in the Columbia Basin of the Pacific Northwest USA. *Phytobiomes* 2: *in press*. <http://dx.doi.org/10.1094/PBIOMES-05-18-0022-R>

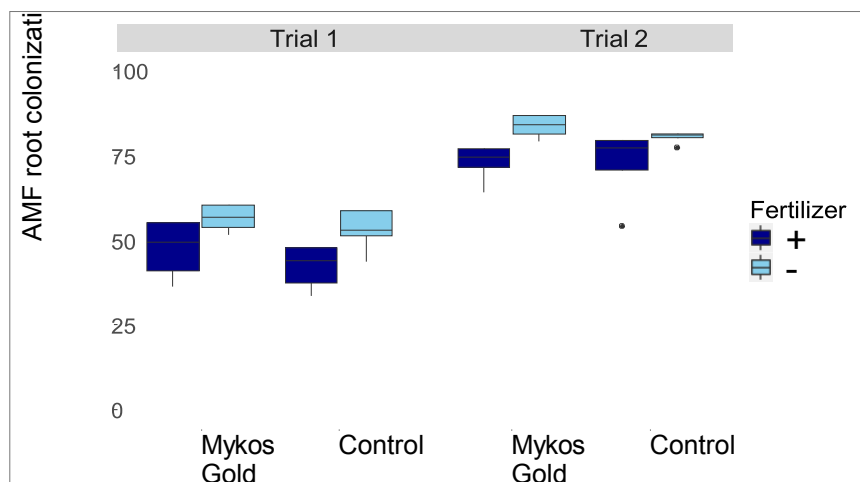


Figure 1. AMF root colonization rates in two field trials from this study in which half the plots received a pre-plant, banded fertilizer application (“+”), and half the plots did not receive this fertilizer application (“-”). Plots inoculated with Mykos Gold Granular were compared to non-inoculated control plots in combination with both fertilizer treatments. Notice that AMF root colonization rates were greater in plots without the pre-plant fertilizer application; and that

there was little difference between AMF colonization rates of onion plants in the inoculated (Mykos Gold Granular) plots and the non-inoculated control plots.

Growth chamber trials

Over the duration of this project, eight growth chamber trials were completed to complement the 18 field trials. This included three trials that were each repeated (six trials), plus two individual trials. To make growth chamber trials as representative as possible of the target growing environment in the Columbia Basin, and based on recommendations of the commercial AMF inoculant manufacturers to get the products in the soil alongside the seed as close to planting as possible, which means early spring for most onion and carrot growers in the Columbia Basin, soil was sampled from onion production fields in the Columbia Basin to set up each growth chamber trial. The soil was pasteurized to eliminate endemic AMF and ensure that any AMF activity detected was a result of the added AMF inoculant(s). Initial soil phosphorus (P) concentration of the soil was approximately 16-18 ppm. The fields sampled were selected for low soil P to facilitate amending soil P to greater concentrations for evaluating the impact of soil fertility on AMF inoculants. In some growth chamber studies, some soil treatments entailed amending the soil with superphosphate to create intermediate (40-60 ppm) and high (75-100 ppm) soil P treatments. Additional fertilizer added to the soil in these growth chamber studies was a nitrate-type Long Ashton suspension without micronutrients or P. One observational unit (replicate) in growth chamber trials was a 7 cm diameter x 24 cm long Conetainer (Deepot) in which 500 g soil was added and seeded with 10 onion seed. Each treatment combination was replicated five times, and each trial was arranged as a randomized complete block design. Most of the growth chamber trials were repeated, for a total of 10 replicates. AMF inoculants were each either blended into the soil or applied as a seed coating, depending on the trial.

Seedlings were grown for eight weeks at 15°C to mimic cooler, spring planting conditions. Observations in growth chamber trials typically included weekly seedling emergence counts, and measurement of maximum shoot length (averaged for all seedlings in a conetainer), onion seedling dry weight (total for all seedlings in a conetainer), and foliar onion nutrient concentration 8 weeks after planting. In addition, the degree of root colonization by AMF was evaluated in every growth chamber trial using the root staining and microscopic examination protocol described above in the section “Field Trials”.

In the first set of growth chamber trials, Mykos Gold Granular was blended into the soil prior to seeding. This product results in an average AMF root colonization rate of 82% which was significantly greater than 0% colonization observed in the roots of plants growing in non-inoculated control soil. In one of the two repeats of this trial, Mykos Gold Granular was also associated with significantly taller onion plants and greater onion dry weight than that of the plants in the control soil. In both trials, Mykos Gold Granular was associated with elevated concentrations of many foliar nutrients. However, such striking effects on onion growth were not observed in subsequent trials with this product over the duration of this project, despite following near-identical procedures. As a result, new (“fresh”) batches of Mykos Gold Granular were

requested from RTI-Ag to avoid the potential confounding effect of reduced shelf-life of the product affecting results of the trials. The reason for a reduction in efficacy of Mykos Gold Granular at causing onion root colonization and growth promotion in subsequent trials was not determined conclusively in this study, but highlighted concerns others have noted with variation in efficacy among trials when using commercial AMF inoculants.

While never as extensive as in the first trials, Mykos Gold Granular continued to cause more AMF root colonization than any other AMF inoculants tested in the growth chamber trials. When evaluated in soil with a lower P concentration of 16-18 ppm, Mykos Gold Granular typically resulted in 30-50% root colonization by AMF. The only other product consistently associated with root colonization rates significantly greater than 0% was AGTIV Granular, which was tested in two growth chamber trials. Under the lower soil P conditions that favored AMF root colonization, AGTIV Granular induced an average of 6% root colonization. Liquid formulations of Mykos Gold and AGTIV, however, were ineffective at causing AMF root colonization, whether mixed into soil pre-seeding or applied directly to the seed by commercial seed treaters. Granular and powder formulations of other products mixed into the soil also were ineffective. Mykos Gold Liquid was tested in a growth chamber trial in 2016 as a seed treatment in the presence and absence of several other treatments typically used in onion seed coatings for bulb crops in the Columbia Basin: Thiram (active ingredient, a.i., = thiram), Apron (mefenoxam), Farmore D300 (mefenoxam + fludioxonil + azoxystrobin), and Farmore I300 (Farmore D300 + the insecticides spinosad + thiamethoxam). Mykos Gold Liquid was also tested using primed onion seed. Many growers had expressed interest in applying AMF inoculants to seed because of the ease of application that would not require modifying their planting equipment if AMF inoculants could be delivered effectively in this manner. For this reason, a number of field trials planted in the first field season (2016) entailed AMF inoculants applied to seed. This growth chamber trial was set up to assess the potential impact on seed-applied AMF inoculants of other seed treatments very commonly used by onion and carrot growers in the Columbia Basin. In this growth chamber trial, weekly seed germination counts were collected as well as onion shoot height, dry biomass, and root colonization by AMF 8 weeks after seeding. Low to no AMF root colonization was observed in any of the treatments with Mykos Gold Liquid (similar to the non-inoculated control soil), even in the absence of any fungicide and insecticides on the seed. A subsequent growth chamber trial comparing Mykos Gold Liquid with Mykos Gold Granular, with both products applied to the soil at equivalent rates of spore amendment, revealed that the liquid formulation failed to result in any root colonization by AMF whereas the granular formulation did result in root colonization. Subsequent communication with staff at RTI-Ag revealed there were issues with the liquid formulation not permitting spores of the AMF to germinate when applied to the soil (proprietary inhibitors added in the liquid formulation to prevent the spores from germinating during storage of the product apparently prevented the spores from germinating even when the product was added to soil). Given these results and confirmation provided by the manufacturer, no further trials were pursued with Mykos Gold Liquid in this study. Furthermore, results of growth chamber trials funded by the WSU BIOAg grant demonstrated that most of the fungicide seed treatments used by conventional onion growers in the Columbia Basin have an inhibitory effect on AMF, even when the inoculants are applied to the soil.⁴ Jin et al. (2013) showed similarly that rhizosphere fungal communities were severely inhibited by seed treatments containing contact and systemic fungicides.⁸

Except for the first growth chamber trial in this study with Mykos Gold Granular, AMF root colonization rates in onion growth chamber studies did not result in any significant improvements in plant growth or foliar nutrient acquisition. In fact, some results indicated a potential negative relationship between AMF root colonization rate and onion growth (significantly shorter shoots and onion dry weight than in the

⁸ Jin, H.Y., Germida, J.J. and Walley, F.L. 2013. Suppressive effects of seed-applied fungicides on arbuscular mycorrhizal fungi differ with fungicide mode of action and AMF species. *Applied Soil Ecol.* 72:22-30.

control soil), probably reflecting the cost to the host plant in photosynthate and/or P of the AMF association. Such effects have been observed in other research trials under P-sufficient conditions.⁹ In four growth chamber trials, three levels of soil P concentration were evaluated in a factorial design with AMF treatments to explore the interaction between available soil P concentration and AMF inoculant effects on onion growth. Echoing findings from the field trials, less AMF root colonization was observed as soil P concentration increased. Mykos Gold Granular caused 76% less AMF colonization of onion roots when soil P concentration was at 74 ppm vs. 25 ppm; and 64% less root colonization in soil with 45 vs. 25 ppm P. However, a positive onion plant growth response to increasing soil P was observed from 18 to 40 ppm P, with negligible additional growth response between 40 and greater concentrations.

Conclusions

1. Field and growth chamber studies clearly demonstrated that the two liquid formulations of AMF inoculants evaluated in this study were not effective at causing root colonization by AMF under the conditions of these trials. Personal communication by the project leader with an AMF inoculant company representative confirmed that AMF spore germination was slower in the liquid formulation of AMF products, delaying root colonization. This suggests liquid formulations may not be effective for applying AMF inoculants in direct-seeded crops like onion and carrot, given the importance of rapid colonization of the roots by AMF after germination to promote early growth, potentially outcompete or limit the ability of plant pathogens to colonize the roots, or trigger the host physiological response associated with beneficial effects of AMF to plants.
2. AMF inoculants were not effective at promoting AMF root colonization in soils with medium to high P concentration. Efficacy of AMF inoculants was best at soil P concentrations of 16-20 ppm.
3. AMF colonization rates of less than 80% were not associated with consistent improvements in onion crop health, growth, or productivity. However, the project generated preliminary evidence of performance benefits from colonization rates of 80% or greater.
4. AMF inoculants appear to offer little to no advantage in direct-seeded onion and carrot crops grown under the typical, high-input practices of the Columbia Basin. However, these inoculants may benefit crops exposed to stresses such as soil nutrient scarcity, water deficiency, transplant stress, salt stress, etc. as demonstrated in many published studies. The capacity for Columbia Basin growers to provide almost ideal growing conditions for direct-seeded onion and carrot crops appears to limit the benefits of AMF inoculants in this region.

Recommendations

1. Growers of direct-seeded onion or carrot crops in the Columbia Basin probably will not benefit from the use of AMF inoculants unless planting into soils with significantly lower soil P concentration than 40 ppm (Olsen), and probably should avoid using AMF inoculants unless they anticipate crop stress such as nutrient deficiency, heat stress, salt stress, etc. Conventional fungicide seed treatments (particularly Farmore D300 which has two active ingredients that are inhibitory to AMF) are likely to have adverse effects on the potential benefits of AMF inoculants in direct-seeded onion and carrot crops.
2. Growers of direct-seeded onion or carrot crops probably should avoid liquid formulations of AMF inoculants without independent, direct evidence that the application of such products result in increased root colonization by AMF.
3. Further tests of granular AMF inoculants in direct-seeded crops in field and growth chamber trials are needed to clarify the optimum balance of soil-applied fertilizers and AMF colonization of roots for enhancing crop growth and production. Another avenue of interest for research is testing AMF inoculants in the absence of soluble fertilizers, e.g., in organically-managed fields.
4. Although most onion and carrot growers test their soils to determine appropriate fertilizer application rates, this study provided evidence that some fields have excessive soil P levels needed for optimum crop growth.

⁹ Thomson, B.D., Robson, A.D. and Abbott, L.K. 1986. Effects of phosphorus on the formation of mycorrhizas by *Gigaspora calospora* and *Glomus fasciculatum* in relation to root carbohydrates. New Phytol. 103:751-765. Dr. Lindsey du Toit was the Principal Investigator and primary contact for grower cooperators and

AMF product manufacturers. She coordinated grower surveys, oversaw the evolving research plan and maintained trial data throughout the project. Dr. du Toit supervised the Scientific Assistants based at the WSU Mount Vernon NWREC who worked on field and growth chamber trials, and academic staff who participated in various stages of the project, including almost 8 months of microscopic work required for quantifying AMF root colonization for many of the trials: Dr. Leonard Kiirika participated on the project from February to mid-April 2016; Mr. Brian Henrichs was involved from May 2016 to April 2017; Ms. Erin Miller assisted from May through October 2017; and Dr. Louisa Winkler assisted with data analyses, report writing, and final collation of the study results for preparation of publications from March through October 2017.

Dr. Tim Waters was co-PI and took primary responsibility for coordinating field trials with grower cooperators. He oversaw Scientific Assistants based at the WSU Benton and Franklin Co. Extension Office. He also worked with grower-cooperators and agronomists on equipment modifications and calibration for applying various AMF inoculants.

Both Dr. du Toit and Dr. Waters contributed to the project outreach to stakeholders by publicizing project results at field days each year and stakeholder meetings such as the Pacific Northwest Vegetable Association Annual Convention & Trade Show in Kennewick each November, and generating publications from the study.

Grower-cooperators who served as hosts for this project in their commercial production fields included River Point Farms (primary contact was Dan Jepsen), Hartley Farms (agronomist Wes Locke), Locati Farms (Michael Locati), Mercer Canyon Farms (Dewey Holliday), and L&L Farms (Kevin Kudsk and Kerrick Bauman). In addition, Klaustermeyer Farms (Jim Klaustermeyer Sr.) was the host for trials in commercial carrot fields. As hosts, each grower-cooperator performed all the field preparation, treatment application, and crop planting and management, providing all the necessary labor and equipment. In some cases, growers also provided additional personnel to help with field trial evaluations.

Skagit Seed Services of La Conner, WA provided custom seed treatments for the trials in this project that entailed AMF seed treatments. Most of the AMF inoculant manufacturers with products tested during the project provided their product free of charge, with the exception of several shipments of AGTIV products. The companies involved were Reforestation Technologies Incorporate-Ag based in Gilroy, CA; AGTIV in Rivière du Loup, Quebec, Canada; Mycorrhizal Applications, Inc. in Grants Pass, OR; Plant Health Care, Inc. in Pittsburgh, PA; and Plant Health LLC in Corvallis, OR.

These stakeholder contributions comprised the cost-sharing for this project.

This project was focused primarily on onion and secondarily on carrot because of onion and carrot grower interest in AMF, and the lack of independent information on the potential benefits of AMF inoculants in these high-value, high-risk, direct-seeded vegetable crops in the Columbia Basin. Only one trial was carried out in a carrot crop, but the technical difficulties of studying AMF in carrots were substantial, particularly root colonization by AMF. Furthermore, the carrot industry expressed less interest in using AMF products than the onion industry, particularly once the lack of efficacy of the two liquid formulations of AMF inoculants evaluated in this study was demonstrated, together with the adverse effects of fungicide seed treatments on AMF, and the lack of evidence of any benefits of the AMF treatments in the carrot trial at Klaustermeyer Farms. Liquid formulations had been considered of the greatest interest for seed treatments by many of the growers involved in this study.

Goals and Outcomes Achieved

The short-term Expected Measurable Outcome described in the project proposal was:

“Independent, unbiased assessment of the relative efficacy and potential economic viability of commercial AMF products currently being promoted to onion and carrot growers in the Columbia Basin.”

Eighteen field trials and eight growth chamber trials carried out for this project generated independent, unbiased data on the efficacy of nine AMF products. Efficacy was assessed in terms of impacts on root colonization rates and crop performance (health, growth, and productivity). In addition to testing the efficacy of granular or powder product formulations applied in-furrow with seed or applied as seed treatments, the project also implemented replicated, randomized trials to address: (1) the impact of additional nutrients contained in an AMF inoculant product on that product's efficacy; (2) the potential for applying liquid inoculants as onion seed coatings, alone or in combination with commonly used fungicide seed treatments; (3) the impact on product efficacy of applying a liquid AMF formulation as a seed treatment or soil drench; (4) the impact on product efficacy of applying a granular AMF formulation with the seed in the top layer of soil (mimicking banding) or blending into soil (mimicking incorporation); and (5) the interaction of AMF inoculant effects with those of soil nutrient concentrations, particularly P. The field trials were completed over 2 summer field seasons and one overwintered season (latter in Walla Walla), and represented a range of growing conditions and onion market types in the Basin, as well as fresh market carrot production. The dynamic companion growth chamber trials to the field trials allowed research questions to be addressed more thoroughly.

This large body of data is a valuable resource to growers of direct-seeded onion crops considering how the use of AMF inoculants might be integrated into their crop management. It offers direct insight into the economic viability of these products. More broadly, it contributes to scientific understanding of the dynamics of AMF communities in agricultural soils. After sharing results of the growth chamber and field trials using two liquid formulations of AMF inoculants, one larger-scale onion farm in the Columbia Basin that had been using a liquid inoculant informed us they had adjusted their AMF program, resulting in a saving of more than \$50,000/year. Another farm stated in their cost-sharing letter for this project that "As growers, we have been bombarded with biological sales consultants claiming their products are the best thing since sliced bread. The work of Dr. du Toit and Waters has been critical in assisting growers to make more informed economic and agronomic decisions" (Josh Gefre, Agronomist at Mercer Ranches).

The long-term Expected Measurable Outcome described in the project proposal was:

"Development of an improved, sustainable production practice for onion and carrot growers, i.e. effective use of AMF inoculants on at least 50% of onion and carrot acres in the Columbia Basin, with a concomitant ~25% reduction in onion and carrot acres subjected to soil fumigation (or ~50% reduced soil fumigation rates) and ~50% reduction in P fertilization rates in onion and carrot crops."

Although initial studies by the project team had indicated that AMF inoculants could have substantial positive impact on crop growth and could become a substitute for at least a part of the soil fumigant and fertilizer applications, subsequent results were disappointing. Results from the project indicated that, under conditions typical of direct-seeded onion and carrot production in the Columbia Basin (relatively high soil P concentration, application of more-than-adequate levels of other plant nutrients in soluble form, and the use of fungicidal seed treatments), there was little to no economic benefit of adopting routine use of AMF inoculants in these cropping systems. Some growers in the Columbia Basin have begun to adopt AMF inoculants. Communication of this project's findings to growers is anticipated to save the expense of applying AMF products in circumstances that are not likely to result in any benefit. This project and the preceding project funded by the WSU BIOAg program demonstrated that soil fumigation with metam sodium has a more minor effect on onion root colonization by AMF endemic in fields in the Columbia Basin than medium to high concentrations of soil P (above 20 ppm P).

The trial results build the case for a general reduction in rates of fertilizers applied to onion and carrot crops in the Columbia Basin. This was communicated to growers at the 2018 WSU Onion Cultivar Demonstration and Field Day, and will continue to be communicated through journal and Extension publications, in reports written for individual grower-cooperators, and at grower events. Further research on optimizing fertility practices for onion and carrot production to avoid excessive rates of application is likely to have much greater long-term economic and environmental impact than further studies with AMF inoculants, as surveys of both conventional and organic fields in the Columbia Basin have demonstrated

AMF to be present in all the fields tested, even those fields that had been subjected to fumigation with metam sodium about once every three to four years.

Project goals specified in the work plan included 12 field trials in the Columbia Basin. Ultimately, 18 field trials were completed in nine separate onion crops and one carrot crop, substantially exceeding that goal (and not counting an unreplicated AMF inoculant trial set up in an onion seed crop near Soap Lake, WA in 2015-16, which also revealed no benefit to any of the four AMF inoculants applied in that trial). Six grower-cooperators were recruited to host these trials. Although the goal initially was to complete trials in two carrot crops, the difficulty of studying AMF in carrots and subsequent lack of interest from the carrot industry once results with liquid AMF inoculants were shared, led the team not to pursue further carrot trials.

Goals also included a program of growth chamber trials to compare a diversity of commercial AMF inoculants, in Project Years 1 (Oct 2015 - Sep 2016), 2 (Oct 2016 – Sep 2017) and 3 (Oct 2017 – Sep 2018); and the use of growth chamber trial results to direct the design of field studies (the exact number of trials was not specified in the original proposal). Two growth chamber trials were carried out in late 2015, four in 2016, and two in 2017. As detailed above, the field and growth chamber studies were highly beneficial in directing the course of the project. For example, early indications from the field and growth chamber trials that liquid AMF formulations were ineffective, were followed by growth chamber trials designed to establish whether the application method could be adapted to increase efficacy of liquid formulations. When the growth chamber trials demonstrated no efficacy of these liquid products, regardless of application method, liquid formulations were dropped from all the field studies for the 2017 season. One of the original objectives was to assess the potential benefits of AMF inoculants at suppressing soilborne diseases such as pink root and Fusarium basal rot of onion, and cavity spot of carrot. Although this aspect of the proposal was examined in the numerous field trials, it was not pursued in the growth chamber trials because of the dominating evidence of potential inhibitory effects of soil fertility levels of AMF inoculants. Given the typical grower fertility practices, it quickly became evident that we needed to prioritize examining in detail the impact of typical soil fertility levels encountered in onion and carrot crops in this region on the potential efficacy and benefits of AMF inoculants. The fairly limited expense for achieving optimum (to above optimum) soil fertility levels for carrot and onion production, compared to the risk of yield reduction if fertility levels fall too low and the inability to guarantee that AMF inoculants will compensate for potential losses from low fertility levels, emerged as the main reason AMF inoculants are not likely to be of much benefit under the current onion and carrot production practices in the Columbia Basin.

Outreach goals included preparation of reports for stakeholders and manuscripts for submission to scientific journals. To date, four papers have been published in *Plant Disease Management Reports*. A further six reports are in preparation for submission to this same technical journal in December 2018. One longer academic manuscript bringing together the findings and placing the results in the context of published literature will be prepared for submission in 2019. One stakeholder-oriented article has been submitted to the industry publication *Onion World*, and accepted for printing in the January or February 2019 issue. As planned, initial results from two field trials were presented at the Pacific Northwest Vegetable Association Annual Convention & Trade show in November 2016, and at the National Allium Research Conference / National Onion Association Annual Meeting in Savannah, GA in December 2016. Results were also presented to onion growers at smaller meetings in the winters of 2015 and 2016 in preparation for the subsequent field season and designing grower-cooperator field trials. In August of each of 2017 and 2018, results were shared at the WSU Onion Cultivar Demonstration and Field Day.

An initial goal of this project was to survey onion and carrot growers in the Columbia Basin to assess current use and understanding of AMF. A survey was disseminated in December 2015 and again in the

winter of 2016-17, but only two responses were received. Thus, there was no opportunity to develop a baseline dataset at the beginning of the project.

Instead, an end-of-project survey was used as an opportunity to evaluate the impact of the project and document the industry's evolving relationship with AMF inoculants. This survey was conducted at the 2018 WSU Onion Cultivar and Demonstration Field Day, held in the Columbia Basin near Prosser, WA and received around 70 valid responses. Responses revealed that 29% of crop consultants and seed company representatives had recommended AMF inoculants for onion or other crops, and 43% of growers have used them. Sixty percent of respondents felt they did not have enough evidence to make informed decisions about the use of AMF inoculants, and 80% reported that university research was an important source of information to them on this topic. These results underline the importance of publishing findings from this project and communicating them to the industry.

Beneficiaries

Growers of direct-seeded onions and carrots in the Columbia Basin are the primary beneficiaries of this research. Crop consultants and agronomists advising such growers on the use of products such as AMF inoculants are also beneficiaries. The project has generated objective research on AMF inoculants, a growing class of commercial products, which will help the onion industry make informed decisions about their use. The number of onion growers/farms in Washington State that were the targeted beneficiaries of our AMF project is ~175 farms. The majority of the onion acres are grown in the Columbia Basin on about 20 farms, some of which were grower-cooperators on the project and most of which heard directly or indirectly about this project at field days, the PNVA Annual Convention & Trade Show, and other outreach events. A much greater number of onion growers across the country, and even some in other countries, read about this work through the publications in *Onion World* as detailed in the final report.

Carrots are grown on 150 or so farms statewide, but the majority are grown in the Columbia Basin by ~15 farms, which were the targeted beneficiaries of this project.

The most effective AMF inoculant tested in this project, Mykos Gold Granular, costs around \$5.30/lb. Applied once during the growing season at the recommended rate of 5-10 lb/acre, the cost of using Mykos Gold Granular is approximately \$26.50-\$53.00/acre, which is more expensive than most fungicide applications. Producers on several of the larger onion farms in the Columbia Basin indicated they had begun using AMF inoculants in onion production on a routine basis, including some liquid formulations, despite not having independent data to verify the benefits that had been promoted by companies selling these products, and not having set up trials on their farms to assess whether the perceived benefits were real from adopting AMF inoculants. After sharing results of the replicated, randomized growth chamber trials and numerous companion field trials on multiple farms, one of the larger onion farms in the Columbia Basin, which was a host for field trials each season, informed us that results of this study reduced their expenses by more than \$50,000/year. Other farms have not shared the quantitative nature of economic benefits derived from this study, but the most frequent response from the cooperators and other stakeholders has been respect for the independent data generated under their production conditions and practices in the Columbia Basin that revealed the very limited to no benefits of AMF inoculant use in their cropping systems.

Lessons Learned

One important lesson learned from carrying out this project was that AMF root colonization readings, done by microscopic examination, are extremely time-consuming. Using the modified gridline-intersection method on 40 root sections per plant, it took 40-60 minutes to read the roots of a single plant. In a typical growth chamber trial with five replicates of a 3 x 5 factorial design, there were 75 plants to examine, equating to around 70 hours of time at the microscope. In a typical field trial, with five plants sampled per plot from a 2 x 2 factorial design with a minimum of three replicates, examining the roots of 60 plants equated to 40-60 hours of work per trial. There were insufficient hours available to perform root

colonization readings for every trial, so root readings were not completed for those trials in which the field data (stand counts, disease ratings, and other growth parameters) offered no evidence of AMF inoculant benefits. However, quantifying root colonization by AMF was ultimately the only way to prove that AMF were or were not associated with the impact of the treatments evaluated on the other plant traits measured. The project staff advise future investigators of AMF-related topics to plan trials carefully with an eye to minimizing the required number of root readings; and/or to be prepared for significant labor to quantify root colonization. Although molecular methods of AMF quantification have been developed, the very limited amount of plant tissue that can be used for DNA quantification makes it almost impossible to translate results from a few grams of root tissue for each plot to large-scale field trial results, particularly given the high degree of variability in AMF colonization even among roots on the same plant and among plants in the same plot.

During the growth chamber studies, fruiting bodies of a saprophytic fungus, *Peziza*, developed on the surface of the soil in some of the containers. Spores of this fungus must have been present in the field where the soil was collected, as the spores of this fungus are known to be stimulated to germinate after fires, which the soil pasteurization process must have mimicked. The fungi were observed in some containers but not others, and where present, dramatically reduced onion growth, negatively impacting the data. In one growth chamber trial, so many plots were affected by this saprophyte that those plots had to be dropped from the statistical analyses.

Although the project goals included adoption of AMF inoculants on a large percentage of the onion and carrot acres planted in the Columbia Basin, with concomitant reduction in reliance on soil fumigation and reduction in soil fertilizer application rates, the results did not justify continued pursuit of this goal. However, as stated in the original proposal, it is just as important to demonstrate objectively which products and application methods do not work in these cropping systems as it is to demonstrate which products/methods of application are effective. Independent data generated by this project and other university research is critical to help protect growers from unscrupulous claims of product manufacturers. While it has been a major disappointment not to find a means of optimizing AMF inoculant use to address the economic and environmental goals/benefits noted in the original proposal, i.e., reducing the reliance on soil fumigation and higher rates of fertilizer application, the growers involved in this project have expressed sincere appreciation for independent research that enables them to make informed decisions regarding AMF inoculants.

Prior to conducting field trials with AMF inoculants, the team anticipated finding very low levels of AMF activity in non-inoculated control plots owing to the widespread practice in the Columbia Basin of fumigating fields with metam sodium, a broad-spectrum fungicide and fumigant. However, onion roots generally showed 40-50% rates of colonization in the non-inoculated control plots, which was not increased by any of the AMF inoculant treatments in any of the field trials, and which reflected the presence of endemic AMF in all of these fields. Similar results were observed during field surveys of onion bulb crops conducted by Dr. du Toit's group with Dr. Tim Paulitz, USDA ARS plant pathologist, in 2014-15. The explanation may lie in the fumigation product and method of application: metam sodium most commonly is chemigated by center pivot. The limited depth of movement of the product by chemigation into the soil profile might be a major factor limiting the effects of this product on AMF in the soil profile, as metam sodium has very poor vapor pressure and, hence very poor mobility in soil. Research by Kyle Coleman (NovaSource) with onion and potato growers in the Columbia Basin has shown metam sodium to be limited to the top 4 inches of the soil profile or less when applied by chemigation, whereas shank applications can place the product at precise depths in the soil profile based on the depth of shanking.

The project team had hoped to establish a strong baseline for AMF inoculant use among Columbia Basin onion and carrot growers at the start of the project in 2015. A survey was mailed to over 30 growers on two occasions that winter of 2015-16, but only two responses were received. The team considered the probable

explanation to be ‘survey fatigue’ and limited time among growers, because the interest of growers serving as cooperators in this study indicated this lack of response did not reflect a lack of interest in the research. These factors were taken into consideration when designing the end-of-project survey which was completed during the 2018 WSU Onion Cultivar Demonstration and Field Day in August 2018 at Hartley Farms. More than 100 onion growers, crop consultants, seed company representatives, and other stakeholders (including researchers and extension specialists from three universities) were present. The survey consisted of physical ballots which respondents dropped into ballot boxes as they waited in the lunch line. The placement of the survey at the center of this activity made it difficult for attendees to ‘dodge’ participation, yielding a very high response rate (approx. 80%). The team considered this aspect of the survey to have been very successful. A flaw in the survey design, however, was the use of separate ballot boxes for each question, limiting the ability to track responses of individuals among the questions asked. Future surveys should be designed to provide each respondent with a single sheet on which their responses can be tracked among all the questions and related to their profession. Primary results from the survey were as follows:

- 1) A large percentage of farmers surveyed (43%) reported having used AMF products. Crop consultants and seed company representatives seem to be more hesitant about AMF products than farmers, with only 29% having recommended these products in the past.
- 2) The majority of respondents (64% of a total of 69 valid responses) reported that results from this project would influence their use of AMF products, but opinion was split as to whether they were more or less likely to use AMF products (45 and 25%, respectively). We note that results from the project did **not** support the value of AMF products in Columbia Basin onion crops. This survey result may indicate that respondents had not clearly understood the research; perhaps not surprising, since it was presented in the form of a five-minute speech and not all attendees were listening.
- 3) The majority of respondents (60%) reported not feeling adequately informed about AMF products, demonstrating the need for research results such as those from this project. A number of comments indicated that stakeholders value the opportunity to see research taking place in the field.
- 4) University research was the single most popular source of information about AMF products, listed as a preferred resource by 80% of respondents. The second most popular source was “colleagues”, listed by 41% of respondents.
- 5) Respondents overwhelmingly (70%) indicated that this research would influence their fertilizer use. Indeed, the research appears to have been more influential for fertilizer use than for AMF product use (64%), perhaps because fertilizer use is more widespread. As with AMF products, however, respondents showed split opinions regarding their inclination to increase (26%) or decrease (34%) their fertilizer use, suggesting that an opportunity to communicate results more clearly to stakeholders is needed.
- 6) University research was less dominant as a preferred resource for fertilizer decision-making than for AMF product decision-making (58 vs. 80%). Instead, private consultants were the most selected source of fertilizer information. Comments also indicated that stakeholders actively use their own experimentation and farm-specific observations to develop fertilizer programs.

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Additional Information

In Project Year 1, four grower-cooperators provided all the equipment, labor/salaries, fertilizers, herbicides, and other maintenance expenses for setting up and maintaining field trials in five onion crops and one carrot crop (based on the size of the trials, each was valued at ~\$10,000 in-kind support). 6 trials x an estimated \$10,000 = approximately \$55,000 in-kind support for grower-cooperator field trials in 2016.

In Project Year 2, four grower-cooperators provided all the equipment, labor/salaries, fertilizers, herbicides, and other maintenance expenses for setting up and maintaining field trials in seven onion crops. Based on

the size of the trials, which ranged from 12 single-bed plots of ~50' each to 40 plots of ~250' single-bed plots, the in-kind support was valued at ~\$60,000 for grower-cooperator field trials in 2017.

In Project Year 3, one grower-cooperator carried out two overwintered trials with sixteen blocks measuring 8' by 120' for a total area of approximately 15,360 square feet. This trial was estimated to have been valued at ~\$5,000.

Based on the cost-share letters provided by grower-cooperators, the specific donations/in-kind support from these stakeholders are as follows (total value of \$118,500):

- Locati Farms in Walla Walla: \$10,000 in estimated support for one trial in 2017 and two overwintered trials in 2017-18 in Walla Walla sweet onion crops.
- L&L Ag Production LLC: \$20,000 for onion field trials (2 trials in 2016 and one in 2017) near Connell, WA
- Hartley Farms: \$25,000 for onion field trials (2 trials in each of 2016 and 2017) near Paterson, WA
- Klaustermeyer Farms, Inc.: \$2,500 for a carrot trial near Basin City, WA
- Mercer Ranches: \$25,000 for dehydration onion trials near Paterson, WA
- River Point Farms: \$20,000 for 4 onion field trials and other support in 2017 near Irrigon, OR
- Schulthies Farm: \$16,000 for onion field trials near Prosser, WA

This does not include the value of onion seed donated by companies like Bejo Seeds America, AMF inoculants donated by all of the product manufacturers except for some of the AGTIV products used in several growers' field trials (growers either paid for the product or we paid the cost of the product from this grant), and fungicides donated by chemical companies. These additional donations have an estimated value of ~\$5,000.

Academic journal publications

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Extension publications

du Toit, L.J., Waters, T.W., Derie, M.L., and Henrichs, B. 2016. The potential role of mycorrhizal inoculants in Columbia Basin onion production. Pp. 8-9 in: 2016 WSU Onion Cultivar Demonstration and Field Day Handout, 25 Aug. 2016, Othello, WA. 16 pp.

du Toit, L., Waters, T., Derie, M., Holmes, B., Darner, J., Henrichs, B., Knerr, J., Paulitz, T., Sharma-Poudyal, D., Miller, E., Morgan, P. and Winkler, L. 2018. *Do AMF inoculants help onion crops?* 2018 WSU Onion Cultivar Demonstration and Field Day packet.

<https://s3.wp.wsu.edu/uploads/sites/2082/2018/09/2018WSUOnionFieldDayPacket.pdf>

Industry publications

Winkler, L.R., du Toit, L.J., and Waters, T.D. 2018. WSDA Specialty Crop Block Grant K1769: Evaluation of arbuscular mycorrhizal fungi for enhanced growth, phosphorus use efficiency,

and management of soilborne pathogens of onion and carrot in the Columbia Basin. End-of- project survey report.

Winkler, L.R., Waters, T.D. and du Toit, L.J. 2019. Do onion growers benefit from mycorrhizal inoculants? The effects of mycorrhizal inoculants on onion crops in the Columbia Basin. Onion World, in press (to be printed in January or February 2019).

Additional publications in preparation

du Toit, L.J., Derie, M.L., Holmes, B.J., Miller, C.E., Batson, A., Winkler, L.R., Waters, T.D., and Darner, J. 2019. The effects of arbuscular mycorrhizal fungal inoculants on pink root and yield in an onion crop near Paterson, WA, 2017. Plant Disease Management Reports 13: to be submitted in Dec. 2019.

du Toit, L.J., Derie, M.L., Miller, C.E., Winkler, L.R., Batson, A., Waters, T.D., and Darner, J. 2019. The effects of arbuscular mycorrhizal fungi inoculants and pre-plant, banded fertilizer application on pink root and onion growth in field trials near Irrigon, OR, 2017. Plant Disease Management Reports 13: to be submitted in Dec. 2019.

du Toit, L.J., Derie, M.L., Miller, C.E., Winkler, L.R., Waters, T.D., and Darner, J. 2019. The effects of arbuscular mycorrhizal fungi inoculants on pink root and onion growth in a field trial near Connell, WA, 2017. Plant Disease Management Reports 13: to be submitted in Dec. 2019.

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Winkler, L.R., du Toit, L.J., Derie, M.L., Holmes, B.J., Miller, C.E., and Morgan, P. 2019. The effect of soil phosphorus levels and arbuscular mycorrhizal fungal inoculants on onion growth, 2017. Plant Disease Management Reports 13: to be submitted in Dec. 2019.

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End-of-project Survey Report

Louisa Winkler, Lindsey du Toit, and Tim Waters, Washington State University, Sep. 2018

A survey was conducted at the 2018 WSU Onion Cultivar Demonstration & Field Day, held August 30 at Hartley Farms, Prosser, WA. Attendees of the event included farmers, agronomists, seed company representatives and some researchers. All were invited to complete the survey by marking their responses on ballots and placing the ballots in a box. Each question was marked on a separate ballot. Approximately 70 responses per question were received. The exact number of valid responses is given below for each question.

QUESTION 1

If you are a crop consultant, agronomist or seed company representative, have you ever recommended AMF inoculants for onion or other crops? OR, if you are a farmer, have you ever used AMF inoculants on onion or other crops?

Total valid responses (n) 70

Crop consultant, agronomist or seed company representative (n)*.....65

% "Yes" 29

% "No" 71

Farmer (n)* 30

% "Yes" 43

% "No" 57

*Twenty-two respondents answered as both crop consultant and farmer.

Comments

1. We focus on genetics
2. [I have not used/recommended them] But I'm interested
3. Researcher
4. Mixed results showing any impact
5. Not specific products / overseas grower (New Zealand)
6. We use liquid [AMF products] with drip [irrigation]

INTERPRETATION A large fraction of farmers surveyed (43) reported having used AMF products. Crop consultants and seed company representatives seem to be more hesitant about AMF products than farmers, with only 29% having recommended them in the past. **QUESTION 2**

Will the results of this AMF research influence your willingness to use or recommend AMF inoculants in onion or other crops?

Total valid responses (n) 69

Yes (%).....	64
Type of change not stated (as % of “yes” responses).....	30
MORE likely to use or recommend AMF products (as % of “yes” responses).....	45
LESS likely to use or recommend AMF products (as % of “yes” responses).....	25
No (%).....	16
Not sure (%).....	20

Comments

1. Not sure of application to our situation but on face of results in WA, no
2. Never use it
3. AMF don't work in high input agriculture
4. Not our game

INTERPRETATION The majority of respondents (64%) reported that results from this project would influence their use of AMF products, but opinion was split as to whether they were more or less likely to use AMF products (45 and 25%, respectively). We note that results from the project did **not** support the value of AMF products in Columbia Basin onion crops. This survey result may indicate that respondents had not clearly understood the research; perhaps not surprising, since it was presented in the form of a five-minute speech and not all attendees were listening.

QUESTION 3

Do you feel you have adequate information to make decisions about the use of AMF products in onion or other crops?

Total valid responses (n) 75

Yes (%).....	40
No (%).....	60

If no, what additional information would help you make that determination?

1. With written publication
2. Best way to apply it
3. Would want to see more data on other crops
4. Research specific to our situation
5. More trials
6. How to measure total benefit
7. More years of research
8. [I would like to] see more field trials
9. Have not seen trials personally

10. I am an entomologist
11. Not familiar with [this AMF] research
12. More personal research
13. Need more on suppliers

INTERPRETATION The majority of respondents (60%) reported not feeling adequately informed about AMF products, demonstrating the need for research results such as those from this project. A number of comments (8, 9, 12) indicated that stakeholders value the opportunity to see research taking place in the field.

QUESTION 4

Which source(s) of information would you use to make decisions regarding use of AMF products?

Total valid responses (n) 75

AMF product manufacturers (% responses including this category)	27
Private consultants, field reps, agronomists (% responses including this category)	37
University research (% responses including this category).....	80
Colleagues (% responses including this category)	41

52% of responses listed more than one source.

Other

1. History on farm
2. Visual/personal in field look
3. Independent scientific validation [is] important
4. Growers
5. Other public trial results

INTERPRETATION University research was the single most popular source of information about AMF products, listed as a preferred resource by 80% of respondents. The second most popular source was “colleagues”, listed by 41% of respondents.

QUESTION 5

Will the research results presented today regarding the effects of fertilizer on AMF influence your onion fertilization program or fertilizer recommendations?

Total valid responses (n) 67

Yes (% total responses)*

Yes, I am likely to INCREASE rates of pre-plant or other fertilizer applications

% total responses..... 18

% “yes” responses

Yes, I am likely to DECREASE rates of pre-plant or other fertilizer applications

% total responses..... 24

% “yes” responses

No (% total responses)

*Forty percent of “Yes” respondents did not specify the nature of the influence on their practice or recommendations.

Comments

1. Not applicable [to me] but results tend to support current practices.
2. Less P
3. Different conditions in New Zealand [where I am from] but still lots of food for thought.
4. Not yet, need more data
5. Need more research, more consistency

4

INTERPRETATION Respondents overwhelmingly (70%) indicated that this research would influence their fertilizer use. Indeed, the research appears to have been more influential for fertilizer use than for AMF product use (64%), perhaps because fertilizer use is more widespread. As with AMF products, however, respondents showed split opinions regarding their inclination to increase (26%) or decrease (34%) their fertilizer use, suggesting that an opportunity to communicate results more clearly to stakeholders is needed.

QUESTION 6

Which source(s) of information do you use to make decisions about fertilizer programs?

Total valid responses (n) 71

Fertilizer manufacturers (% responses including this category) 32

Private consultants, field reps, agronomists (% responses including this category) 73

University research (% responses including this category) 58

Colleagues (% responses including this category) 39

59% of responses listed more than one source.

Comments

1. Our observations
2. Our observations [?]
3. Does it all run downhill
4. Experience
5. Internal staff
6. In-house discussions

INTERPRETATION University research was less dominant as a preferred resource for fertilizer decision-making than for AMF product decision-making (58 vs. 80%). Instead, private consultants were the most selected source of fertilizer information. Comments also indicated that stakeholders actively use their own experimentation and farm-specific observations to develop fertilizer programs.

QUESTION 7

Please provide any comments and recommendations regarding the AMF inoculant research presented today. If you wish to be contacted, include your phone number or email address. **Comment**

Contact information

Would like to talk more.

Donovan.keen@aswilcox.co.nz, +64-27-836-5269

Well presented without preaching [?] or withholding straight answers - well done!

-

Very useful.

-

Thanks.

-

Thanks for the info. May influence drip irrigation user.

-

Seed trials on different soil types.

nicolas.puelma@vegetableseeds.basf.com

Recommendation - I'm not experience and need information

f.tapiz@andessouthernseeds.com.

Pay Lindsey more.

-

More years trialing.

-

More years of trialing to develop consistent [results].

-

Arbuscular mycorrhizal fungi (AMF) form associations with many crop plants, including onions. AMF can help onion plants acquire soil nutrients and water more efficiently, particularly phosphorus (P), and increase resistance to some diseases. A number of AMF inoculant products are on the market today but tests of these products in commercial onion production fields have been limited. From 2016 to 2018, WSU researchers and Extension faculty led a series of field trials in the Columbia Basin, alongside growth chamber tests, to

help clarify the potential impact of nine commercial AMF inoculants on onion production. In 16 trials on four farms, some products increased AMF colonization of onion roots but none improved crop performance under host farm practices. The effects of AMF inoculants on onion growth were inconsistent in growth chamber vs. field trials. Moderate to high soil P levels appear to be a primary factor negating potential benefits of AMF inoculants in onion crops in the Columbia Basin.

Do AMF inoculants help onion crops?

Project team: Lindsey du Toit, Tim Waters, Mike Derie, Barbara Holmes, Jennifer Darnier, Brian Henrichs, Jenny Knerr, Tim Paulitz, Dipak Sharma-Poudyal, Erin Miller, Paul Morgan and Louisa Brouwer (née Winkler).

Field Trials

Commercial AMF products were tested in 16 onion field trials on four farms in the Columbia Basin. Most inoculants were applied in granular formulation at the manufacturers' recommended rates, banded and incorporated in the bed or applied in-furrow with the seed at planting. Growers used their own equipment and their standard fertilization and pest control programs. Microscopic quantification of onion root colonization by AMF indicated that Mykos Gold Granular (RTI-Ag, Gilroy, CA) was the most effective product tested. Root colonization was increased slightly by Mykos Gold Granular in most trials in which it was tested, but colonization also was observed in all non-inoculated control plots (Fig. 1).

Although AMF colonization rates were slightly greater in plots inoculated with certain AMF products, including granular Mykos Gold and AGTIV (Premier Tech Agriculture, Rivière du Loup, Quebec), inoculants had no impact on bulb yield (Fig. 2).

Fig. 2. Bulb yield by grade in three onion field trials where Mykos Gold and AGTIV granular formulations were evaluated. Error bars show standard deviation of total bulb weight in all three grades.

Fig. 1. Onion root colonization by AMF in three field trials where Mykos Gold Granular was compared to a non-inoculated control treatment.

Growth Chamber Trials

Growth chamber (controlled environment) tests of five AMF inoculants were carried out using pasteurized soil collected from the Columbia Basin. Each inoculant was incorporated into the soil at a 1% rate guided by the manufacturers' recommendations. Onions were seeded into the soil and monitored for eight weeks.

Fig. 4. Plant biomass in two growth chamber tests of Mykos Gold Granular and three formulations of AGTIV in pasteurised soil.

Fig. 3. Root colonization by AMF in two growth chamber tests of Mykos Gold Granular and three formulations of AGTIV.

Root AMF colonization (Fig. 3) was greatest for Mykos Gold Granular in both trials (15%). AGTIV Granular and Powder formulations caused limited colonization (<10%), but AGTIV Liquid was not effective. Likewise, in separate growth chamber trials, Mykos Liquid failed to cause root colonization by AMF.

Onion plant biomass was not improved by the four AMF products tested (Fig. 4), although inoculation with Mykos Gold Granular increased onion plant height in earlier trials.

Influence of soil fertility on AMF colonization of onion roots

Field Trials

Effects of a pre-plant, banded fertilizer application on AMF colonization of onion roots was tested in field trials on two farms using Mykos Gold Granular. There was a clear negative impact of this fertilizer application on AMF root colonization in both Mykos Gold-inoculated and non-inoculated plots (Fig. 5). On average, AMF root colonization rates were 15% less in plots that received a pre-plant, banded fertilizer application than in plots that did not.

Growth Chamber Trials

The two growth chamber trials introduced on the previous page tested four AMF inoculants at each of three soil P concentrations. In these two trials and earlier trials, AMF root colonization rates decreased as soil P concentration increased (Fig. 7).

The effect of pre-plant, banded fertilizer application on onion crop yield also was tested in four onion crops on three farms. A significant positive yield response to the pre-plant fertilizer application was observed in two of the three trials (Fig. 6). This may reflect lower pre-fertilization soil nutrient status in the two trials in which onions were responsive to the fertilizer application. In Trial 1 (no significant yield response), soil analyses indicated 64-78 ppm phosphorus (P) and 97-121 lb/a nitrogen (N). The Trial 3 site had 32 ppm P and 102 lb N/a. (Soil analyses were not available for Trial 2).

Fig. 5. AMF root colonization rates in two trials in which half the plots received an application of pre-plant, banded fertilizer (“+”), and half the plots did not (“-”). Plots inoculated with Mykos Gold Granular were compared to non-inoculated control plots.

Fig. 6. Yield of marketable bulbs in three trials in which half the plots received a pre-plant, banded fertilizer application (“+”), and half the plots did not receive this fertilizer application (“-”).

Fig. 7. AMF colonization of onion roots in one of two growth chamber trials in which four AMF products (Mykos Gold Granular and three formulations of AGTIV) were added to soil with low (25 ppm Olsen P), medium (45 ppm) or high (74 ppm) phosphorus (P) concentration. The most effective inoculant tested in this study, Mykos Gold Granular, was 76% less effective at causing AMF colonization of onion roots when soil P concentration was 74 vs. 25 ppm; and 64% less effective at 45 vs. 25 ppm.

Influence of soil fertility on AMF colonization of onion roots

Onion plant biomass was affected much more by the amount of soil P than by AMF inoculant products (Fig. 8). Onion biomass increased by 80% on average when soil P was increased from 25 to 45 ppm. An increase in soil P beyond 45 ppm, however, generated little response.

Fig. 8. Biomass of onion plants measured at 8 weeks in a growth chamber test of Mykos Gold Granular and three formulations of AGTIV at three concentrations of soil P.

The team is grateful to onion growers, seed companies and AMF product suppliers who generously supported this research. Funding was provided by a Washington State Department of Agriculture Specialty Crop Block Grant (No. K1769) and a WSU CSANR BioAg grant.

Influence of soil fertility on AMF colonization of onion roots
Influence of soil fertility on AMF colonization of onion roots

Project Title: USA Pear Road Show in Southern China

Project Summary

2015-16 was the third full season of market access for U.S. pears in China, where consumers are more familiar with crisp, Asian pear varieties. Following the success of the USA Pear Road Show conducted in 2014-15 in Beijing and Shanghai, the activity moved to Guangzhou and Shenzhen to continue to introduce USA Pears as a new item in the produce department. The Road Show served as a mobile classroom, educating consumers about USA Pears, as well as a mobile billboard as it traveled between locations. When it reached the supermarket / hypermarket destinations, the outfitted truck unfolded in the parking lot, where consumers learned about the varieties, origin, versatility in recipes, and nutritional benefits of pears. The Pear Bureau targeted all shoppers as well as children, both of which are key demographic targets. The Road Show served as a centerpiece activity to increase the effectiveness of the other promotional activities. The Road Show generated excitement and attention for the new product among retailers, consumers, and the media.

The 2015-16 season was the third full season of market access in China, prior to which the Northwest pear growers enjoyed two wildly successful export seasons to China. Exports reached 180,000 boxes (44-lb boxes) in 2013-14 and surpassed 225,000 boxes in 2014-15, becoming the 5th largest export market for the industry.

With the industry facing the ongoing ban in Russia for the last few years – previously the industry’s 3rd largest export destination and a market that took over 550,000 boxes – there has been a push to increase the export volumes to other export markets to offset the loss of Russia. China is one of the industry’s top growth markets with a potential to reach 500,000 boxes in the next 3-5 seasons. The Pear Bureau needs to continue creating new USA Pear consumers in China. Many consumers are unfamiliar with the taste and texture of USA Pears, but once they do taste a ripened pear, they enjoy the experience. Because most Chinese consumers are familiar with crispy Asian pear varieties, a lot of education is needed in order to get consumers more familiar with the taste, flavors, ripening and varieties of Northwest pears. The Road Show activity was designed with these goals in mind and has been an ideal promotion to influence large numbers of Chinese consumers and create excitement for USA Pears at retail.

In the previous season, 2014-15, the Pear Bureau conducted the USA Pear Road Show in Beijing and Shanghai. The Pear Bureau set out to continue the success of the first season and bring the USA Road Show to consumers in the Pearl River Delta area of China, focusing on the cities of Guangzhou, Shenzhen, and others in the region. These are the two largest and most important cities in South China, with large populations and an emerging middle class. Guangzhou is one of the leading import areas for USA Pears and a distribution hub for all of China.

The 2015-16 Road Show was a multi-state project between the Oregon and Washington State Departments of Agriculture.

Project Approach

Similar to the first Road Show, the event was the first large-scale promotion of its kind for imported fresh fruit in the region since the country opened to imports of various fruit from countries all over the world in the mid-1990s.

Three leading retail chains with a very strong presence in Southern China agreed to support and participate in the 2015-2016 USA Pear Road Show: Walmart, Vanguard, and Park’N Shop. Guangzhou, Shenzhen, and Zhuhai and Zhongshan in the Pearl River Delta were selected as the target markets for the 2015-2016 USA Pear Road Show.

The first opening ceremony took place at Walmart Xiang Mi Hu Store on December 18, 2015. The event was officiated by Hoa V. Huynh, ATO Guangzhou; Jeff Correa, International Marketing Director of PBNW; Vincent Yeh, Senior Director of Walmart China; and Louis Ng, PBNW China Representative. The activity included singing and dancing performances, viewing of the USA Pear video teaching pear characteristics, and children's coloring activities to support USA Pear sampling conducted on site to attract consumer attention towards the event. Chinese media was invited by the public relations agency to generate massive coverage. The USA Road Show continued in Shenzhen at 13 additional venues at major retailers through January 17, 2016.

The second 2015-2016 Road Show Opening Ceremony was launched at the Vanguard Li Wan Store in Guangzhou on January 22, 2016. The event was officiated by Hoa V. Huynh, ATO Guangzhou; Senior Management of Vanguard Retail Chain; Vanguard Li Wan Store Manager; and Louis Ng, PBNW China Representative. In addition to the typical Road Show activities, a local artist dressed in the costume of The God of Fortune also appeared at the show to bless consumers with Chinese New Year Wishes and distributed USA Pear Red Packets to the crowd. The event generated very massive consumer attention towards the Road Show despite the cold and rainy weather conditions. The USA Road Show continued at six additional venues until the end of January before the show was paused for the pre-Chinese New Year festive season, as retail store outdoor spaces were assigned to their own activities during the holiday.

The USA Pear Road Show was resumed on February 26, 2016 at Park'N Shop Wen Hua Plaza Store in Dongguan in the North of Shenzhen. Then the show truck moved around at show venues in Shenzhen, Zhuhai and Zhongshan. The event was finally completed at Vanguard Shi Qi Store on March 20, 2016.

It was estimated that around 95,000 Chinese consumers visited the 58-day road show in four cities, with 80,000 of them staying more than 10 minutes at the venue. Around 25,000 children and their family members participated in the USA Road Show Coloring activities with 16,000 USA Pear Dolls presented as participation gifts. A total of 90,000 consumer leaflets were distributed to visitors in show period.

A total of 200 half boxes of USA Green and Red Anjou Pears were sampled at various venues of the Road Show in the four target markets in South China. Around 70,000 to 75,000 Chinese consumers tasted the pre-ripened pear samples on the spot.

The Pear Bureau home office worked closely with in-country representative, Louis Ng & Associates (LNA), to strategize and develop the activities. LNA then handled preparations including identifying and booking the appropriate road show venues, coordinating with local government and community city offices for approval, selection of the truck contractor, design of the truck, the arrangement of public liability insurance, the selection of road show performers, and production of the road show video and printed materials. PBNW was in constant communication with LNA throughout the process to provide approvals and maintain communications via email, conference calls, and reporting.

PBNW stakeholders including growers and shippers were kept informed of the progress of the activity via monthly reports, newsletters, and Board of Directors meetings.

This project did not benefit non-specialty crops.

Goals and Outcomes Achieved

The Road Show activity is extremely effective at generating consumer awareness and building familiarity with the pears because it attracts attention and engages shoppers outside the store. The children's coloring contests keep parents in the promotion area for an extended period of time, allowing demonstrators to offer samples of ripened pears. Providing consumers with a ripened Northwest pear creates a positive experience leads consumers to buy pears in the store.

The primary long-term benefit of the Road Show is the ability to impact such a large group of consumers, educating them about USA Pears and giving them the opportunity to sample a ripe pear. This leads to new pear purchasers (nearly 35% of responses) and helps PBNW capture the potential of the Chinese market – 75% of more educated consumers said that the information provided would influence them to buy more pears in the future.

Based on observations, it was estimated that about 95,000 consumers visited the Road Show venues. It is estimated that over 60,000 consumers stayed more than 2 minutes at the show and about 70,000 to 75,000 of them sampled USA Pears; around 25,000 family members and children participated in coloring activities with 16,000 children fully completed the coloring sheets. All in all, it could be concluded that at least 60,000 consumers or around 76% of the visitors became more educated about Northwest pears after staying at the events longer than 2 minutes. About 35,000 consumers stayed at least 1 minute at the show venue during the period and became aware of USA Pears.

The promotion was successful and sales were increased above the benchmark, with the activity's influence on first time purchasers growing significantly higher than the benchmark to surpass the goal. The results highlight the importance of food safety in China.

During the 2015-2016 USA Pear Road Show in South China, an evaluation of 180 randomly selected consumer samples was conducted by Louis Ng & Associates Limited on the spot at various Road Show venues in Shenzhen, Guangzhou and cities in the Pearl River Delta during the show period starting December 18, 2015 to March 20, 2016. Only consumers that sampled USA Pears were randomly selected and asked the questions during the evaluation to quantify consumer perceptions on USA Pears in South China.

GOAL	2014/15 BENCH- MARK	2015/16 TARGET	2015/16 RESULTS
A. % increase of NW Pears sales during the promotional period over two weeks prior to the Road Show	80.3%	100%	94.6%*
B. % of consumers who purchased USA Pears for the first time after the Road Show	18%	20%	34.59%
C. % of consumers who consider health and nutrition important purchase decision motivators	11.5%	15%	36.11%
D. # of consumers who became more educated about NW Pears after staying 1- 2 minutes	35,000	40,000	35,000
E. # of consumers who became more educated about NW Pears after staying longer than 2 minutes	50,000	60,000	60,000
F. % of more educated consumers who reported that the info will influence them to buy more USA Pears	76%	75%	75.44%
G. USA Pear Exports for November and December	67,443 boxes	78,000 boxes	55,850 boxes
H. % of consumers w/food safety as a purchase motivator	41%	50%	67.78%
I. % of consumers with children who like NW Pears after sampling	87%	83%	79.70%

** Based on responses from 22 produce managers/staff of the participating retail stores of the 2015-16 USA Pear Road Show.*

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 75.44% reporting that the

information provided will influence their purchase decisions and 34.59% 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. Following the Russian market ban, 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 a season of a slowing economy, stock market crashes, unfavorable exchange rate, and increased competition in China, the USA Pear Road Show and PBNW's promotional support inspired confidence in the trade to handle increased volumes of USA Pears.

According to 22 participating retail store produce duty managers/staff in four cities that responded to the evaluation phone calls, an average of 94.6% sales growth of USA Pears was recorded when the USA Pear Road Show took place outside their stores as compared with the prior two week average normal sales volumes at their outlets without USA Pear Road Show activity supports. The participating retailers also estimated that there was an average of over 20% new customers that purchased USA Pears for the first time as a result of the Road Show activities. 100% of the participating stores were pleased to have participated at the Road Show.

Lessons Learned

Conducting an outdoor activity requires considering several factors, and PBNW would recommend holding such activities in the best weather months that fit within the market window. Despite best planning efforts, the overall temperatures in both Shenzhen and Guangzhou were unexpectedly cooler than usual during the period, with rain, hail, and even the first snow in Guangzhou since 1957 disrupting the scheduled activities.

In addition to the unfavorable weather, the U.S. Embassy issued a warning regarding a potential terrorist attack in Beijing, requiring that activities in public areas throughout the country receive approval from the Urban Management Offices in Shenzhen and Guangzhou. Two days of Road Show activities were unfortunately called off at the last minute at Walmart in Shenzhen and Vanguard in Zhuhai in February and March due to interference by the local city management offices before the show began. All of these issues were addressed by the PBNW representative in China, who obtained the proper approvals as required and negotiated with retailers to reschedule the promotion days. Increased lead time for planning and reserving some contingency funds in the budget may help address these challenges for future activities.

To attract active participation among Chinese consumers at the Road Show, activities with family elements should always be included. One of the very popular activities at the 2015-2016 USA Pear Road Show continued to be the children's coloring activity. In addition, the appearance of The God of Fortune added further attraction among consumers to stay at the shows. Such elements should be considered as an integral part of the event in the future.

All of the outcomes of the project were extremely positive, especially given the challenges faced during the season that were out of anyone's control.

In terms of volume decline, according to the Global Trade Atlas, USA Pear exports to China through May were 2,529 MT; this is a 37.7% decline from the previous season's totals during the same time period. The reason for the drop in USA Pear exports include the slowing Chinese economy, devaluation of the Chinese Yuan, the stock market crashes that may have had an impact on importers' cash flow during the first half of the season (the beginning of the Road Show Promotion period), and increased competition from European pears that are extremely cheap (around half as expensive as USA Pears despite having higher freight charges). The USA Pear crop also had more smaller sized pears, which are not typically preferred in the Chinese market; the preferred larger size pears were sold at premium prices in 2015-16.

The best recommendation to address challenges like these is to be thorough in preparations, anticipate that there will be some unexpected issues over the course of the activity, and reserve some contingency funding in the budget to help address these issues.

Contact Person

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Additional Information

Cash Match:

Travel

Louis Ng & Associates travel expenses to plan/oversee Road Show activities:

\$18,014.41 Contractual

Uniform expenses, performers/dancers:

\$3,593.70 Other

Vendor bank fees:

\$24.79 Total

Contribution:

\$21,632.90

See promotion calendar, evaluation report, sample media report, and photos attached.

2015-2016 USA PEAR ROAD SHOW IN SOUTH CHINA

Among Shenzhen, Guangzhou and cities in the Pearl River Delta, a total of 58 days of the 2015/16 USA Road Show were conducted.

USA Pear Road Show in China 2015-2016					
Ref	City	Date	Retailer	Location/Branch	Number of Days
1	Shenzhen	2015.12.18 - 2015.12.20	Walmart Hypermarket	Xiang Mi Hu Branch	3
2	Shenzhen	2015.12.22- 2015.12.23	Trust Mart Supermarket	Da Yi Branch	2
3	Shenzhen	2015.12.24 - 2015.12.25	Walmart Hypermarket	Heng Jiang Liu Yue Branch	2
4	Shenzhen	2015.12.26 - 2015.12.27	Walmart Hypermarket	Heng Jiang Liu Yue Branch	2
5	Shenzhen	2015.12.2 9	Trust Mart Supermarket	Da Yi Branch	1
6	Shenzhen	2015.12.30 - 2015.12.31	Vanguard Supermarket	Sha Jing Branch	2
7	Shenzhen	2016.1.1 - 2016.01.03	Vanguard Supermarket	Long Gang Branch	3
8	Shenzhen	2016.01.05 - 2016.01.06	Walmart Hypermarket	Sha Jing Branch	2
9	Shenzhen	2016.01.07 - 2016.01.08	Walmart Hypermarket	Sha Jing Branch	2

10	Shenzhen	2016.01.09- 2016.01.10	Walmart Hypermarket	Heng Jiang Liu Yue Branch	2
11	Shenzhen	2016.01.12 - 2016.01.13	Vanguard Supermarket	Bao An Branch	2
12	Shenzhen	2016.01.1 4	Vanguard Supermarket	Ji Xiang Branch	1
13	Shenzhen	2016.01.15 - 2016.01.16	Vanguard Supermarket	Heng Gang Branch	2
14	Shenzhen	2016.01.1 7	Vanguard Supermarket	Ji Xiang Branch	1
15	Guangzhou	2016.01.19 - 2016.01.20	Vanguard Supermarket	Hua Du Branch	2

16	Guangzhou	2016.01.21	Vanguard Supermarke t	Xin Tang Branch	1
17	Guangzhou	2016.01.22 - 2016.01.23	Vanguard Supermarke t	Li Wan Branch	2
18	Guangzhou	2016.01.24	Vanguard Supermarke t	Xin Tang Branch	1
19	Guangzhou	2016.01.26 - 2016.01.27	Trust Mart Supermarke t	Huang Hua Gang Branch	2
20	Guangzhou	2016.01.28 - 2016.01.29	Trust Mart Supermarke t	Pan Yu Branch	2
21	Guangzhou	2016.01.30 - 2016.01.31	Trust Mart Supermarke t	Pan Yu Branch	2
22	Dongguan	2016.02.26 - 2016.02.28	Park n Shop Supermark et	Wen Hua Plaza Branch	3
23	Shenzhen	2016.03.01- 2016.03.02	Trust Mart Supermarke t	Da Yi Branch	2
24	Shenzhen	2016.03.03 - 2016.03.04	Walmart Hypermarke t	Jian She Road Branch	2
25	Zhuhai	2016.03.05 - 2016.03.06	Walmart Hypermarke t	Xiang Zhou Branch	2
26	Zhongshan	2016.03.08 - 2016.03.09	Walmart Hypermarke t	Huo Ju Branch	2
27	Zhongshan	2016.03.11 - 2016.03.13	Park n Shop Supermark et	Shi Qi Branch	3

28	Zhongshan	2016.03.15-2016.03.16	Vanguard Supermarket	Shi Qi Branch	2
29	Zhongshan	2016.03.18-2016.03.20	Vanguard Supermarket	Shi Qi Branch	3
TOTAL PROMOTION DAYS					58

2015-2016 USA Pear Road Show Evaluation Summary Report

During the 2015-2016 USA Pear Road Show in South China, an in-house evaluation of 180 randomly selected consumer samples was conducted by Louis Ng & Associates Limited on the spot at various Road Show venues in Shenzhen, Guangzhou and cities in the Pearl River Delta during the show period starting December 18, 2015 to March 26, 2016. Only consumers that sampled USA Pears were randomly selected and asked the questions during the evaluation to quantify consumer perceptions on USA Pears in South China.

Following are the results of the consumer evaluation.

	Overall		Shenzhen		Guangzhou		Pearl River Delta	
	# of respondents	%	# of respondents	%	# of respondents	%	# of respondents	%
Age Group	Age Group		Age Group		Age Group		Age Group	
< 10	36	20%	15	19%	11	18%	10	25%
11-15	21	12%	9	11%	7	12%	5	13%
16-20	18	10%	7	9%	7	12%	4	10%
21-35	24	13%	11	14%	8	13%	5	13%
36-45	39	22%	15	19%	16	27%	8	20%
46-60	24	13%	13	16%	7	12%	4	10%
> 60	18	10%	10	13%	4	7%	4	10%
Total	180	100%	80	100%	60	100%	40	100%
Gender	Gender		Gender		Gender		Gender	
M	70	39%	33	41%	20	33%	17	43%
F	110	61%	47	59%	40	67%	23	58%
Total	180	100%	80	100%	60	100%	40	100%
Working Status	Working Status		Working Status		Working Status		Working Status	
Working	72	40%	31	39%	25	42%	16	40%
Non-working	9	5%	8	10%	1	2%	0	0%
Retired	18	10%	10	13%	4	7%	4	10%
Student	62	34%	20	25%	26	43%	16	40%
Pre-school	19	11%	11	14%	4	7%	4	10%
Total	180	100%	80	100%	60	100%	40	100%

Martial Status	Martial Status		Martial Status		Martial Status		Martial Status	
Single	92	51%	41	51%	30	50%	21	53%
Married	86	48%	38	48%	29	48%	19	48%
Divorced	2	1%	1	1%	1	2%	0	0%
Total	180	100%	80	100%	60	100%	40	100%
Family w/w o children	Family with/without young children		Family with/without young children		Family with/without young children		Family with/without young children	
With	133	74%	60	75%	40	67%	33	83%
Without	47	26%	20	25%	20	33%	7	18%
Total	180	100%	80	100%	60	100%	40	100%
Educa- tion Level	Education Level		Education Level		Education Level		Education Level	
Pre school to Primary	58	32%	23	29%	20	23%	15	37.5 %
Secon- dary School	54	30%	27	34%	17	28%	10	25%
College or Above	57	57%	22	28%	22	37%	13	32.5 %
No Educa- tion	11	8%	8	10%	1	2%	2	5%
	180	100%	80	100%	60	100%	40	100%
	Question 1 - After sampling the fruit, do you like USA Pears?							
Yes	133	74%	61	76%	46	77%	26	65%
No	13	7%	13	16%	0	0%	0	0%
No prefer- ence	34	19%	6	8%	14	23%	14	35%
Don't know	0	0%	0	0%	0	0%	0	0%
Total	180	100%	80	100%	60	100%	40	100%
	Question 2 – Will you purchase USA Pears in the future?							
Yes	130	72.2%	54	68%	47	78.3%	29	72.5%
No	15	8.3%	13	16%	2	3.3%	0	0%
Don't know	33	18.3%	11	14%	11	18.3%	11	27.5%

Not applica-ble	2	1.2%	2	1.2%	0	0	0	0%
Total	180	100%	80	100%	60	100%	40	100%
	Question 3 - Who will consume USA Pears in your family?							
All	80	44%	33	41%	35	58%	12	30%
Children	40	22%	15	19%	9	15%	16	40%
Elderly	6	3%	4	5%	2	3%	0	0%
Children & Elderly	13	7%	9	11%	3	5%	1	3%
Don't know	41	23%	19	24%	11	18%	11	28%
Total	180	100%	80	100%	60	100%	40	100%
	Question 4 – Would you feed your young children with USA Pears?							
Yes	123	68%	52	76%	40	67%	31	78%
No	4	2%	2	3%	0	0%	2	5%
Don't know	53	29%	26	38%	20	33%	7	18%
Not applicabl e	0	0%	0	0%	0	0%	0	0%
Total	180	100%	80	100%	60	100%	40	100%
	Question 5 – How will you rate the USA Pear Road Show with a scale of 1 to 10 with 10 being the best?							
1-5	0	0%	0	0%	0	0%	0	0%
6	1	1%	0	0%	1	2%	0	0%
7	47	26%	20	25%	13	22%	14	35%
8	64	36%	28	35%	24	40%	12	30%
9	35	19%	18	23%	11	18%	6	15%
10	33	18%	14	18%	11	18%	8	20%
Total	180	100%	80	100%	60	100%	40	100%
	Question 6 – Have you learnt that USA Pears need to be ripened before consumption from the Road Show?							
Yes	152	84%	67	84%	53	88%	32	80%
No	0	0%	0	0%	0	0%	0	0%
Don't know	28	16%	13	16%	7	12%	8	20%
Total	180	100%	80	100%	60	100%	40	100%

	Question 7 – Will you purchase USA Pears for the first time after the Road Show?							
Yes	46	34.59%	21	34.43%	16	34.78%	9	34.62%
No	60	45.11%	27	44.26%	20	43.78%	13	50.00%
Don't know	21	15.79%	10	16.39%	8	17.39%	3	11.54%
Purchased the fruit before	6	4.51%	3	4.92%	2	4.35%	1	3.84%
Total	133	100%	61	100%	46	100%	26	100%
	Question 8 - % of consumers who consider health and nutrition important purchase decision motivators							
Yes	65	36.11%	29	36.25%	22	36.67%	14	35.00%
No	101	56.11%	44	55.00%	33	55.00%	24	60.00%
Don't know/No answer	14	7.78%	7	8.75%	5	8.33%	2	5.00%
Total	180	100%	80	100%	60	100%	40	100%
	Question 9 - % of consumers who became more educated about Northwest Pears after staying 1-2 minutes							
Yes	22	50.00%	10	50.00%	7	46.67%	5	55.56%
No	10	22.73%	4	20.00%	3	20.00%	3	33.33%
Don't know	12	27.27%	6	30.00%	5	33.33%	1	11.11%
Total	44	100%	20	100%	15	100%	9	100%
	Question 10 - % of consumers who became more educated about Northwest Pears after staying longer than 2 minutes							
Yes	103	75.74%	46	76.67%	34	75.56%	23	74.20%
No	15	11.03%	6	10.00%	5	11.11%	4	12.90%
Don't know	18	13.24%	8	13.33%	6	13.33%	4	12.90%
Total	136	100%	60	100%	45	100%	31	100%
	Question 11 - % of more educated consumers who reported that the infor will influence them to buy more USA Pears							
Yes	43	75.44%	16	74.51%	17	77.27%	10	76.92%
No	10	17.54%	4	13.73%	4	18.18%	2	15.38%
Don't know/ Not applicable	4	7.02%	2	11.76%	1	4.54%	1	7.69%
Total	57	100%	22	100%	22	100%	13	100%

	Question 12 - % of consumers w/ food safety as a purchase motivator							
Yes	122	67.78%	58	72.50%	34	56.67%	30	75.00%
No	22	12.22%	9	11.25%	9	15.00%	4	10.00%
Don't know	36	20.00%	13	16.25%	17	28.33%	6	15.00%
Total	180	100%	80	100%	60	100%	40	100%
	Question 13 - % of consumers with children who liked NW Pears after sampling							
Yes/ Good for kid consump tion	106	79.70%	48	78.69%	32	80.00%	26	78.79%
No	25	18.80%	11	18.33%	7	17.50%	7	21.21%
No Prefer- ence	2	1.50%	1	2.98%	1	2.50%	0	0
Total	133	100%	60	100%	40	100%	33	100%

Prepared and Submitted by:-

Louis Ng & Associates Limited

Dated: June 20, 2016.

Project Title: Physiological responses of apple under photosensitive hail netting

Project Summary

Sunburn has always been a relevant issue for tree fruit production in Washington State. However, as temperatures continue to increase in Washington's tree fruit producing regions, the corresponding increase in sunburn pressure on apples has been substantial. Additionally, the production of high value cultivars is changing the economics of sunburn protection strategies in the orchard. The aim of the project was to evaluate photosensitive anti-hail nets as an alternative to irrigated overhead cooling to reduce sunburn in tree fruit orchards. The project had three primary objectives:

- Determine how photosensitive anti-hail nets modify the microenvironment to mitigate stress-inducing conditions in WA State's growing environment (high light intensity and temperature)
- Identify the impact of photosensitive anti-hail netting on fruit quality and horticultural management
- Develop information for the industry to use when considering using anti-hail netting for tree fruit production through innovative, technology-based extension efforts.

Washington is the nation's largest apple producer. Apples are the most valuable agricultural crop grown in Washington State. In many areas of Washington State, apple cultivation is not profitable without the use of protection systems to prevent sunburn (overhead cooling or netting). Even with adequate protection, sunburn can still account to 5-10% of fruit that is rejected at the packing houses.

The aim of the project was to evaluate new colored netting materials (blue, red and pearl) ability to minimize sunburn in addition to providing other benefits such as providing hail protection, modifying tree growth and increasing fruit coloration. This proposal addressed the funding priority "Improve Production Practices through Innovative Technologies". Through conducting objective scientific research evaluating the impact of colored netting on the physiological performance and harvested quality of apple, an alternative approach to the use of overhead cooling for reducing sunburn and other

stress-related disorders was provided to Washington's tree fruit producers. Throughout the 2016 and 2017 growing seasons, tree growth, fruit yield and quality was monitored in the treatment blocks at a commercial 'Honeycrisp' apple orchard in Quincy WA, as well as physiological measurements including photosynthetic patterns, stress indices, light use efficiency and change in both light quality and quantity.

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

Project Approach

Experiments were conducted by the project team in a commercial orchard and at the WSU Tree Fruit Research and Extension Center. There were three colors of netting compared to an uncovered control. In 2015, there was no evaporative cooling installed and in 2016, evaporative cooling was installed in the uncovered control to compare sunburn incidence with just cooling compared to the use of protective netting. The project team collected environmental and physiological data along with fruit yield and quality data in 2016 and 2017. Netting improved the orchard environment making it more favorable for plant and fruit growth. Trees under netting were more robust, photosynthetically efficient, and productive than uncovered trees. There were no major differences among different colors of netting with the exception of blue netting increasing vegetative vigor and decreasing color development for Honeycrisp. Therefore, blue netting is much more suited to a cultivar like 'Granny Smith' than bicolor cultivars like Honeycrisp. These results were communicated to local, national and international audiences in both print and at conferences. When the project started, there was approximately 1,000 acres under protective netting with all of it a non-transparent white material. Since then, the team has provided industry and peer-reviewed publications, presentations,

and reports that have increased the industry interest in the use of protective netting, not just on Honeycrisp but on other high value cultivars. Currently, there are between 6,000 and 8,000 acres of netting over apple orchards in Washington State with more to be installed in the near future. The project team is not recommending the use of a specific color of net since this does not contribute as much as just having protective netting alone. Protective netting also has added benefits under specific configurations to control insects and/or to protect from hail events that occur infrequently in tree fruit producing regions in WA.

- Dr L. Kalcsits, was responsible for managing the project and the postdoctoral research associate hired to oversee the ecophysiological measurements. He was also responsible for all metrological measurements and both pre and post-harvest fruit quality.

Dr. G. Mupambi joined Dr. Kalcsits' lab as a postdoctoral scholar in April, 2016 and conducted research related to this project and provided support to Dr. D. Layne to fulfill the extension objectives of the project.

- Dr S. Musacchi was in charge assessing change in light quality and quantity and vegetative growth measurements.
- Dr D. Layne oversaw the extension outreach from the project.

The project did not benefit non-specialty commodities.

Goals and Outcomes Achieved

The following activities were completed in order to achieve the performance goals and Expected Measurable Outcomes of the project:

Project Activity	Status
Measure vegetative growth to compare shoot vigor in different netting treatments versus the control.	Completed
Measure bloom each spring to determine the influence of netting on flower induction and return bloom.	Completed
Determine how netting influences the microenvironment under the netting (temperature/humidity/windspeed/light radiation) and within the soil (temperature, moisture).	Completed
Measure photosynthetic activity during the full day and determine light saturation levels for leaves under each color of netting and the control.	Completed
Evaluate sunburn incidence and other postharvest disorders on fruit.	Completed
Measure fruit quality at harvest and after storage.	Completed
Netting field day in Quincy, Washington before harvest to highlight preliminary results (August 2016/2017).	Completed
Develop web content including videos, webinars, instructional videos and research updates to extend research findings to the industry and other academic audiences.	Completed
Work with stakeholders to create an extension bulletin to provide information for orchard design guidelines and horticultural considerations for tree fruit production under netting.	Completed
Present results at the state and national horticultural society meetings and publish in international peer-reviewed journals.	Completed

One of the measurable outcomes was to provide information to growers to increase the adoption of netting in orchards across Washington State. Data was collected from more than twenty apple orchard owners or managers from a survey conducted in the summer of 2017 representing approximately 46,000 acres (approximately 26%) of the estimated total 179,146 acres planted to apples in WA (USDA 2017). Based on the surveyed acreage, 2,347 acres (approximately 5.1%)

was covered under nets while an additional 3,417 acres (approximately 7.4%) are planned to be covered 2018. This trend of increased plantings under netting is forecasted to increase, there are many growers that are still raising capital and incorporating netting systems into their new plantings.

Activities and goals	Actual accomplishments
Presented results at the state, national and international horticultural society meetings and publish in international peer-reviewed journals.	The results were widely presented to industry in Washington State, across the nation and internationally for invited talks. Additionally, the project team published 4 peer-reviewed articles and an additional 3 peer-reviewed conference proceedings articles.
Worked with stakeholders from the Washington Tree Fruit Research Commission to create an extension bulletin to provide information for structural design guidelines and horticultural considerations for tree fruit production under netting.	The team conducted a survey on the use of netting by apple growers in WA and used this information in an extension publication that provides information on design guidelines and horticultural considerations for apple production under netting. This extension bulletin has been accepted and will be published in 2019 using the WSU extension publishing service.
Developed an educational web video and research updates were disseminated to the industry and other academic audiences.	Information from the research was shared through state, national and international conferences, invited seminars, extension publications, field days and peer reviewed scientific publications. Additionally, there was one video summarizing the projects progress in 2017.
Netting field day was held at Quincy, WA before harvest to highlight preliminary results (August 2016/2017).	The project team held two successful and well attended field days in 2016 and 2017.
Fruit quality was measured at harvest and after storage.	Over three years of fruit quality measurements, the project team determined that growing fruit under netting did not negatively impact fruit quality. There were slight reductions in total soluble solids, titratable acidity and fruit color. Reduced color had a negligible impact on fruit quality in Honeycrisp apple.
Sunburn incidence and other postharvest disorders were evaluated at harvest and after post-harvest storage on fruit.	Netting reduces sunburn incidence and increased the percentage of high-grade fruit packout increasing income for growers. Specifically, comparisons between the benchmark sunburn protection strategy, evaporative cooling, and netting showed that netting was as effective at reducing sunburn in apple but netting color did not affect fruit sunburn as much.

Photosynthetic activity and light-use efficiency was measured under heat stress conditions and tracked throughout the season under each color of netting and the control.	Netting increased leaf level photosynthetic light use efficiency under heat stress conditions normally experienced in WA. Our research showed that netting improved photosynthesis over the whole growing season compared to an uncovered control.
The influence of netting on the microenvironment under the netting (temperature/humidity/windspeed/light radiation) and within the soil (temperature, moisture).	Netting increased soil moisture content, reduced soil temperature, increased diffuse radiation and light scattering, and decreased wind speed. Humidity and air temperature were relatively unchanged under netting compared to the uncovered control.
Vegetative growth was measured to compare shoot vigor in different netting treatments versus the control.	Netting had a positive effect on vegetative growth which resulted in better canopy development on young trees under netting.
Return bloom was measured each spring in 2017 and 2018 to determine the influence of netting on flower induction and return bloom.	There was no negative effect on return bloom and fruit set, the use of netting did not affect yield when deployed after pollination.

At the start of the project, there was minimal information available in Washington State on the use of protective netting. This was particularly true for netting overtop of ‘Honeycrisp’ apple which is rapidly expanding in production and acreage. All three major objectives were completed as planned during the project period. When the project started, there was approximately 1,000 acres under protective netting with all of it being a non-transparent white material. Since then, industry has been provided peer-reviewed publications, presentations, and reports that have increased the interest in the use of protective netting, not just on Honeycrisp but on other high value cultivars. Currently, there are between 6,000 and 8,000 acres of netting over apple orchards in Washington State with more that will be installed in the near future.

Beneficiaries

The 1,450 Washington State apple growers as well as the tree fruit industry in Washington State have benefitted the most from the completed project. The project team has provided tractable information that gives producers unbiased evidence needed to transition their orchard systems to netting protection systems. Additionally, the project team has comprehensively identified the impacts of netting on environment, physiology, and fruit quality. This is showcased by the substantial investment in netting protection systems throughout Washington State since the start of the project. The data collected as part of this project has supported extension personnel throughout Washington State and the nation in providing guidance for the adoption of netting protection systems for specialty crops. Lastly, there have been substantial academic outputs from the project that include peer-reviewed publications, peer-reviewed conference proceedings, a peer-reviewed review article, extension publications, and numerous invited presentations locally, nationally, and internationally.

Grower cooperator estimates indicate two additional packed boxes of fruit per harvested bin of apples from the use of netting. Current box prices for Honeycrisp apple are between \$30-\$40 per box and average yield of apple from Washington State orchards is approximately 60 bins per acre. This amounts to an additional \$3,600-\$4,800 per acre of revenue per year. These valuations indicate that it would take approximately 2-3 years to pay for the cost of netting in an orchard in full production. With approximately 5,000 acres of additional orchards netted in Washington State since the start of the project, the yearly increase in revenue to the growers in Washington State that use netting is between \$18 and \$24 million. The project team estimates that the total acreage under netting will continue to grow for high value cultivars and the economic benefit of this project will continue to increase in the near future.

Lessons Learned

Some additional insight was gained on the adoption of netting into orchard systems. There are many different commercial systems and products advertised. With the capital cost of implementation being substantial, it is essential that producers do their due diligence on confirming the shade percentage of the net, the photostability of the net and the suitability of netting for their operations. There are several approaches that growers can take in covering their orchards with nets that range in cost from as low as \$3,000 per acre to as much as \$18,000 per acre. These different systems can change the level of risk and longevity of the netting. Additionally, with the rapid expansion of netting in orchards in Washington State, there have been issues surrounding the availability of lifts and equipment used to install, deploy, and contract netting each year. This is an important consideration affecting timing and feasibility of the project.

There are two unexpected outcomes that were identified with this project. Retrofitting existing orchards is costly and time consuming relative to installing the netting structure prior to planting.

Many producers are now planning ahead and making their orchards “netting ready” even if they are not sure they will add netting in the near future. Additionally, the labor costs and equipment availability is spurring engineering and research into making deployment and retraction easier in the spring and fall. In other growing regions that use netting around the world, the scale of those operations are substantially less than in Washington State and the increased scale is placing unforeseen pressure on equipment and labor for installation and maintenance. Making installation, deployment, and retraction easier is critical to increase the flexibility and reduce maintenance costs of the systems that are used. There are many approaches to solve this problem and more work will be required to identify more efficient netting systems for adoption on large scales.

All activities, goals and Expected Measurable Outcomes were achieved for this project.

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Additional Information

Total level of cash or in-kind donations include the installation of netting material and infrastructure and annual maintenance costs, deployment and retraction of netting, and the supply of fruit from the commercial grower to a value of approximately \$144,000.

Additionally, the WTFRC provided matching funding for the project for a complimentary project and the value of those matching funds was \$141,815. Additionally, unrecovered F & A match from WSU was \$49,721.58. The total matching amount was \$335,536.58.

This project included Special Purpose Equipment. The original agreement allowed for the purchase of spectroradiometer and fluorometer for \$25,000. The spectroradiometer was purchased using other funding prior to the start of this grant. Due to this change prior approval was granted to purchase a plant canopy imager for the project with funds allocated for special purpose equipment. The fluorometer with the purchase price of \$8,595, had a value of \$4,430.80 at the end of this grant. The plant canopy imager, with the purchase price of \$9,180, had a value of \$4,486.92 at the end of this grant.

Project Outputs:

Research Publications: 2 published peer reviewed articles, 2 additional manuscripts under preparation

- Mupambi G., Layne D., Musacchi S., Serra S., Schmidt T., and Kalcsits L.A. Protective Netting Improves Leaf-Level Photosynthetic Light Use Efficiency in ‘Honeycrisp’ Apple Under Heat Stress. *HortScience*. 53(10)1416–1422.
- Kalcsits L., Musacchi S., Layne D.R., Schmidt T., Mupambi G., Serra S., Manoella Mendoza M., et al. 2017. Above and below-ground environmental changes associated with the use of photoselective protective netting to reduce sunburn in apple. *Agricultural and Forest Meteorology*. 237-238:9–17.

Peer-reviewed conference proceedings: 1 accepted manuscript (In press)

- Kalcsits L., Asteggiano L., Schmidt T., Musacchi S., Serra S., Layne, D., and Mupambi G. 2017. Shade netting reduces sunburn damage and soil moisture depletion in ‘Granny Smith’ apples. *Acta Horticulturae*. (In press).

Research Reviews: 1 published peer reviewed article

- Mupambi G., Anthony B.M., Layne D.R., Musacchi S., Serra S., and Schmidt T., and Kalcsits L.A. 2018. The Influence of Protective Netting on Tree Physiology and Fruit Quality of Apple: A Review. *Scientia Horticulturae*. 236:60–72.

Extension: 1 Extension manuscript accepted for publication by WSU extension, 1 educational video produced

- Mupambi G., Layne D.R., Kalcsits L.A., Musacchi S., Serra S., Schmidt T., Hanrahan I., (2018). Use of Protective Netting in Washington State Apple Production. Submission ID:2018-2233
- Photoselective Anti-Hail Netting Trial for ‘Honeycrisp’ Apple. <https://www.youtube.com/watch?v=WhrtjGSiYtg>. WSU CAHNRS Youtube Channel.

Field days: Two field days were held at the grower cooperator sites on August 14, 2016 and May 28, 2017. There were between 90-120 attendees for each field day.

Invited presentations: (5 International, 0 national, 3 state)

- Mupambi G. Better safe than sorry: Results of shade net studies in Washington State. Hortgro Science Technical Symposium 2018. The Lord Charles Hotel, Somerset West, South Africa. May 31, 2018.
- Kalcsits L. 2018. Benefits and risks of integrating protective netting into apple production. International Fruit Tree Association Annual Meeting. Napier, New Zealand. February 26, 2018.
- Kalcsits L. Benefits and Risks of Integrating Protective Netting into Apple Production. Ontario Fruit and Vegetable Convention Niagara Falls, Canada. February 22, 2018.
- Mupambi G. Optimizing light conditions for apple production in Washington State using protective netting. WSU Hort 509/510 Seminar Series. WSU Tree Fruit Research and Extension Center, Wenatchee. Broadcast to Pullman, Mt Vernon, Prosser and TriCities. February 22, 2018.
- Mupambi G. Adoption of protective netting in WA apple production. North Central Washington Apple Day. Wenatchee Convention Center, Wenatchee, WA. January 18, 2018.
- Kalcsits L. 2017. Optimizing abiotic stress to increase fruit quality and productivity. International Fruit Tree Association Annual Meeting. Wenatchee, WA. February 23, 2017.
- Kalcsits L., Wheeler C, Asteggiano L[†], Jarolmasjed S, Khot L, Layne D, Mendoza M, Musacchi S, Sankaran S, Schmidt T, Serra S, Zuniga C. 2016. Overhead netting to modify orchard environments. Washington State Tree Fruit Association Horticultural Show. Yakima, WA. December 7, 2016.

- Kalsits L. 2016. Update on photosensitive netting trials in Washington State. International Fruit Tree Association. Grand Rapids, Michigan, February 10, 2016.

Conferences: 2 international, 1 national, 1 state

- Mupambi G., Layne D.R., Musacchi S., Serra S., and Schmidt T., and Kalsits L.A. Seasonal adaptation of 'Honeycrisp' apple grown under colored protective netting in a semi-arid environment. International Horticultural Congress: 12 - 16 August 2018 Istanbul – Turkey. (Oral)
- Mupambi G., and Kalsits L.A. Seasonal Ecophysiological Adaptation of Apple Trees Under Photosensitive Shade Netting. 2017 Washington State Tree Fruit Association Horticultural Show. (Oral)
- Mupambi G., Layne D., Musacchi S., Schmidt T., Serra S., and Kalsits L.A. 2017. Blue Photosensitive Protective Netting Improves Light Use Efficiency in *Malus domestica* Borkh during a Heat Stress Event. 2017 ASHS Annual Conference, The Hilton Waikoloa, Waikoloa Hawaii, September 19-22, 2017. (Oral)
- Kalsits L, Wheeler C, Asteggiano L[†], Jarolmasjed S, Khot L, Layne D, Mendoza M, Musacchi S, Sankaran S, Schmidt T, Serra S, Zuniga C. 2016. Light, air, and soil environment manipulation using photosensitive anti-hail netting in a high latitude, desert environment. ISHS Symposium on orchard systems, rootstocks and environmental physiology. Bologna, Italy. August 29 - September 2, 2016.



Project Title: Developing value-added products from Washington grown red raspberries

Project Summary

Red raspberries are highly susceptible to bleeding, crumbling, and color deterioration when used in baked products, mixes or other products where the berry should remain intact. Although the flavor and health benefits of raspberries are highly desirable to the food industry, this deterioration makes manufacturers reluctant to use raspberries in products that require whole berries to be recognized in the final product.

This project adds the missing element to help family farms: product development using innovative technologies to expand the use of raspberries as an ingredient, especially as “whole berries.” In this 2½ year project, the goal was to develop a technology to produce high-quality, dehydrofrozen red raspberries with structural integrity to increase markets for processed whole berries in baked and snack products. The project began in October, 2015.

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

Project Approach

This project successfully developed baking-stable red raspberries through five significant activities/steps: (i) impregnation of firming agents into red raspberries, it was determined that the optimal concentrations of low methoxyl pectin and calcium ions in the solution as 10 g/kg solution and 30g/kg pectin. In addition, vacuum impregnation level of 50.8kPa and processing time of 7 min was optimized. (ii) partial removal of water using hot air drying, coating partially dried berries with biopolymer/hydrocolloid solutions, the optimal air drying temperature of 65°C and final moisture content of 0.65 H₂O/g fruit was determined. (iii) coating partially dried berries with biopolymer/hydrocolloid solutions sodium alginate, two different cellulose gums and one chitosan-based solution were investigated for coating partially dried berries. The optimal concentrations of biopolymer coating solutions were: sodium alginate at 0.4% (w/v), and two other carboxymethylcellulose at 0.05 and 0.1% (w/v) resulted minimal of bleeding obtained was 13.9, 18.1 and 16.0% respectively, while commercial frozen raspberries showed an oozing of 62.9%, (iv) freezing of treated red raspberries, developed red raspberries were subjected to three months storage at three constant storage temperatures and also fluctuated storage temperature to simulate commercial storage conditions. The results suggested that the developed red raspberries maintained the structural integrity and (v) baking trials using frozen/thawed red raspberries, bakery products incorporated with dehydrofrozen red raspberries were developed. A commercial baker also developed baked products and these products were tasted at the Washington Red Raspberry Commission meeting. It was found that the dehydrofrozen red raspberries based muffins were liked better than those based on commercially available frozen berries. Development of research bulletins, The projects findings were communicated with different stakeholders: Commissions and Councils e.g. Washington Red Raspberry Commission, National Processed Red Raspberry Council; raspberry processing companies: Enfield farms, Maberry Packing, Firestone Pacific Foods; Baking companies/laboratories: Memorable Events and Catering and Bread Laboratory of WSU, Mount Vernon. While research bulletins were not developed, results of the project were published in the form of research papers and thesis which are available for distribution.

The project idea was conceived by Dr. Sablani. Dr. Sablani also supervised the experimental study. Graduate student Armando Quintanilla performed all experiments. Frank Younce, pilot plant manager, helped design the vacuum impregnation chamber and assisted with air drying operations. The graduate committee (Drs. Juming Tang, Barbara Rasco and Joseph Powers and lead project investigator Dr. Sablani) interpreted experimental data and wrote manuscripts.

This project specifically benefitted raspberry.

Goals and Outcomes Achieved

The project demonstrated successful pilot scale production of whole red raspberries compatible with baked products. The performance of baking-stable red raspberries was evaluated by a commercial bakery. The company found superior performance and noted no bleeding of dehydrofrozen raspberries compared to commercial frozen raspberries in grocery stores. The method of producing baking-stable red raspberries was filed as an invention disclosure. The results of this project were communicated to raspberry processing companies based in Washington State through the WRRC and NPRC networks.

The industrial adoption of the method to produce dehydrofrozen berries is currently being discussed with Washington-based companies. Hence, commercial production of baking-stable red raspberries is on the horizon for the future. Increases in demand for red raspberries and economic returns for growers may occur after industrial adoption of this technology. This project successfully developed the technology for processing baking-stable raspberries and protected the process through invention disclosure.

All activities were performed as outlined in the proposal. The goal of producing baking-stable red raspberries from fresh berries was successfully achieved. The method developed through this project did not utilize frozen red raspberries as a starting material since frozen berries sustained significant bleeding and loss of firmness after thawing.

Baking-stable dehydrofrozen red raspberries are currently not available in the US market. For the first time, this project demonstrated technical feasibility of producing dehydrofrozen red raspberries that are stable during baking as tested by a commercial bakery. Several bakeries showed willingness to test the dehydrofrozen berries in their bakery products. Since the method of producing these berries was filed for an invention disclosure, baking trials for these berries involved one test kitchen. Dehydrofrozen raspberries are expected to be available in the market after this technology is adopted commercially. The industrial implementation of the process of manufacturing dehydrofrozen berries is currently being discussed with Washington-based companies.

Beneficiaries

All 165 raspberry growers in Washington benefit from this project. As a result of this project, a vacuum chamber was fabricated, which will be utilized in undergraduate/graduate teaching. Graduate student Armando Quintanilla completed his doctoral dissertation through involvement in this project. A research paper documenting a method for firming red raspberries was published for the scientific community. The bakeries and raspberry industry were made aware of a new method for producing baking stable berries through WRRC and NPRC networks.

In this project, baking stable red raspberries resulted in significantly lower drip loss (1.3%) compared to commercially available frozen berries (16.8%) upon thawing. The dehydrofrozen berries were also significantly less susceptible to the temperature abuse that normally occur during transport and storage. The drip loss in dehydrofrozen berries was 0.5-0.6%, while commercial frozen berries resulted in a drip loss of 20-35% when berries were exposed to 23°C for 6 hours. In baking trials, dehydrofrozen berries (14%) showed significantly less bleeding compared to commercial frozen raspberries (63%).

Positive economic impacts are expected after industrial production of baking stable berries. Commercial adoption of this baking stable manufacturing method is currently being discussed with several companies.

Lessons Learned

The support of specialty crop growers and processors support is critical to the success of the project. The project received excellent support by WRRC and NPRC. Seasonal availability of fresh raspberries and

careful planning of the experimental study was important to the success of this project.

No unexpected results or outcomes were experienced during this project.

Proposed activities and goals were achieved. It was expected to test baking-stable berries with five bakeries. Since commercial trials were successful and the method of producing baking-stable berries was filed for an invention disclosure, baking trials for these berries were kept to one test kitchen. Currently, the industrial adoption of this new technology is being discussed with few companies. At this moment, raspberries companies are fully occupied with harvesting and freezing of red raspberries. The commercialization efforts will continue after raspberry harvesting season. The industrial adoption of new technology, product or method takes time, regardless of how promising they are. Any change in current production practices involves new financial investments. Hence, the adoption of new practices is gradual.

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Additional Information

Total in-kind and cash match utilized in this project was \$52,235. Dr. Sablani's salary contribution was (@ 0.5 month/year plus benefits) at \$13,859. The use of pilot plant, food engineering and food chemistry facilities was \$10,000, while unrecovered indirect costs incurred by the university were \$18,376. The Washington Red Raspberry Council (WRRC) and National Processed Raspberry Council (NPRC) provided significant input, including connections with red raspberry growers, and processors, as well as the bakery company who assisted with commercial trials of raspberries in bakery products developed in the food processing pilot plant. WRRC and NPRC efforts amounted to \$10,000.

Publication:

Quintanilla, A., Mencia, A., Powers, J., Rasco, B., Tang, J., Sablani, S. S. (2018). Vacuum impregnation of firming agents in red raspberries, *Journal of the Science of Food and Agriculture* 98: 3706-3714

Doctoral Dissertation:

Quintanilla, A. (2018). Development of vacuum impregnation and edible film coating in dehydrofrozen red raspberries, Ph.D. Thesis, Washington State University, Pullman, WA

Invention Disclosure:

Sablani, S. S., Powers, J. and Quintanilla, A. 2018. Baking-stable red raspberries. Invention Disclosure/Trade Secret submitted to Washington State University.

Project Title: SE Asia market activation

Project Summary

The long-term sustainability of the Washington state potato industry is dependent upon international exports. Specifically, since the domestic sales of fresh potatoes continue to trend downward. However, international markets have proven to be a bright spot for the industry and in particular for Washington state potato growers. Historically, approximately 90% of Washington's potato crop leaves the state with nearly half of the crop destined for foreign markets. As efforts to market potatoes domestically have led to increased challenges, Washington state potato growers, packers, and shippers look for new and additional international opportunities that will provide them increased stability. The proximity of their fields to the deep-water ports of the Puget Sound are a key advantage in their international new efforts.

South East Asia continues to be a key region internationally to market potatoes. South East Asia has a growing GDP, an expanding middle class and younger population demographics of individuals who are looking to improve their lifestyles and enrich their diets. This specific project focused on the countries of Myanmar and Vietnam. Previous work and contacts had been made within these two markets. However, the West Coast port slowdown significantly hampered efforts to grow potato exports and sales to those markets. Specifically, in Vietnam sales were lost to competitive growing regions and never regained. This project was to focus on rebuilding relationships and interest amongst buyers and consumers in each market, with the hope to increase sales of fresh potatoes in Washington to both countries.

Vietnam-

After many efforts were made to attain market access to Vietnam for fresh potatoes from the U.S., an agreement was finally reached to allow access for fresh U.S. potatoes in 2010. Initial figures showed success with sales of fresh potatoes to the region shortly after market access was granted. During the 2011-2012 season, 487 metric tons of fresh potatoes were exported to Vietnam. In 2012-2013 season, 2,299 metric tons of fresh potatoes were exported to the same country. However, during the 2013-14 growing season only 1,265 metric tons of fresh potatoes were exported to Vietnam. This declining number in sales of fresh potatoes can be attributed to an increase in potato sales from other regions to Vietnam combined with tariff issues impacting imports from the U.S. To date, fresh U.S. potatoes experience a 20% tariff while potatoes from the other main competing region, China, enter the country tariff free. This has led competing products in the market to be more than half the cost of potato products from the U.S. and Washington state. This caused a need to help reacquaint the Vietnamese consumer with Washington potatoes and reverse the downward trend of sales to the market.

Myanmar-

Myanmar was under a military dictatorship dating back to the early 1960's through 2011. During this era many countries (including the U.S.) had strained relations with Myanmar thus impacting the ability to trade. However, democratic reforms began to occur within the country which eventually led to the lifting of economic sanctions imposed on Myanmar by many other countries. With the easement in sanctions, Myanmar is poised for growth with many consumers within the country starting to enjoy greater economic success and conditions that allow for more disposable income on various items, including food. As such the Washington state potato farmers have expressed interest in the Myanmar market. It is critical for the potato industry within Washington State to look for opportunities within developing markets. This allows them to expand sales beyond the current established and mature markets that they enjoy success in, such as Japan.

The project built upon a previous SCBGP project that took place in 2014. That project was a joint trade mission between the potato commissions of Washington and Oregon and both state's Agriculture Directors. During the trade mission, many great contacts were made and much interest was shown in Washington state potatoes. However, within a week of returning from the trade mission the West Coast port slowdown hit and significantly hampered any follow-up efforts. Within Myanmar, which was an

exploratory stop on the last mission, all progress ceased as no follow-up activities could take place. In Vietnam sales of potato products declined as buyers had to turn to other markets to supply their needs. The purpose of this project helped to re-engage both markets.

Project Approach

The goal in Myanmar was to further investigate and follow-up on what insight was received during the previous trade mission. The previous visit indicated that chipping potatoes would be the best near-term opportunity. The plan was to get samples of chipping potatoes to the manufacturers before the visits to the countries. This would ensure that meaningful conversations with potential customers took place and fostered the discussion of follow-up opportunities with these companies.

The goal in Vietnam was to stimulate interest in Washington potatoes and attempt to see more potatoes enter their market. This would be accomplished through workshops with decision makers highlighting Washington potatoes and then have display contests, that would get the product into the hands of consumers.

The significant contributions and roles of project partner are:

- Mel Calloway- Potato Farmer and Committee Member WSPC / Was a spokesperson regarding potato farming in Washington state and learned about various market opportunities for her farm and the state's potato industry.
- Joe Bippert- International Program Manager, WSDA / Helped manage various elements of the mission including the coordination of governmental meetings.
- Ryan Holterhoff- Director of Marketing and Industry Affairs WSPC / Helped to coordinate the program and events with contractor within each market to develop schedule and ensure goals were being achieved.
- Francis Lee- United Base Company / Contractor on the project with the role of setting up all meetings and developing the trade mission schedule.

No other commodities other than potatoes benefited from this project.

Goals and Outcomes Achieved

Activities Completed:

August 2016: Contractor conducts a pre-visit to Myanmar to adequately line up meetings and finalize the agenda for the trade mission. At this time contacts are made with importers and potato chip manufacturers who are willing to run test shipments of Washington chipping potatoes through their facilities.

September & October 2016: Send test samples of fresh chipping potatoes to Myanmar in preparation of visit to allow potato chip manufacturers the opportunity to use the product in their facilities and determine how they will work for their needs. Also during this time, buyers are connected to exporters of Washington potatoes to ensure promotional activities in Vietnam are successful.

Monday - November 7, 2016: The trade mission began with a briefing with FAS, meeting in Yangon. Followed by meetings with importing company, Grand Cherry Xeno. The importer provided information about their clients/customers and perspective of demand for fresh potatoes. Importer took team to visit two different potato chip manufacturing companies. The purpose of the meetings were to explore the possibility of the manufacturers using fresh chipping potatoes from Washington within their process.

Tuesday – November 8, 2016: A different importer was met on this day, Tin Ye Win Group. This importer's representative also provided information regarding perceived demand for Washington potatoes within the customers they work with. Following the briefing meeting at their office headquarters the team then visited two different potato chip manufacturers.

We developed a better understanding of shipping protocols of fresh potatoes arriving in Myanmar from Washington State. In fact our conversations caused Myanmar's government to review their status and what they would require for fresh potato imports. The government surprisingly made the requirement beginning on January 1, 2017 that all imports of fresh potatoes would need a Pest Risk Assessments (PRA). This move then had the FAS office in Yangon in conjunction with APHIS and the potato industry start to begin discussions on how best to address the new requirement. In March Myanmar's government agreed to extend the requirement until July 31, 2017. However, by the time this extension was in place it was not possible for us to acquire and send quality chipping potatoes that weren't already under contract elsewhere due to the timing of the season.

Due to the need for a complete pest risk assessment for potatoes to Myanmar, an import permit for the fresh potato shipment to Myanmar was not issued until January 31, 2018. The shipment of fresh potatoes arrived in Myanmar late March 2018. The customers commented that while there was some rot found within the shipment, its quality and flavor was preferable to the current local and Chinese potatoes in the marketplace. Although the pricing of Washington State potatoes would not be competitive with local product this time of year. The WSPC learned the best window to be competitive with local and Chinese potatoes would be in the fall. No additional fresh Washington State potatoes have been shipped to Myanmar but shippers not have good knowledge of the market conditions and will focus future sales on fall and early winter shipments.

Wednesday – November 9, 2016: A travel day from Myanmar to Vietnam. On the journey to the airport, the largest wholesale market within Yangon, Myanmar was visited. During the market visit potato distributors were met who are selling local potatoes from Myanmar. The purpose of the stop was to learn how/where potatoes were being distributed.

Thursday – November 10, 2016: In Ho Chi Minh City, Vietnam. Country briefing by USDA/FAS. Following briefing the team conducted the "Why Choose Washington Potatoes Workshop." Nearly 50 produce buyers, chefs and other foodservice personnel attended the meeting. During the meeting, attendees learned about various aspects of the growing and shipping of Washington potatoes. Following the presentations attendees sampled different potato varieties which had been prepared into a handful of different dishes. This allowed attendees the chance to be inspired and think creatively how they might use Washington potatoes within their menus. Following the workshop the team visited two of the display contest winners that had Washington potatoes on showcase.

Friday- November 11, 2016: The team visited three other winners of the Washington potato display contest. Following the visits to the supermarkets a key importer who had imported many Washington potatoes was met. The team learned more about what their success and challenges were.

The data below is reflective of potato shipments specifically just from Washington State to Vietnam. Significant growth has occur as a result or the trade mission associated with the grant.

14/15 *6,250. lbs.

16/17 *11,500. lbs.

17/18 *787,500 lbs.

* WSDA F2A Commodity Inspection Division, Shipper Export Detail Report

The outcomes are long-term but initial steps were made to ensure they were achieved. Myanmar- The team developed a better understanding of shipping protocols of fresh potatoes arriving in Myanmar from Washington State. In fact the conversations caused Myanmar's government to review their status and what they would require for fresh potato imports. The government surprisingly made the requirement beginning on January 1, 2017 that all imports of fresh potatoes would need a Pest Risk Assessments (PRA). This move then had the FAS office in Yangon in

conjunction with APHIS and the potato industry start to begin discussions on how best to address the new requirement. In March, Myanmar's government agreed to extend the requirement until July 31, 2017. However, by the time this extension was in place it was not possible to acquire and send quality chipping potatoes that weren't already under contract elsewhere due to the timing of the season.

Assuming the restrictive PRA doesn't go into effect as is and stall all shipments, the shipments will be tracked to Yangon to ensure product arrives within the country without any issues. All learnings have been shared with chip exporters and as additional information is gained, it too will be shared.

Vietnam-

The team wants to reverse the trend of declining shipments to the country. The year started with positive input but the team will need to work the relationships to build customer recognition of the brand and the quality of the product that is entering their market. There is a portion of their population that is looking to incorporate safe, wholesome and nutritious products into their diets. This makes promotional efforts important at this time to be able to capitalize on this interest.

In Myanmar, the activities consisted of focusing on making relationships with importers and potato chip manufacturers. The reason is that chipping potatoes open the door to other potato imports. Also during previous work, it was learned that the local potato chip manufacturers in Myanmar were anxious to look for supplies that would help them stay competitive with other brands entering their market space. At the same time, clarification as to what requirements would be necessary to import fresh potatoes into Myanmar was needed. The goals were achieved as the meetings allowed for multiple interest from importers who were looking to utilize a test shipment of potatoes for the potato chip manufacturers who were their customers. This also proved to be successful because the Myanmar government instituted shipping requirements of fresh potatoes. This is currently under review and negotiation with the USDA to determine how the potato industry can best cooperate with the requirements.

In Vietnam, the goal was to see exports of fresh potatoes from Washington State begin to increase. Much work was put into allowing access for fresh USA potatoes in Vietnam. However, following initial success multiple factors caused importers to drop dramatically, to a point where very few Washington potatoes were entering Vietnam. The goal was to drive interest amongst consumers and rebuild trust with importers. Initial steps were made with both goals. Follow-up work will be required from Washington's potato exporters and commission office to ensure sales continue to grow, but initial shipments were well received by importers and consumers.

For Myanmar, the achievement has been to accelerate the process of allowing fresh potato shipments into the country by clarifying requirements and increasing interest from customers and buyers.

For Vietnam, the team saw significant improvement in the number of imports going into the country. During the 14/15 marketing year there were 25 (cwt) of fresh potatoes exported to Vietnam from Washington. In the 15/16 marketing year, export stats show a total of 46 (cwt) imported from Washington to Vietnam. For the 16/17 marketing year through May 11, 2017 that amount jumped to 3,150 (cwt). A nice increase that will hopefully be sustained as they look to go into the future shipping seasons.

Beneficiaries

The first group of beneficiaries in Washington are the fresh chipping potato exports as this was the type of potato that their customers seemed to see the most benefit from in the near term. Shipping info with the chipping potato industry has been shared and hopefully shipments begin to enter the country this fall, assuming PRA issues can be sorted.

The other group to benefit will be the fresh potato exporters in Washington. This is due to the re-energized momentum of sales opportunities into Vietnam. This will allow exports a new market to market their potatoes and allow them to expand their opportunities to sell potatoes.

The quantitative data that concerns the beneficiaries of the project and/or that describes the economic impact of the project:

Myanmar

Data still to be determined. No shipments have entered due to new PRA requirements from Myanmar's government. Negotiations currently underway from both sides to allow access in the future.

Vietnam

For the 16/17 marketing year through May 11, 2017 the amount jumped to 3,150 (cwt) a 14,900% increase compared to imports through May 11 during the previous marketing year (15/16).

Positively the team and the farmers in Washington learned that both of these markets have great potential for Washington potatoes. It is critical to start looking beyond the mature Asian markets to find and cultivate success for the future of exports. These markets could eventually someday replace countries like Japan and Korea in the amount of imports they receive.

Myanmar

Challenges

Price – The Burmese are very price sensitive. The typical price of a bag of local potato chips is 100 Kyat (about \$0.08). Total cost per bag of chips is 80 Kyat (about \$0.06) and often higher as costs of raw products vary considerably. This means sustainable profits are only achieved through high volume sales but can also create losses for processors given unfavorable cost fluctuations. Processors stated that consumers would not tolerate even the slightest price increase.

Competition – Products such as Frito Lay are expanding in Myanmar and their economies of scale could end up forcing local processors out of business. Even if local processors chose to increase their competitive position by producing a higher quality potato chip, without consolidation these factories do not have the capacity to import direct from Washington; they must go through an importer which will increase the cost of what they consider to be an already high price per container.

Local Production – Potatoes are a major crop for Myanmar. In order to protect the local crop, the Burmese government requires significant documentation for imported agricultural goods.

Regulation – While the current import requirements are simply a phytosanitary certificate, USDA FAS shared that the government is looking to implement a Pest Risk Assessment by January 1, 2017. It will be important to work with USDA APHIS to help the regulators understand the process.

Infrastructure – Myanmar has very little to offer by way of infrastructure. Importers will not be able to store potatoes in optimal conditions to ensure maximum quality.

Opportunities

Diversification – As more high-end retailers invest in Myanmar and as their economy continues to grow, local manufacturers will be able to market to a higher income consumer willing to pay more for a premium product. They will also continue to be able to supply the local consumer with the existing lower cost chips made from

local potatoes. This will allow them to compete with other high-end foreign competitors while still maintaining the local market share.

Demand – There is a high demand for snack foods in Myanmar. The delegation observed many consumers, especially school-age children, snacking on potato chips throughout their day.

Foreign Investment – With the demand for snack foods, there is likely to be opportunities for foreign investors in Myanmar. Foreign retailers are also taking notice of the market and have already begun expansion in major cities like Yangon and Mandalay.

Vietnam

Challenges

Consumer Habits – The Vietnamese consume significant amounts of rice and do not regularly incorporate potatoes in their diets.

Product Knowledge – Little is known of the different varieties available in Washington. Consumers do recognize russets, and during the education/sampling event seemed pleased with the russet flavor, but also complained that the raw product looked “dirty.” There is very little knowledge on how to cook using any of the varieties.

Tariffs – High import duties on US products are competing against other FTA countries like China. Vietnam is a TPP country and this could change if TPP is ratified.

Infrastructure – Improvements on infrastructure are noticed, but there is still a lot of ground that needs to happen by way of cold chain. There is still very little cold storage and the majority of deliveries are still by motorbike.

Opportunities

Price – The Vietnam consumer is price sensitive, but they pay attention to premium “value” and are willing to pay more for something they perceive as a premium product. Food safety is of high importance for consumers. Consumer perception of US products is high.

Consumer Habits/Age – One-half of the population in Vietnam is under 45 years old. Younger generation of consumers favor western foods and likes to eat out.

Retail – There has been an uptick in the modern retail sector.

Unexpected Outcomes:

Upon return the goal was to send a test shipment container of fresh chipping potatoes to Myanmar. However, their country closed access of fresh potato products. After a few weeks the ban was lifted as negotiations continue, however once the market was opened available chipping potatoes that could be used for the shipment could not be found due to the timing in the season. The issue was finally resolved in February and there were not the appropriate amount of potatoes that could be sent as part of the trial.

Lessons Learned

The main issue was in Myanmar that impacted the follow-up work. A test shipment of chipping potatoes was to be sent but the market closed to fresh potato shipments for a period of time. By the time it opened back up finding enough quality chipping potatoes that weren’t already under contract that late in the season wasn’t possible. Helping with a test shipment in the fall when a new crop is available is being explored.

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Additional Information
See Attachment C-15-SCBGP-WA-0017

Project Title: Bridging the GAP between voluntary and required food safety standards

Project Summary

WSDA sought funding to provide outreach and education to Washington fruit and vegetable growers to assist them in meeting the new mandatory Food Safety Modernization Act (FSMA) Produce Safety Rule, and obtain the USDA Good Agricultural Practices and Good Handling Practices (GAP/GHP) certification required for entry into many markets.

Buyers in every market, regardless of scale, are concerned about on-farm food safety in production and handling practices. Increasingly, buyers are requiring third-party food safety certifications like the USDA GAP/GHP audit – but only 8% of farms that responded to WSDA’s 2014 specialty crop grower survey were GAP certified. In addition, a significant number of growers either do not understand the value of securing the certification, or fully understand the requirements to getting certified. Over half of the farms that responded to the survey reported that they are unsure or unclear what would likely be involved if they were to have their operation GAP certified. Growers also expressed great concern about the upcoming, mandatory FSMA Produce Safety Rule, anticipated to be finalized by October 2015. Even small farm operations, which will likely qualify for an exemption to the Produce Safety Rule, will face increased pressure to meet GAP or FSMA standards as buyer expectations for food safety planning and documentation increase.

The growing focus on food safety in the general marketplace and the implementation of the FSMA Produce Safety Rule were the main drivers behind the timeliness and importance of this project. In addition, at the outset of this project Washington fruit and vegetable growers and processors were to have a unique new market opportunity in selling to schools through the USDA’s Pilot Project for Procurement of Unprocessed Fruits and Vegetables (PPUFV). Washington was one of just eight states nationwide selected by USDA to participate in this program, which allows the use of school lunch entitlement funds for purchasing minimally processed fruits and vegetables, including locally grown items. This represented a significant market access and development opportunity. The Office of the Superintendent of Public Instruction (OSPI) stated that \$1.4 million had been set aside for use in the PPUFV project in Washington in the 2015-2016 school year. However, for farms, there is a real barrier to access to participating as vendors, which is that farms and processors are required to have an integrated food safety program that complies with USDA GAP/GHP certification, or another accredited Global Food Safety Initiative (GFSI) food safety certifier. This project, as a continuation of WSDA’s existing Bridging the GAPs work, explicitly addressed the food safety planning, implementation, and certification requirements for entry into this new market for Washington specialty crop producers and processors.

This project was a continuation of WSDA’s previous Bridging the GAPs work, which continues to be necessary as the landscape of on-farm food safety continues to evolve with the implementation of the new FSMA Produce Safety Rule and changing buyer expectations for food safety assurances. The original Bridging the GAPs project was a SCBG- funded project that educated small and mid-sized diversified growers about voluntary food safety certification (GAP/GHP audits) in order to improve on-farm food safety practices and increase access to diverse markets, as well as prepare for the upcoming FSMA Produce Safety Rule standards, which were not yet published at the time. The on-farm educational workshops from the original Bridging the GAPs project, and the resulting Bridging the GAPs Farm Guide (“Farm Guide”)

publication, were very well received. Growers requested additional guidance and workshops, and asked if the Farm Guide would be updated when the FSMA Produce Safety Rule was finalized, then projected for 2015.

The initial Bridging the GAPs project not only provided excellent opportunities for grower networking and learning about GAP certification and food safety, it also built grower trust in WSDA as a dependable source of information on on-farm food safety practices regardless of farm scale or production practice. Growers now turn to WSDA for up-to-date, reliable, and practical information about produce safety standards and practices. Approximately 185 growers, educators, and farm advocates benefited directly from those on-farm food safety workshops, which provided the opportunity to share real-life examples of different models for implementing on-farm food safety, and receive feedback from GAP/GHP auditors. The workshops served as a forum for WSDA to provide updates on FSMA implementation, and for farmers to learn from one another, and allowed for many farmers to become food safety leaders and examples in their regions. After participating in Bridging the GAPs events, trainings, and/or workshops, nine previously uncertified farms successfully completed their WSDA GAP/GHP audits; 95% of post-workshop survey respondents indicated they would make a change or improvement in their on-farm food safety practices. 57% of participants indicated that they plan to request a GAP audit in the next five years, and an additional 20% indicated they do intend to become GAP certified, but were uncertain of the timeframe.

In the prior project, WSDA found there was a continuing misperception regarding the stringency of practices required for a successful GAP audit, and the expense associated with GAP practices and audits. This is to say at the end of the previous Bridging the GAPs project, there remained continuing interest in securing voluntary food safety certifications and on-going need of support to achieve that in the coming years. In addition, growers continued to express anxiety about the upcoming FSMA Produce Safety Rule, for which publication of the standard had been delayed, and was expected to be released in the fall of 2015.

Project Approach

WSDA staff:

Conducted on-going review and analysis of the FSMA Produce Safety Rule and implementation guidance. Throughout the length of the project period, WSDA worked diligently to stay informed with updated food safety regulations impacting small to mid-sized diversified farmers by engaging with state and federal entities, influencing regulatory recommendations and interpretations, and by staying educated through training courses, meetings, listservs, listening sessions, news articles, and webinars. Three WSDA staff members participated in a two-day Produce Safety Alliance (PSA) Train-the-Trainer course (two in 2016, one in 2017), in order to be able to teach PSA Grower Trainings on the Produce Safety Rule, and one staff member achieved Lead Trainer status which grants additional training opportunities. In addition, two of these staff members attended Produce Safety University (in 2017 and 2018), a weeklong USDA training course focused on food safety concerns as they relate to school food; two staff attended a three-day WSDA training course on the FSMA Preventative Controls for Human Food Rule (in 2017); one staff member attended a three-day USDA Harmonized GAP audit training hosted by the USDA (in 2017); and one staff member attended a three-day Produce Safety Rule On-Farm Readiness Review training hosted by the National Association of Departments of Agriculture and the PSA (in 2018).

In November 2015, the highly anticipated FSMA Produce Safety Rule was finalized and

published after four years of comments, revisions, and scientific research. WSDA quickly mobilized to become subject matter experts in the Produce Rule by carefully reading the 800-page legislation to understand both the fine details and larger picture impact. WSDA cross-referenced the legislation with interpretations from news, businesses and other non-profit advocacy and education groups to become fully conversant in the text. Some of those entities include the National Sustainable Agricultural Coalition, Wild Farm Alliance, Produce Safety Alliance (PSA), Sprout Safety Alliance, and the California Leafy Green Products Handler Marketing Agreement.

Though the Rule was published in 2015, the U.S. Food and Drug Administration (FDA) continues to refine the specific details on several of the more technical requirements of the Rule and compliance timelines for some of these requirements have been postponed to allow for additional stakeholder input, FDA research, and clarification of standards; at the time of this final report, a handful of specific Produce Safety Rule standards have been deferred until FDA issues further guidance, so the full details of all requirements of the Produce Safety Rule are still not known.

Therefore, there is need for on-going attention to review and analysis of Produce Safety Rule standards and implementation guidance. In addition, WSDA developed familiarity with the USDA's newly developed Harmonized GAP and Harmonized GAP Plus+ audit standards, which were influenced by the Produce Safety Rule standards.

Developed guidance documents and revisions to the Bridging the GAPs Farm Guide to incorporate new Produce Safety Rule standards and requirements, with context for how it relates to voluntary (USDA GAP/GHP) standards.

In September 2018, WSDA published a fully revised second edition of the Bridging the GAPs Farm Guide that updates the guide to include guidance on preparing for both the USDA GAP audit and understanding the requirements of the FSMA Produce Safety Rule. The updated guide includes several new chapters on an introduction to food safety, overview of GAP, overview of FSMA Produce Safety Rule and comparisons between the two. Throughout the guide expanded chapters highlight key areas in which the USDA GAP checklist and the FSMA Produce Safety Rule specifically align and where they differ notably. The second edition guide includes additional recordkeeping templates, information resources, and reference documents related to the FSMA Produce Safety Rule. The new content provides context and background information on on-farm food safety practices, food safety programs, and specific, relevant

information on Produce Safety Rule requirements, standards. The guide includes tools and resources to assist farmers with implementation and compliance.

WSDA published 600 print copies of the Second Edition Bridging the GAP Farm Guides in English, each with an attached thumb drive containing digital versions of the templates, resources, and reference documents. WSDA also began planning to have the updated Farm Guide translated into Spanish and printed, using other funding sources. Eventually, digital versions of the complete, updated English and Spanish Farm Guides will be posted on the WSDA website for online reference and download.

Due to delays at the FDA in the roll out of the FSMA Produce Safety Rule standards and supporting guidance, throughout the project, WSDA frequently updated training materials and handouts with the best available news and information about FSMA. Project staff adapted these materials and presentations for farmer audiences with varying acreage, products, markets, and other regional characteristics. WSDA staff also edited and updated relevant fact sheets in the WSDA Handbook for Small and Direct Marketing Farms (aka the “green book”) on the topics of GAP certification and the Food Safety Modernization Act. This publication is the primary guidance resource for small and mid-size farms in Washington, including specialty crop producers. Providing updated information in this particular resource for specialty crop producers about the new Produce Rule requirements and clarifying the similarities and differences in the new rule and the voluntary GAP standards is critical. The updated green book is due to be released in late 2018.

- **Developed a farmer tracking system in Salesforce.**

WSDA took steps to implement a farmer tracking system as part of developing a food safety mentor referral program. However formal mentorship program has not gained traction with producers and there was no active interest in a formal referral program, so WSDA did not pursue this activity. The Regional Markets program uses a Salesforce system, which was customized and updated to allow for more precise tracking of food safety technical assistance provided to specialty crop producers and to monitor their progress towards a successful GAP audit. The customized database went live in Winter 2017. More information about this is provided in the Lessons Learned section of this report.

- **Conducted six on-farm workshops across the state to provide updated information and respond to farmer questions and needs, while facilitating informal regional learning networks among area growers and resource providers.**

WSDA staff executed the following six on-farm workshops:

Oct. 24, 2015	Viva Farms, Burlington WA (Skagit County)	Bilingual English-Spanish workshop. Classroom presentation and on-farm training. 25 attendees.
March 23, 2016	Dharma Ridge Farm, Quilcene WA (Jefferson County)	Classroom presentation and on-farm training. Coupled/co-promoted with WSDA Local Buying Mission and FamilyFarmed’s Wholesale Success events in region. 24 attendees.
Oct. 10, 2016	Heavenly Hills Harvest Farm, Sunnyside WA (Yakima County)	Bilingual English-Spanish

		workshop. All on-farm workshop. 33 attendees.
Aug. 28, 2017	Northwest Organic Farms, Ridgefield WA (Clark County)	All on-farm workshop. 25 attendees.
June 20, 2018	Apple Cart Fruit, Tonasket WA (Okanogan County)	All on-farm workshop. 19 attendees.
July 9, 2018	Spoon Full Farm, Thorp WA (Kittitas County)	All on-farm workshop. 12 attendees.

- **Presented on GAPs, FSMA Produce Safety Rule, and on-farm food safety practices at conferences and events.**

WSDA staff presented and tabled at numerous events on on-farm food safety topics. Over the course of the project, approximately 2,090 specialty crop growers received direct or indirect education about on-farm food safety through workshop or training attendance, resource distribution and/or technical assistance via phone, email, or in person discussion. At least 616 growers attended an on-farm food safety presentation and/or received follow-up one-on-one assistance from WSDA staff.

The following list captures the majority of events WSDA presented and/or tabled at:

November 2015	Tilth Producers conference (Spokane)
November 2015	Department of Labor and Industries Agricultural Business Training Day event (Tumwater)
November 2015	WSU Cultivating Success class (Shelton)
November 2015	Focus on Farming (Monroe)
December 2015	Wallace Center “Practical Food Safety for Farmers and Handlers” training (Spokane)
January 2016	Washington State Farmers Market Association Annual Conference (Olympia)
February 2016	WSU Cultivating Success class (Everett)
February 2016	Sustainable Connections Farm-to-Table Trade Meeting (Bellingham)
March 2016	Farm Business Training Program for Beginning Farmers (Acme)
May 2016	Wholesale Success training (Yakima)
June 2016	Seasonal workshop at Cloud Mount Farm Center (Everson)
November 2016	Tilth Alliance conference (Wenatchee)

November 2016	Focus on Farming (Monroe)
November 2016	Department of Labor and Industries Agricultural Business Training Day event (Tumwater)
February 2017	Washington State Farmers Market Association Annual Conference
February 2017	San Juan Island Agricultural Summit (San Juan Island)
February 2017	Pike Place Market Small Business Resource Fair (Seattle)
February 2017	Sustainable Connections Farm-to-Table Trade Meeting (Bellingham)
February 2017	Pierce County Farm Forum (Puyallup)
May 2017	PSA Grower Training for WSDA Fruit and Vegetable Inspectors (Ellensburg)
October 2017	Presentation to Tilth Alliance incubator farmer at Red Barn Ranch (Auburn)
October 2017	King County On-Farm Food Safety Workshop for Hmong Farmers (Kent)
November 2017	Focus on Farming (Monroe)
November 2017	Tilth Alliance conference (Vancouver)
November 2017	Women in Agriculture Conference (Des Moines)
November 2017	Center for Latino Farmers educational series workshop (Yakima)
December 2017	PSA Grower Training at Viva Farms (Mount Vernon)
January 2018	Wholesale Success workshop (Vancouver)
February 2018	Pike Place Market Small Business Resource Fair (Seattle)
February 2018	Neighborhood Farmers Market Association Annual Vendor Meeting (Seattle)
March 2018	WSU Cultivating Success class (Renton)
March 2018	San Juan Agricultural Summit Farmer Short Course (Lopez Island)
April 2018	Bilingual PSA Grower Training at Viva Farms (Mount Vernon)
May 2018	King County On-Farm Food Safety Workshop (Fall City)
May 2018	King County On-Farm Food Safety Workshop (Woodinville)

- **Provided technical assistance to specialty crop growers working to improve on-farm food safety, obtain GAP/GHP certification, become eligible vendors in the PPUFV, and meet new FSMA Produce Safety Rule and Preventative Control standards.**

WSDA worked with numerous project partners to tailor each training and workshop to the unique needs of

each farming community, based on scale, products, growing practices, level of familiarity with food safety programs, and so on. At each on-farm workshop, WSDA educators, GAP/GHP auditors, host farmers and other state and local resource providers were present to answer the specific questions of growers who attended, and offered follow-up information by email when necessary. Growers that attended trainings and workshops also received Farm Guides, which provided step-by-step instructions, examples, tips, and records templates to support farmers implementing food safety practices and prepare for GAP/GHP audits on their farms after the training ended. In this way, growers received technical advice and support relevant to their needs via the trainings.

In addition, WSDA worked extensively with Oxbow Farm and Conservation Center in preparing for its first GAP/GHP audit. Specifically, WSDA provided training advice, resource recommendations and food safety documentation review. In 2016, Oxbow Farm hired a consultant to conduct a mock audit on their farm and WSDA Project Manager and Project Coordinator attended as assisting educators. Together WSDA educators, farmers, and consultants debated practical solutions that could meet both production needs and food safety standards; the farm's main concern was developing and maintaining systems for traceability and sanitation in their packing house that would fit with their existing processes and practices.

In relation to the PPUFV, WSDA contacted over 100 Washington farms and other produce vendors to assess their interest in becoming approved vendors for the program, and offer technical assistance in the lengthy application process if so. In all, 8 Washington farms that attended on-farm food safety trainings and received technical assistance and support from WSDA staff were successfully approved as vendors for the PPUFV between 2015 and 2018; an additional two food processors and distributors exclusively selling Washington-grown foods and 10 distributors selling some Washington produce were supported in their application process to become approved vendors.

Throughout the project, WSDA worked with a large number of national, state, and local partners to learn and clarify food safety standards; plan and promote workshops and trainings; develop resources; and teach and support farmers in a variety of ways across the state. Their contribution was extremely valuable in making this Bridging the GAPs II project successful. The major contributions of project partners are described in brief:

- **Workshop host farms:** Workshop host provided the setting for the on-farm workshops, offering real life farm examples for attendees to observe, including GAP/GHP auditors for whom exposure to small-scale, diversified farms was critical to their ability to provide audit services to these producers. Farm hosts provided information about their farm business and practices, and positioned themselves as a peer learning resource for other farmers in their region. The six farms that hosted WSDA Bridging the GAPs workshops as part of this attended project were: Viva Farms, Dharma Ridge Farm, Heavenly Hills Harvest Farm, Northwest Organic Farms, Apple Cart Fruit, and Spoon Full Farm.
- **Washington State University Extension:** WSU Extension staff provided support in numerous ways, most notably by partnering on outreach and co-hosting regional trainings. WSU Extension staff in several counties supported workshop development and promoted workshops through various channels and provided additional speaking/presentation opportunities by requesting WSDA staff provide food safety training for aspiring farmers in WSU Cultivating Success classes.
- **WSDA Fruit & Vegetable Inspection Program:** WSDA GAP/GHP auditors attended every workshop to both provide input on acceptable food safety practices and GAP/GHP standards from the perspective of actual auditors, as well as to develop their own familiarity with small and mid-scale diversified farming operations so as to be better positioned to understand and accurately assess such farms in future audits. In addition, WSDA GAP/GHP auditors provided input and reviewed materials relating to GAP standards, including revisions and additions made to the second edition of the Farm Guide.
- **WSDA Produce Safety Program:** The WSDA Produce Safety Program was created mid-project, as part of a co-operative agreement with the FDA to support the implementation of the FSMA Produce Safety Rule in Washington. Given her expertise developed in part through this project, the original Bridging the GAPs Project Coordinator Karen Ullmann was transferred to the newly formed Produce Safety Program as its Outreach and Education Coordinator. Karen and other Produce Safety Program staff provided significant collaboration and support throughout the remainder of the project by helping plan, promote and teach the final two on-farm workshops; contributing significant planning, writing, and editing to the revision of the Farm Guide; securing funding to support training opportunities for

project staff; and collaborating on continued education and understanding of the FSMA Produce Safety Rule.

- **WSDA Organic Program:** Organic Program staff attended three of the six on-farm workshops in order to better understand the overlap of food safety standards and Organic standards to enhance their own capacity, and support attending organic farmers. The Organic program also helped WSDA promote workshops and other training opportunities to organic farms throughout the state.
- **WSDA Communications team:** The Communications team helped promote Bridging the GAPs workshops and related events through its various channels, including social media. The Communications team also provided editorial and other practical support in the revision and publishing of the second edition of the Farm Guide.
- **OSPI Child Nutrition Services:** OSPI Child Nutrition Services sub-contracted with WSDA Regional Markets farm to school staff (using Child Nutrition SAE funds) to launch an education and outreach campaign with school districts and farmers on how to utilize the USDA Pilot Project for Unprocessed Fruits & Vegetables. OSPI-CNS worked with the WSDA Regional Markets farm to school staff to develop trainings and a toolkit for school districts to grow participation, purchases, and spending through the USDA Pilot Project. WSDA Farm to School also developed trainings and education to encourage farmers and other food suppliers to sign up as vendors for the USDA Pilot Project (one of the eligibility criteria being GAP certification). OSPI-CNS was a strong supporter of the project in order to increase the amount of purchases school districts were making through the program, in particular to diversify the type of purchases from various vendors including GAP certified farms.
- **Tilth Producers / Tilth Alliance, Washington State Farmers Market Association, Washington Sustainable Food and Farming Network / Food Action, Pike Place Market, Neighborhood Farmer's Market Association, San Juan Island Agricultural Guild, Sustainable Connections, Pierce County Farm Forum, and Snohomish County Focus on Farming:** These statewide non-profit organizations helped WSDA connect with producers by sharing information through their farmer networks and helped to coordinate speaking opportunities for WSDA staff. The annual Tilth Producers/Tilth Alliance conference, Washington State Farmers Market Association conference, Sustainable Connections Farm to Table, Farm Forum, and Focus on Farming conferences are consistently well-attended outlets for information sharing and networking. WSDA attended these conferences as presenters and tradeshow representatives each year along with many farmers, researchers, advocacy groups and non-profits invested in securing the viability and productivity of Washington agriculture.
- **The Produce Safety Alliance (PSA), National Sustainable Agricultural Coalition, FamilyFarmed, Wild Farm Alliance, Sprout Safety Alliance, and California Leafy Green Products Handler Marketing Agreement:** These national non-profit advocacy and educational organizations aided WSDA staff in learning, understanding, and developing proficiency in the FSMA Produce Safety Rule standards by providing educational opportunities and guidance.
- **Methow Conservancy, Local Inland Northwest Co-operative (LINC Foods), Transformation Sunnyside, Center for Latino Farmers, Washington Young Farmers Coalition, and multiple local farmers market organizations:** These regional cooperative businesses, non-profit organizations, farmer groups, and other organizations provided insight on local farmers' training needs, helped make contact with potential host farms, provided input on workshop development, promoted workshops, and in some cases provided additional speaking/presentation opportunities.
- **Viva Farms and King Conservation District:** WSDA secured additional grant funding to conduct Bridging the GAPs education and resource development with farmers in Skagit County (with Viva Farms) and King County (with King Conservation District), beyond the scope of this SCBG project. These training opportunities provided additional educational support and resource development capacity that benefitted subsequent SCBG on-farm workshops and resources, including the Second Edition Bridging the GAPs Farm Guide.
- **WSDA Regional Markets Program Farm to School staff and SCBG-funded Value Chains Project:** Chris Iberle, who staffs the Farm to School work and related Value Chains Specialty Crop Block Grant project, provided outreach, education, and technical assistance to farms, processors, and distributors interested in becoming USDA-approved vendors for the PPUFV.
- **Oxbow Farm and Conservation Center:** Oxbow Farm and Conservation Center was an information resource for WSDA project staff and a peer resource for other farms in the Snoqualmie Valley as it prepared for its first GAP/GHP audit and implementation of the Produce Safety Rule. Previously, WSDA had provided training advice, resource recommendations and documentation review to Oxbow Farm as it provided tailored assistance to other local farms. In 2016, Oxbow Farm hired a consultant to conduct a mock GAP audit on their farm and invited the WSDA Project Manager and Project Coordinator to attend as assisting educators. The consultant, with past work experience as an auditor, provided valuable insight on the USDA GAP/GHP audit process and

scoring justifications. WSDA then used the mock audit example as a teaching tool and model for other regions who want to collaborate on food safety planning and certification preparation, and used photos from the audit in the revised edition of the Farm Guide.

Both the FSMA Produce Safety Rule and GAP/GHP Audit standards pertain to the safe production of produce, so the sole focus of this project was on specialty crops and project funds were used to provide education and assistance only to specialty crop growers.

Goals and Outcomes Achieved

To achieve the performance goals established in the expected measureable outcomes for this project, WSDA conducted six on-farm workshops across; presented on GAPs, FSMA Produce Safety Rule, and on-farm food safety practices at numerous conferences and other events; reviewed and analyzed new food safety standards and guidance and developed and revised training curricula and resource materials on GAP and Produce Safety Rule requirements, and distributed those materials; and provided technical assistance to farms that requested support achieving a first time GAP audit, implementing the FSMA Produce Safety Rule, or becoming approved vendors in the PPUFV.

The Expected Measureable Outcomes include increased grower readiness and intention to meet voluntary and regulatory food safety standards through education, outreach and resource distribution; successful first time GAP certification achievement; and approval of new vendors to the PPUFV. Each of these expected measureable outcomes was intended to be completed within the timeframe of this project.

- WSDA met or exceeded its goals in increasing grower readiness and intention of implementing food safety practices on their farms and supporting new vendors in the approval process for the PPUFV.
- WSDA fell short of its goal of seeing new growers achieve successful GAP audits on their farms during the project timeframe. This is due to a mix of factors. Through the project it became clear that preparation for a first time GAP audit is a longer-term activity that may take a farm years after their first participation in a workshop. In addition, many farms have taken a “wait and see” attitude in response to the ever-changing landscape of food safety expectations as FDA continues to change the implementation timelines and requirements for the Produce Safety Rule. During this project, WSDA noted that farms generally take approximately two to three years to prepare for and attain GAP certification, and that many farms at this time are waiting to certify until more recommendations are provided by FDA regarding the Produce Safety Rule. WSDA also found that some growers opt to not complete a formal GAP audit on their farms, as their desired markets do not require it or it is not a cost-effective certification to hold; though many still worked to implement GAP-aligned food safety practices on their farms without advancing to an audit. Though the goal of 20 new farms was not met during this project, WSDA made significant progress in moving many Washington produce farms towards meeting their food safety goals. Of the 138 on-farm workshop attendees, 90% reported that their knowledge of GAPs increased by attending the workshop; and 94% reported that their knowledge of general on-farm food safety practices increased by attending the workshop.

GOAL 1	TARGET 1A	PERFORMANCE MEASURE 1A	ACHEIVEMENT 1A
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Specialty crop growers will be informed and prepared to meet voluntary (buyer-driven) GAP standards and FSMA Produce Safety Rules	Education and TA about on- farm food safety will be provided to 1,000 specialty crop growers across WA	# Farm Guides distributed # Growers attending on-farm workshops # Growers receiving TA Additional measure: # Growers reached at other WSDA presentations (conferences, etc.)	-- Approximately 661 first edition Farm Guides distributed. (Additional 600 second edition Farm Guides printed.) -- 138 people attended the on-farm workshops. The great majority were growers, with some resource providers also attending in order to learn on-farm food safety practices to better support farmers in the region. -- At least 616 people, mainly growers, attended a food safety presentation on GAP and Produce Safety Rule standards and/or received follow-up one-on-one assistance from WSDA staff. -- At least 2,090 people, mainly specialty crop growers, received direct or indirect education about on-farm food safety through workshop or training attendance, resource distribution
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			and/or technical assistance via phone, email, or in person discussion.
	TARGET 1B	PERFORMANCE MEASURE 1B	ACHEIVEMENT 1B
	80% of workshop attendees will report improved readiness to comply with FSMA Produce Safety Rule	Post-workshop participant surveys	90% of workshop attendees reported that their knowledge of the FSMA Produce Safety Rule increased as a result of attending the workshop. In addition: 90% of workshop attendees reported that their knowledge of GAPs increased by attending the workshop; and 94% of workshop attendees reported that their knowledge of general on-farm food safety practices increased by attending the workshop.
GOAL 2	TARGET 2	PERFORMANCE MEASURE 2	ACHEIVEMENT 2
Growers will improve food safety practices on their farm	75% of growers will improve food safety practices on their farms	Post-workshop participant surveys	88% of workshop attendees reported that they intend to use the knowledge, strategies, or technologies they learned in the workshop to improve food safety practices on their farm. Most growers listed one or more specific food safety improvement they intended to implement; examples include “Better kept records for traceability” “Harvest bins off ground” “Keep animals out of fields” “Look into sanitizer options” “Labeling for farm visitors” and “Pack shed design”

GOAL 3	TARGET 3	PERFORMANCE MEASURE 3	ACHEIVEMENT 3
Growers ready and active in getting GAP certifications	20 new farmers will succeed in securing their first GAP certification. Baseline: 383 Washington growers held current GAP certification at time of project proposal.		In October 2017, 316 Washington farms held current GAP certification. In November 2018, 279 Washington farms held current GAP certification.

The initial benchmark for Washington farms that successfully completed a GAP/GHP audit was 383 farms in 2015. The number of Washington farms with GAP certification decreased to 328 in 2016, then to 316 in 2017, and to 279 in 2018. The reason for this overall decline in numbers is hard to determine as these results reflect farms of all scales and represent only one GAP certifier (i.e. does not include private GAP certifications that Washington growers may have opted for). WSDA has noted that farms generally take approximately two to three years to attain GAP certification, and that many farms at this time are waiting to certify until more recommendations are provided by FDA regarding the Produce Safety Rule. WSDA post-workshop survey results also show that the attending small, diversified farms vary greatly in their projections for when they might request a GAP audit. Approximately one third plan to request an audit in the next one to two years, one third plan to request an audit in the next five years, and one third are uncertain or are not interested in attaining GAP certification.

GOAL 4	TARGET 4	PERFORMANCE MEASURE 4	ACHEIVEMENT 4
The USDA Pilot Project of Unprocessed Fruits and Vegetables approved vendor list will include options for school districts seeking Washington-grown produce	At least 20 produce growers or distributors selling Washington-grown produce will be on the USDA- approved vendor list. Benchmark: At time of project proposal, there was 1 Washington-based produce company listed, and no growers.	Monitoring list of growers and produce companies on the USDA-approved vendor list for the PPUFV who sell and identify Washington-grown produce.	Between 2015 and 2018, 20 business (growers, processors, or distributors) applied and were approved for the PPUFV. Of those, 8 are Washington farms; 2 are processors or distributors selling only Washington grown foods; and 10 are distributors selling some Washington grown produce.

The 20 vendors approved for the PPUFV between 2015 and 2018 were:

Approval date	Vendor
2/10/2015	Pacific Coast Fruit Co.
7/10/2015	Spokane Produce, Inc.
7/20/2015	First Fruits Marketing of Washington
8/24/2015	Penny's Salsa
8/27/2015	American Produce Express, LLC.

9/16/2015	Charlie's Produce
9/17/2015	Columbia Fresh Packing, LLC
10/20/2015	Food Services of America
11/2/2015	Columbia Fruit, LLC
3/17/2016	Tahoma Farms
6/3/2016	Organically Grown Company
7/29/2016	Cloudview Eco Farms
8/10/2016	Hopewell Farm
12/13/2016	Bellewood Acres
1/24/2017	Four Elements Farm
5/25/2017	Duck Delivery of Washington, Inc.
7/14/2017	Easterday Farms Produce Co.
8/24/2017	Yaksum Orchard
10/20/2017	LINC Foods
4/6/2018	Cloud Mountain Farm Center

Beneficiaries

The primary beneficiaries of this project are small and mid-scale diversified produce growers in Washington. They benefited directly by receiving education, training, resource materials, and technical assistance to improve their on-farm food safety practices, help them achieve a successful GAP audit, prepare for FSMA Produce Safety Rule requirements, and communicate effectively with their buyers about their food safety practices.

These specialty crop farms also benefitted indirectly through WSDA's on-going buyer-side education efforts, including schools. Buyers' lack of understanding about food safety standards and food safety programs can reduce farmer access to markets or place undue burden on farms to try to comply with excessive or inapplicable standards. Greater clarity around the standards themselves and ways of direct communication between farmers and buyers about food safety practices, rather than third party certifications, enhances farmers' market access.

Additionally, 20 food businesses that sell Washington-grown produce (including 8 farms, 2 processors, and 10 distributors) successfully achieved their goal of becoming approved vendors in the USDA PPUFV during this project, enabling them to access a unique, new wholesale market. This also benefited participating schools in Washington that have a new procurement channel to buy and serve fresh fruits and vegetables, including Washington-grown produce, in school meals. WSDA Farm to School included the GAP requirements for produce growers in USDA Pilot Project vendor trainings around the state, relying on the Bridging the GAPs farm guide as an introductory resource. WSDA Farm to School held six vendor workshops with 28 farmers or food producers, covering food safety requirements for vendor participation in the USDA Pilot Project at each training. WSDA also collected some new resources and information for suppliers on GHP Part 7 Food Defense, a requirement for distributors participating in the USDA Pilot Project, which many smaller distributors (such as food hubs) were unfamiliar with. This was a barrier for one food hub to participate in the USDA Pilot Project, but another in the state used those resources to add GHP Part 7 Food Defense to their GAP/GHP audit and successfully became an

approved vendor.

Over the course of the project, WSDA provided produce safety education and assistance to approximately 2,200 people either directly or indirectly through trainings, resource distribution and/or technical assistance. This includes 138 attendees at on-farm workshops and at least 616 attendees at other training events such as conference sessions. WSDA did not collect actual or anticipated sales data from these growers.

WSDA also contacted over 100 Washington farms and other produce vendors to assess their interest in becoming approved vendors for the program, and offer technical assistance in the lengthy application process if so. In all, 8 Washington farms that attended on-farm food safety trainings and received technical assistance and support from WSDA staff were successfully approved as vendors for the PPUFV between 2015 and 2018; an additional two food processors and distributors exclusively selling Washington-grown foods and 10 distributors selling some Washington produce were supported in their application process to become approved vendors. Since WSDA began working on the PPUFV, supporting both vendors and school buyers, sales through the program increased dramatically. The economic impact of sales through the PPUFV in Washington were captured for the 2015-16 and 2016-17 school years; however, due to changes in the reporting process, sales values from school year 2017-18 are unavailable. For school years 2015- 2017, purchases through the PPUFV have totaled \$1,358,930, with 61% (\$828,947) spent on source-identified Washington-grown products.

Lessons Learned

There is a strong, ongoing desire for education and support related to on-farm food safety amongst small and mid-scale produce growers in Washington. This interest stems from both confusion about existing food safety standards, and anxiety about the implementation and impact of the FSMA Produce Safety Rule. At the same time, given the evolving landscape of on-farm food safety and lack of clarity on some Produce Safety Rule standards, some smaller growers are hesitant to start new voluntary food safety programs (and may contribute to reduced interest in first time GAP audit certification by smaller and diversified farms for whom an audit is a significant expense) or fully implement Produce Safety Rule practices until there is more concrete federal guidance. This sets a dynamic in which food safety educators are responding to farmers who hunger for training and resources that they may not act on immediately.

There is still significant confusion among farmers about the differences between voluntary GAP audits and required FSMA rules- and about which is most relevant and applicable to an individual small specialty crop farm may vary depending on their particular markets of interest. The WSDA Regional Markets Program is well positioned to respond to this confusion going forward thanks to this specialty crop block grant project and the publications, teaching tools, and workshop design developed through the project. However, with so much resource directed towards FSMA-specific education through the WSDA Produce Safety Program and contracted partners including WSU Extension via the FDA cooperative agreement, there will be a need going forward to clarify the how the lessons and resources developed through this project will contribute to the education landscape with a valuable and needed GAP-inclusive approach.

This project did not have direct unexpected results, though there were some unanticipated and generally positive side effects worth mentioning. One relates to the creation of the new WSDA Produce Safety Program, and the second to delayed FDA timeline the rollout of the FSMA Produce Safety Rule resulting in unexpected benefits to the project outcomes.

- **New WSDA Produce Safety Program and Expansion of Food Safety Education Capacity**
An unforeseen development during the course of this project was the creation of the WSDA Produce Safety Program. A cooperative agreement between the WSDA and the FDA led to the creation of this new program, which is tasked with the implementation of the FSMA Produce Safety Rule in Washington State, including educational outreach, and eventually inspections and enforcement of the Rule. WSDA's previous and ongoing work developing expertise and providing outreach and education about the FSMA Produce Safety Rule was due to the activities funding through this and one previous SCBG funded "Bridging the Gaps" project. Thanks to this work, WSDA was in a position for the new Produce Safety Program to move quickly to provide outreach and education for farms around the state, particularly because the initial

SCBG Project Coordinator Karen Ullmann, was transferred from the Regional Markets Program to the Produce Safety Program to lead those outreach and education efforts. With the opportunity to bring Ele Watts into Karen's vacated role of Project Coordinator for this project, Ele quickly worked to become fluent in the rule and to bring her experience with adult education and training to the project. Karen Ullmann was able to continue collaborating on this SCBG project from her new role. She provided support to planning and teaching of the two final workshops, and contributed significantly to the revision of the Farm Guide. Overall, this happenstance, effectively allowed WSDA to dramatically increase its capacity to serve farms on food safety issues at a critical time. As a result of the expertise developed by staff members through this project, WSDA was able to provide targeted FSMA Produce Safety Rule trainings to both prepare larger farms for inspections, and to increase capacity of smaller scale, highly diversified specialty crop producers with general on-farm produce safety and GAP and other marketplace food safety requirements using the Bridging the Gaps approach.

Delay in FSMA Produce Safety Rule timeline

The significant delays in the timeline of the rollout of the FSMA Produce Safety Rule and accompanying FDA interpretation and guidance impacted the workplan of this project – essentially requiring completion of activities in reverse order. The original plan was to review the complete and final Produce Safety Rule and supporting guidance in late 2015, update and revise training curricula, publish the Second Edition Bridging the Gaps Farm Guide, and *then* execute the on-farm workshops and other trainings. With specific sections of the Produce Safety Rule still needing clarification from the FDA, WSDA did not want to print a new publication. Instead, project staff completed all workshops and trainings prior to updating the Bridging the Gaps Farm Guide, and continuously updated training curricula with the latest news and information as it became available from FDA throughout the project period. While the final rule was released in 2015 as anticipated, FDA continues to refine and adjust the specific details of several requirements of the rule and their related compliance timelines (i.e. soil amendment application requirements and water quality testing requirements). The effect of this was a better and more relevant publication. WSDA staff were able to incorporate all they had learned through teaching and working with farmers over the entire course of the project. This informing of the topics would be most useful to include in the Guide and how best to present the information.

In addition, as part of the extended timeline of releasing and amending the produce Safety Rule standards, FDA held a number of national summits in order to solicit stakeholder feedback on various technical aspects of the standards. The FDA hosted two Soil Summits in 2016 and a Water Summit in 2017 to collect stakeholder input on the rule as written and to provide insight on potential changes to the regulations. WSDA participated in these summits to represent Washington farmers, seek answers to their particular questions, and present their unique concerns to the FDA for consideration. As a result of the feedback gathered at these summits, the FDA is reconsidering the existing soil and water standards, and may revise them to be more realistic and attainable for smaller scale and highly diversified farms, which were likely to be the most impacted by the original standards. New standards have yet to be announced.

WSDA did not develop a formal food safety mentor referral system, mainly due to lack of grower interest of this proposed activity. WSDA did complete the necessary steps to track farmers in the team's Salesforce system, completing a customization and update to allow for more precise tracking of food safety technical assistance provided to specialty crop producers and to monitor their progress towards a successful GAP audit. The customized database went live in Winter 2017.

Through email and in-person communication, growers expressed a disinterest in a formal referral and mentorship program. However, one lesson learned is that the design of the on-farm workshops have provided a useful, informal venue for peer-to-peer learning, where the host farmers served as a de facto mentor to other workshop attendees. With guidance from the workshop trainers, the host farmers shared information about their operations, personal experience, research, their own lessons learned, and future plans related to on-farm food safety practices, preparing for and/or going through GAP audits, and preparing for compliance with the FSMA Produce Safety Rule. Other producers attending the workshops typically shared observations and experiences from their own farms as well, and asked the host farmer questions on a variety of topics related to food safety and other production and handling practices. WSDA concluded that one reason for the lack of interest in the farmer mentorship program is because it did not

offer mentor farmers compensation for their time or expertise. Other, similar mentorship programs that have more successfully recruited farmers paid mentor farmers for their work. Future iterations of this activity should budget for and offer farmers reasonable compensation for their time and knowledge.

WSDA fell short of its goal in seeing 20 new growers achieve successful GAP audits on their farms during the project timeframe, because it became clear that preparation for a first time GAP audit is a longer-term activity, that not all farms need to complete an audit in order to access new markets, and that farmers were delaying implementing new food safety programs in the uncertain period of the evolving landscape of food safety regulations and buyer expectations. During this project, WSDA noted that farms generally take approximately two to three years to prepare for and attain GAP certification, and that many farms at this time are waiting to certify until more recommendations are provided by FDA regarding the Produce Safety Rule. WSDA also found that some growers opt to not complete a formal GAP audit on their farms, as their desired markets do not require it, that it is not a cost-effective certification to attain for potential markets, or that direct-marketing farms have the unique ability to communicate directly with buyers about their on-farm food safety practices. WSDA found that many growers worked to implement GAP-aligned food safety practices on their farms without necessarily advancing to an audit, and expressed continued interest in learning about potentially implementing Produce Safety Rule-aligned practices even if they may qualify for an exemption from the Rule.

Contact Person

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Additional Information

WSDA is the primary source provider for in-kind match, which includes

- Services normally provided by WSDA and calculated at a federally negotiated rate of 17.7% of salaries and benefits,
- Project manager salaries and benefits and indirect expenses,
- Mileage costs.

\$34,573 Indirect costs associates with direct personnel charges to this grant.

\$17,754 Salary, benefits, and indirect costs for the Project Manager for time dedicated to this project.

\$1,162 mileage costs, estimated = \$53,489

This contributed match is less than anticipated primarily because the in-kind match is proportional to direct staff time charged to the project. Due to a budget amendment which shifted funds from staffing costs into direct expense for training and development and printing of the publication, the WSDA in-kind match related to staff time decreased.

However, the project benefited from significant cash contributions from WSDA's Produce Safety Program which paid for travel and training expenses to send project staff to multiple trainings related to the Produce Safety Rule throughout the course of the project. The Produce Safety Program also contributed significant staff time to the project, and in the future will help fund the Spanish translation and printing of the Second Edition Bridging the GAPs Guide. These contributions are noted here because they are significant but a match figure is not provided because all of these contributions were supported with federal funds through a cooperative agreement between WSDA and the FDA.

The following is a sampling of outreach fliers, media coverage, and photographs of project activities:

- A. Food Safety News article on Workshop Co-hosted with Viva Farms
- B. Example Outreach Flier in English and Spanish for Workshop in Yakima Valley
- C. Photo collage from workshops and "mock audit"

FSN Food Safety News

Breaking news for everyone's consumption

Learning to 'Bridge the Gaps' for Small and Mid-Sized Farms

By **Cookson Beecher** on October 26, 2015

Waging a successful battle against the foodborne pathogens that can sicken people — or even kill them — takes some creative strategizing on the part of small- and mid-size farms, primarily because they're so different from large farms and even from one another.

With that in mind, about 25 people took advantage of the invitation to come to [Viva Farms](#), an incubator for new farmers near Burlington, WA, on Oct. 24, 2015, for a free morning workshop on food safety, followed by an afternoon

computer session at Skagit Valley College. (Ongoing verbal Spanish translation was provided during both sessions by Kate Selting-Smith, Washington State University Extension Small Farms Program.)



Tricia Kovacs, left, and Karen Ullmann of the Washington State Department of Agriculture tell a group of farmers attending an Oct. 24 on-farm workshop about Good Agricultural Practices and Good Handling Practices.

Turns out that a computer and a flash drive, complete with practice sheets, templates, and checklists, can be just as useful as a hoe and a tractor when it comes to successful farming in today's world.

Presented by Viva Farms, the Washington State Department of Agriculture, and Washington State University Extension, Saturday's "Bridging the Gaps" workshop was designed to help small and mid-sized diversified farmers learn practical and cost-effective ways to establish food-safety practices on their farms. One of the goals was to help the farmers get started on writing a plan that would meet the requirements of USDA's [Good](#)

[Agricultural Practices \(GAP\) and Good Handling Practices \(GHP\).](#)

On hand to offer advice and information about what farmers need to do to pass a third-party audit was Wade Clark, auditor for the Washington State Department's Fruit and Vegetable Inspection Division.

Passing a third-party audit has become increasingly important to small- and mid-sized farms as they reach out to sell to retailers and institutions, such as schools and hospitals, because many of them require an audit. Then, too, the U.S. Food and Drug Administration's (FDA) Food Safety Modernization Act (FSMA) Produce Rule is expected to be finalized and published soon. And even though it exempts many small-scale farmers, it doesn't exempt them from being responsible for their customers' health — or from lawsuits if their produce ever sickens people.

Farms that pass the audits have their names put on a USDA list which buyers can access. The voluntary GAP/GHP Audit Verification Program was written in response to FDA's ["Guide to](#)

Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables.” A successful audit shows a farm’s commitment to following and maintaining guidelines to help minimize the potential risk for microbial contamination of its produce.

The audit verification program examines such things as worker sanitation, field harvesting and transportation, traceback, water use, manure and compost use, the soils, and temperature controls.

In 2014, the USDA Audit Program performed more than 3,800 Good Agricultural Practices (GAPs) and Good Handling Practices (GHPs) audits in 46 states and Canada, covering in excess of 90 commodities.

Why they were there

Nic Mishouck and Gina Falcetti of Northwest Horticulture said they were at the Oct. 24 workshop because now that they’re selling food, as opposed to just ornamental nursery stock, they wanted to learn what is necessary to meet the requirements of the grocery stores to which they want to sell.

“We’re expanding now,” Falcetti said about their hydroponic lettuce-growing operation, “and we want to get to know the food-safety consultants so we can work with them.”



Senaida Soto, co-owner of a small WA blueberry farm, grew up in Mexico and worked with her father on farms. She said that, in some ways, there wasn’t much of a focus on food safety back then. “Now in comparison, it’s better — much safer,” she said, adding that following food-safety practices benefits both the farmers and the consumers.

“I learned a lot today,” Soto said as she worked on a checklist in the “Bridging the GAPs Farm Guide” and drew a map of her farm using Google Maps during the afternoon computer session.

Francisco Sanchez-Reyes, who works on a blueberry farm in Oregon, photographs some artichoke plants during the recent food-safety tour at Viva Farms near Burlington, WA.

Francisco Sanchez-Reyes, who currently works on an Oregon blueberry farm, said he came to the workshop because he wanted to educate himself about food safety so he can have his own farm one day.

Comparing food-safety concerns here in the United States to those in Mexico, he said that “more than anything, it’s market-driven” in the U.S.

“Consumers want safe food,” he said. “Food safety has had a huge impact on the way things are being grown and harvested.”

As they worked on checklists during the afternoon computer session, Sarah Dublin and Adam McCurdy, who work at Oxbow Farm and Conservation

Center in Carnation, WA, said they wanted to get up to speed on how to implement GAPs since the farm is doing more and more business with wholesalers and institutions.

“All the markets are requiring GAPs, and we also want to be ready for the regulations in the Food Safety Modernization Act,” McCurdy said.

“When we first sat down, our initial question was, ‘Where do we start?’” said Dublin. “It’s so helpful to have facilitators here to help us and a manual that’s so full of information.”

Karen Ullmann from the Washington State Department of Agriculture noted that learning how to establish good food- safety practices on a farm is important not just for the sake of consumers’ health, but also for the economic health of a farm.

“You want to protect your business,” she said. “Markets are looking for food safety and quality assurance.”

Tricia Kovacs, the department’s GAPs project coordinator, told the farmers that in crafting a food-safety plan, they “have to think creatively about what the risks on your farm are, even what’s happening next door, that can affect your farm. A lot of this depends on your situation.”

In other words, there’s no one answer that will fit every farm’s needs.

Always diligent

Senaida Soto, co-owner of Buena Berries, a blueberry farm in Skagit County, WA, works on writing up food-safety practices on her farm as part of the requirements of becoming GAPs-certified.

As the participants walked through Viva Farm’s fields looking at the wide diversity of crops — among them blueberries, artichokes, cabbages, tomatoes and peppers — Kovacs asked them to pretend they were microbes — the kind that can sicken people.

“They want to move from place to place,” she said, adding that’s why a farmer needs to look at his or her entire operation and assess how these microbes could get from place to place and contaminate the produce.

Something as basic as knives used on the farm need this sort of diligence. Keeping them clean and putting them in sanitation buckets is part of this, but putting them in a leather sheath is not a good idea because a leather sheath can’t be sanitized.

That’s just one small part of the overall picture. Another example is assessing hand-washing stations and making sure the water doesn’t pool on the floor, which could allow any pathogens in the water to be picked up by a worker’s boots and transported to other areas of the farm.



Also important is thinking about what's on the bottoms of the bins where food is put when being harvested. If the bins are put on the ground and dragged along, then dirt will be moved from one place to another.

"It only takes a few cells of *E. coli* O157:H7 to make people sick," Kovacs said.

The bottom line, she said, is that farmers need to "think through what can go wrong here," when assessing all of their farm's practices.

The audit

A typical audit, which occurs during harvest season, takes from 2 to 7 hours and starts with a look at the farm's paperwork. The typical cost is \$92 per hour, plus mileage and transportation time.

Clark said an auditor will be looking at a farm's policies and procedures and also at documentation showing that these procedures are taking place.

"We have to verify that you're actually doing it," he said. "The documents corroborate that you're doing what you say you're doing."

After the sit-down session, the auditor goes out into the field to see what's happening there.

An automatic failure, which can end an audit, could result from employees not washing their hands, rodents, fecal matter, and water running from pipes in a cooler onto the produce. But a farmer can fix those problems and ask for the audit to resume.

Kovacs assured the group that, "We're never here to shut you down."

Passing an audit requires an 80-percent grade in each of the audit categories. In all of them, cleanliness is paramount. Also, a written food-safety plan is required to pass an audit.

Traceability considerations

Linda Kosa Postl knows she'll need to be GAPs-certified to sell to a major grocery store in the area where she'll be farming.

One step forward, one step back is what farmers need to document when selling their produce to buyers. If anyone gets sick, someone will call, and a farmer will want to be able to say where the food came from, and, better yet, what part of the farm it came from.

The more detailed the information is about just where the produce came from, the less a farmer will have to recall.



Rob Smith, operations and incubator director for Viva Farms, explained how the farm's produce is labeled, which includes a code number showing the date and location of where the crop was harvested. That's the "going one step back," he said. Using invoices is the "going one step forward."

"There are definitely a lot of good reasons for all of this," Kovacs told the farmers as they stood outside the

farm's cooler.

The computers

In the afternoon, the farmers sat at rows of computers at Skagit Valley College — some of them with people who could help them navigate Internet technology — while Ullmann told them that the session was designed to provide a “deeper dive” into the “GAPs Farm Guide.” Each workshop participant received a free guide and a free flash drive with all the templates and checklists in the guide.

Kovacs and Ullmann explained how farmers could use the checklists, practice sheets, and templates to craft their own food-safety plans. Because they could take the flash drives home, they can keep working on their plans.

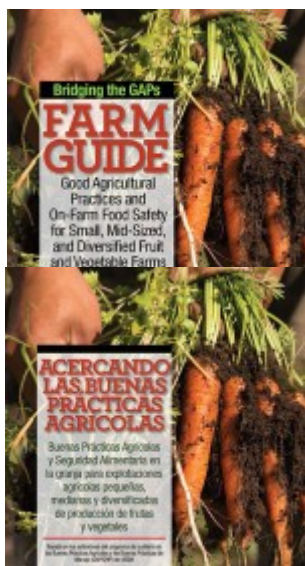
Tricia Kovacs, Washington State Department of Agriculture, displays hand-washing basics at Viva Farms near Burlington, WA: hot and cold running water, soap, individual towels for hand-drying and a trash can, preferably covered, for the towels.

Once the farmers draw up a plan for water use, Kovacs said it's helpful to go back to the audit checklist to make sure it meets all the requirements an auditor will be considering. For example, don't forget to mention if the water provided for hand-washing is potable (meaning it's safe to drink) and if there are signs posted showing the proper hand-washing techniques.

Other things an auditor will be looking for: clean soil, clean water, clean hands, clean surfaces, and how the food is packed, handled, and stored.

Farmers were advised to draw up their food-safety plan in the order of the checklist in the guide to make it easier for the auditor to work through each item.

About the GAPs guide



[“Bridging the GAPs Farm Guide: Good Agricultural Practices and On-Farm Food Safety for Small, Mid-sized, and Diversified Fruit and Vegetable Farms”](#) was developed as a resource to assist farmers as they implement good agricultural practices and prepare for GAP/GHP audits.

Writing a food safety plan using the resources and templates in the guide is a good place to start, although it does not guarantee a successful audit. Throughout the guide are helpful tips about various topics from auditors.

The guide is also available in [Spanish](#).

Other audit resources

- ☐ [On-Farm Food Safety](#): This site will walk a farmer through a self-audit.
- ☐ [Buenas Practicas Agricolas](#)
- ☐ [A Food Safety Plan for You, Templates and Log Sheets](#) (also in Spanish)

Timeline on FSMA rules

The first two of the seven FDA FSMA rules — Preventive Controls for Human Food and Preventive

Controls for Animal Feed — were finalized in mid-September and are now up on the Federal Register. The effective date for compliance for some companies starts in September 2016.

Broadly, the rules governing human food require registered food facilities to maintain a food-safety plan, perform a hazard analysis, and institute preventive controls for dealing with those hazards.

Facilities also have to verify and document that their controls are working.

The Produce Safety Rule is expected to be finalized this month. This rule establishes science-based minimum standards for the safe growing, harvesting, packing, and holding of produce on farms to minimize contamination that could cause serious adverse health consequences or death.

More workshops coming

Kovacs said that the department will be offering more of these free workshops for farmers around the state. For more information, contact her at (206) 256-6150, or email to tkovacs@agr.wa.gov.

Ullmann can be reached at (206) 256-6151, or email to kullmann@agr.wa.gov.

(To sign up for a free subscription to **Food Safety News**, click [here](#).)

Tags: [Cookson Beecher](#), [food safety](#), [Food Safety Modernization Act](#), [FSMA](#), [Good Agricultural Practices](#), [Good Handling Practices](#), [Skagit Valley College](#), [Viva Farms](#), [Washington State Department of Agriculture](#), [Washington State University Extension](#)

- ☐ Heavenly Hill Harvest Farm workshop flier – English and Spanish
- ☐ Clark County workshop flier – English
- ☐ Okanogan County workshop flier – English
- ☐ Kittitas County workshop flier – English
- ☐ Photo collage from workshops and mock audit

B. Example Outreach Flier in English and Spanish for Workshop in Yakima Valley. Workshop was presented with simultaneous Spanish interpretation:



el 10 de Octubre, 2016
1:00 - 4:00 pm

GRATIS
Bilingüe: Ingles / Espanol

Heavenly Hills Harvest
764 South Emerald Road
Sunnyside, WA 98944

Lo Que Aprenderá:

- Mejores prácticas de seguridad alimentaria
- ☀ **Nuevo!** Reglas del Food Safety Modernization Act (FSMA, "Ley de Modernización de Seguridad Alimentaria")
- Ver las practicas en campo
- Entender el proceso de inspección GAP/GHP
- Hablar con los expertos de la región
- Conocer consejos para organizarse y ahorrar

El Departamento de Agricultura del Estado de Washington está ofrecer un taller de Las Buenas Practicas Agrícolas (GAP) y las Buenas Practicas de Manejo (GHP) para granjas de pequeña a mediana escala. Aprender métodos efectivos para implementar la seguridad alimentaria de los expertos de la región.



Incluido con la clase

Una guía para desarrollar su plan de la seguridad alimentaria. Mas info a http://agr.wa.gov/Inspection/GAPGHP/docs/GAP_GHPmanualSpanish.pdf

Inscribirse hoy: wsda.eventbrite.com



Washington
State Department of
Agriculture

Specialty Crop
Block Grant Program

¿Preguntas? Karen Ullmann, (206) 256 - 6151, kullmann@agr.wa.gov

Bridging the GAPs

On-Farm Food Safety Workshop



October 10, 2016 (1:00–4:00 pm)

Heavenly Hills Harvest

Sunnyside, Washington
764 South Emerald Road

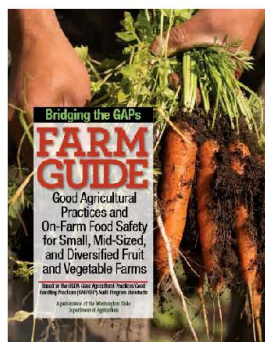
FREE workshop

Bilingual: English/Spanish

What you will learn:

- Food safety best practices
- Understand GAP/GHP audit process
-  **New** FDA Produce Safety Rules
- Cost-saving & organizational tips
- Post-Harvest handling & storage
- Documentation & records guidance
- How to talk to buyers about food safety

Washington State Department of Agriculture is offering an on-farm food safety workshop on Good Agricultural Practices (GAP) and new FDA Produce Safety Rules mandated under the Food Safety Modernization Act (FSMA). Learn practical, cost-effective methods for handling food safety to ensure product quality, stay current with regulations and open market opportunities.



Included with the class – Step-by-step guide for building your own food safety plan. More info at agr.wa.gov/inspection/gapghp/

Register online today: wsda.eventbrite.com



Washington
State Department of
Agriculture

Specialty Crop
Block Grant Program

Questions? Karen Ullmann, (206) 256 - 6151, kullmann@agr.wa.gov

C. Workshop Photos

Olympic Peninsula Workshop – March 2016



Sunnyside, Yakima Valley Workshop – October 2016





Oxbow Farm Mock Audit – July 2016





Project Title: Growing producer-wholesaler opportunities in Whatcom & Skagit counties

Project Summary

In 2014, 42% of Sustainable Connections specialty crop producer (SCP) members were producing more than they could sell, 50% noting that the lack of know-how for working with larger wholesale buyers was the primary barrier to growth in their business. Wholesale buyers that Sustainable Connections worked with were interested in buying more local products, but many were still uninformed about how to best work with local producers.

This project addressed facilitating more connections and sales for SCP in NW WA by working with producers who produce more than they can sell and connecting them with the buyers and resources they need to be successful in selling more of their products to. It also addressed the producer who produces less than they can sell – helping them connect with important resources within the community like forward contracts and buyer/farmer mentorships to help scale their businesses to meet wholesale demand.

With such demand in the marketplace, but with so many producers unable to sell their products, it was clear to Sustainable Connections and the regional farming community that additional support mechanisms and resources were needed to bridge the gap between producers and wholesale buyers as a prime opportunity to increase sales.

In 2013 and 2014, Sustainable Connections held 3 farmer/chef roundtables to discuss what was needed most to help grow connections between the two groups and aid in more ease of working together and selling/buying local products. With 90 attendees over the course of the meet-ups, Sustainable Connections gathered the core ideas for this project from those discussions and the very people and businesses they were looking to serve.

Together in these roundtable work sessions, the participants helped to outline what would be needed for forward contract agreements, farmer chef partnerships and more tailored marketing assistance.

Sustainable Connections responded by taking action and writing up this project proposal to better serve the needs of specialty crop producers in the region.

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

Project Approach

One-on-One Technical Assistance/Marketing Consultations: Sustainable Connections (SC) staff conducted 52 consultations with specialty crop producers to provide marketing assistance, demonstrate valuable resources and support in connection with markets and grow sales of specialty crops, and 43 consultations with wholesale buyers, supporting them in connecting with SCPs, source more local specialty crops, and help them tell farmer stories and market their sourcing of specialty crops. The One-on-One meetings were an appreciated component of the project, as SC regularly received positive feedback, and were able to see immediate shifts in actions from both SCPs and wholesale buyers from becoming active in online marketing to gaining courage to approach wholesale buyers and more. One producer said, “Thank you so much for all this information and for a really great meeting – it was so motivating and I so appreciate it. I’m going to create a marketing to-do list and prioritize next steps so I keep all this moving forward this winter so we are in better shape by next spring.”

Farm-to-Table Trade Meeting: SC hosted 3 Farm-to-Table Trade Meeting events, a full day conference focused on networking, connections and education, with 545 attendees over the three events. Attendees reported making an average of 5-7 new sales connections at each event, and the three events combined

resulted in \$1.16 million in new sales over the following year. This event continues to grow in value and popularity, with all attendees who took the day of survey over the course of the three years rating it valuable, very, or extremely valuable for their business. One wholesale buyer business attendee said, “We will continue to support local and make more local connections buying wise because of events like this.”

Farmer & Chef/Buyer Mentorships: SC facilitated 36 Farmer/Buyer mentorships and 43 additional connections through hosting 6 facilitated Farmer/Chef Mixers over the course of the grant period. For the first half of the project period, farmers and buyers who attended these events gave great feedback around the mentorship pairings SC helped to facilitate. After the January 2017 meet-up, some feedback SC heard was to mix it up a bit and leave the networking events more open and making multiple connections, rather than focusing on the “one” mentorship connection would be best for moving forward. SC shifted the model to be more open for future meetings, and distributed a follow-up survey to track how many connections were made that were to result in sales. Nonetheless, attendees had great feedback, no matter the format – and it seems that attendees like the diversity of meeting styles, not necessarily one over the other. One farmer wrote in follow-up, “I’ve always been really intimidated by going to talk to local chefs, and this event allowed me to connect with all of them in a really personal way. I now have the connections to walk in the door and feel confident about it. You put on an amazing event. Thank you.”

Forward Contracts: SC helped to facilitate a total of 20 forward contracts between SCPs and buyers that resulted in \$64,000 in new sales throughout the project period. One shift SC heard from producers and buyers throughout the project period was that forward contracts were a little too binding for many folks to utilize in reality (though in theory it seemed nice). In 2018, SC created an updated Wholesale Planning Agreement to utilize in lieu of the previous Forward Contract template. SC presented this new tool at the 2018 Farm-to-Table Trade Meeting and distributed to 200+ businesses.

One big success SC saw was between a new flower farmer, Foothills Farm and Haggen stores. In 2016, Foothills Farm had 95% of their products left unsold. In 2017 they sold their entire crop, thanks to new connections and a forward contract, which were initially facilitated through a Sustainable Connections farmer chef mixer and later through one-on-one follow-ups with each party.

Online Resources for SCP Marketing: In 2016, SC created an online resource guide full of best practices and tips for SCPs to sell their products in various wholesale and direct markets (restaurants, grocers, institutions, farmers markets, CSA, farm stand, etc). SC shared the guide with over 300 farmers through the Farm-to-Table Trade Meetings, a presentation at the Tilth conference, on the SC website, and with partner on the San Juan Islands, Olympic Peninsula and a farmer training program in Las Cruces, NM, who tailored the resource to their own region.

The Puget Sound Food Hub Cooperative has been a huge asset to our farming community and getting more sales between wholesale buyers and SCPs. SC staff has worked closely with the Food Hub to refer both farmers and wholesale buyers to the group to aid in buying and selling more local specialty crop products. Cloud Mountain Farm Center has been another close partner, particularly in hosting a few of the Farmer ChefMixers. There is something to be said about hosting these events out at a farm instead of in Bellingham. CloudMountain has also worked alongside SC to support connecting new farmers to wholesale buyers.

Northwest Agriculture Business Center and WSU Whatcom County Extension have been great partners in co-promoting farmer connection events like the Farm-to-Table Trade Meetings and Farmer Chef Mixers. The NW WA Chefs Collective has been a solid partner, with a group of committed chefs and food buyers working together to grow the local food scene and support local producers. Members of the group have done anything from welcoming in new restaurants and chefs into the community to calling to invite farmers to the meet-ups, going out of their way to support local producers and telling the story through

their own businesses.

Majority of the farmers SC works with are SCPs, and here is how tracking happened to ensure this project solely enhanced the competitiveness of specialty crops. For the one-on-one technical assistance consultations, farmer/chef mentorships, and forward contract facilitation, SC utilized WSDA funds for specialty crop producers only. For the Farm-to-Table Trade Meeting and online SCP marketing tools, SC had matching funds through the Whatcom Community Foundation that were able to cover a smaller portion of the costs for any benefit to non-specialty crop producers.

Goals and Outcomes AchievedThe core activities were outlined above in the Project Approach section of this report. In order to collect data to track progress for the project, SC also completed:

Annual Producer/Buyer Surveys: SC conducted surveys each January to capture aggregate data on where farmers and food businesses are seeing successes, challenges, % of local buying, % of products left unsold, resources most needed, etc.

Farm-to-Table Trade Meeting Surveys: 1) Day of survey that captured qualitative and quantitative data – how many connections attendees made, favorite sessions/activities throughout the day, ideas for next event, 2) Post Sales Follow-up Survey – Conducted six weeks after the event, SC sent out an electronic survey to all SCPs and buyers to capture the dollar amount of sales made as a result of the event to date, and dollar amount of sales anticipated over the next year as a result of the event.

One-on-One Technical Assistance baseline & follow-up Surveys: SC conducted a baseline survey for all SCPs and buyers they worked with through one-on-one technical assistance meetings, and sent out the same survey electronically to all participants one-year later to measure progress and benchmarks.

Farmer/Chef Mixer Survey: SC conducted post Farmer/Chef Mixer surveys for the mixers without the mentorship component to capture how many connections were made at the event.

All of the Expected Measurable Outcomes were measurable within the time frame of the grant. The goals for the project were to:

- 1) Increase sales of specialty crops within wholesale markets.
- 2) Grow new relationships through farmer/chef mentorships and forward contracts used between SCPs and local and regional buyers,
- 3) Grow new sales revenue for specialty crop producers in Whatcom and Skagit Counties.

Throughout the last three years, and offerings of three Farm-to-Table Trade Meetings, 95 One-on-One Technical Assistance Consultations, 79 Farmer/Chef Mentorships and connections, 20 Forward Contracts, and one SCP Online Marketing Toolkit, SC working with local SCPs and local and regional food buyers was able to meet all of the goals described.

Outcome 1: Local specialty crops producers will have less of their products left unsold Goal: This project will result in increased sales of specialty crops within wholesale markets

Target: 85% of participating farmers will have a market for 90% of their products by the end of year 3

Benchmark: In 2014, only 58% of producers SC worked with had a market for all of their products _

Achievement: 79% of participating farmers SC worked with throughout the project have a market for all of their products. Another 15% reported they had a market for most of their products (90% or higher), so SC was close to

meeting the target. These numbers are high, compared to the overall averages from the 2017 program survey, where just 61% of producers reported having a market for all their products in 2017.

Outcome 2: Local specialty crops producers will have stronger relationships with wholesale buyers

Goal: This project will result in new relationships through farmer/chef mentorship and forward contracts used between SCPs and local and regional buyers

Target: 36 Farmer/Chef Mentorships established, 25 Forward Contracts initiated

Benchmark: This was the first time SC facilitated farmer/chef mentorships and forward contracts –

Achievement: SC facilitated the establishment of 36 Farmer/Chef Mentorships and 20 Forward Contracts.

Outcome 3: Local specialty crops producers will increase sales

Goal: This project will result in new sales revenue for specialty crop producers in Whatcom and Skagit Counties. **Target:** \$600,000 in new sales generated for SCPs over the project period, \$200,000/year

Benchmark: Not yet established, but based on the 2015 Farm-to-Table Trade Meeting, \$150,000 of new sales will be generated as a result of that event alone.

Achievement: SC more than doubled the target sales number, tracking \$1,462,500 in new sales generated for SCPs over the project period. \$1,160,000 was a result of the Farm-to-Table Trade Meetings, \$64,000 was a result of the Forward Contracts and \$238,500 as a result of the One-on-One Technical Assistance Consultations.

Beneficiaries

Throughout the duration of the project, Sustainable Connections worked with 93 specialty crop producers and 109 wholesale buyers from budding farmers to those with 30 years under their belt, and buyers from restaurants to grocers, institutions to value-added product companies.

Specialty crop producers this project benefitted are growing everything from row crops to mushrooms, cut flowers, heirloom varieties, fruit trees and other perennial crops – a very diverse range of producers.

The Puget Sound Food Hub Cooperative has been a beneficiary of the project as well, as through SC's one-on-one consultations, inspired both farmers to sign up to utilize the Food Hub to sell their products and buyers to purchase products through the platform.

79% of all participating farmers reported having a market for all of their products by the end of the project, and an additional 15% reported having a market for 90% of their products.

\$1,462,500 in new sales generated for specialty crop producer participants throughout the project period, including an average of \$4500 in new sales generated over the next year for SCPs who participated in the One-on-one Technical Assistance consultations.

Lessons Learned

Sustainable Connections staff learned that there's a lot that can change and evolve for SCPs and food businesses over the course of three years.

On Farmer/Chef Mentorships and Farmer/Chefs Mixers. SC staff has found that even though farmers and wholesale buyers come to these events to meet new people and grow their sales connections, there have been more successes when the meetings are tightly facilitated and staff gives participants clear strategies for connecting with other attendees as farmers and chefs can be very shy at times! The first couple Farmer/Chef Mixers SC facilitated were welcomed because it took a lot of that pressure off and gave attendees a clear objective and kept folks moving around the room. And then, folks wanted to mix it up again. Since SC aims to be nimble and meet the needs of the businesses they are serving, the following events shifted a bit to be still facilitated mixers with more open outcomes – staff found that these events were just as valuable and that the moral of the story is – the participants like to mix it up.

The One-on-One Technical Assistance consultations were an incredibly valuable component of the project. Staff found that there is something that just can't replicate this high resource, but high reward, one-on-one tailored time. Though surveys tracked sales data for the project (an average of \$4500 in new sales for consultation participants over the next year), staff also found that SCPs in particular found more ease in marketing their businesses online, creating connections and follow-up mechanisms with buyers and engaging with the community at large. SC cannot stress enough the value of this piece of the project to participants.

The Farm-to-Table Trade Meeting has a much lower baseline number that jumped significantly the first year of the project period, from \$150,000 to \$500,000 in new sales generated between 2014 and 2015. Other than getting a few new larger buyers there, staff isn't sure what caused the big jump, but feel that the successes are building and there is momentum for demand of local foods – and that is exciting.

20/25 of the targeted Forward Contracts were reached. When the project started, local SCP's and wholesale buyers in Whatcom and Skagit Counties had asked Sustainable Connections to create a Forward Contract template that they could utilize in growing sales connections and ensure sales/products that season. As the project continued, SC saw less businesses interested in using the templates. After some digging, SC found that businesses liked the *idea* of Forward Contracts, but in practice it was a challenge, particularly for buyers to commit with a dollar amount upfront. In response, SC reached out to other distributors and wholesale buyers around the region to learn more about the practices they were using, and in follow-up created a Wholesale Planning Agreement - which essentially would serve as a planning tool for both parties and more of a handshake agreement, which culturally for NW WA felt like a better fit. SC finalized and began to share the new Wholesale Planning Agreement at the 2018 Farm-to-Table Trade Meeting and the responses so far have been very positive.

Contact Person

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Additional Information

Sustainable Connections provided \$20,879.12 in matching funds to the project. Of this, \$17,005.47 was allocated towards staff time spent implementing project activities. \$1,495.01 was spent on meeting and conference space for the Farm to Table Trade Meeting. \$2,378.64 was spent on supplies and promotional materials for Farm-to-Table Trade Meeting.

Sustainable Connections farmer marketing toolkit is available at

<https://sustainableconnections.org/wp-content/uploads/Farmers-Marketing->

[Guide.pdf](#) Additional photos of the various events from this grant are

available if desired.

Project Title: Supplemental hop residue trials and codex submission

Project Summary

Washington is the largest hop producing state in the country, with approximately 70% of annual production exported. In order to successfully export, Washington hops must meet the regulatory standards of foreign markets, including pesticide maximum residue levels (MRLs). Because hops are produced in so few countries, hop MRLs often do not exist in foreign markets. This project targeted hop MRL issues, focusing on our largest export market, Europe. The simplest way to seek EU MRLs is **not** to use the complicated, expensive, and time consuming EU regulatory system, but instead go through the Codex Alimentarius Commission. Codex MRLs are international standards used by many markets. Codex is a UN organization that sets international MRLs annually. The European Union has implemented an official policy of adopting new Codex MRLs as their own, so long as they do not raise an official objection prior to the setting of the new Codex MRL. Using this system, the US hop industry has been able to obtain numerous key hop MRLs in the EU, allowing those plant protection products to be applied to the crop for export to the EU. The Codex method of obtaining EU MRLs is less expensive and more efficient than seeking EU MRLs directly.

The EU requires **four** hop residue trials to establish a hop MRL (a minor crop). When reviewing the chemicals to be evaluated by Codex in 2015 and beyond, the hop industry noted two important crop protection compounds (flonicamid and flupyradifurone) had only three hop trials submitted to Codex. The lack of a fourth trial would have resulted in the EU not accepting the Codex MRL and likely would not have resulted in a Codex MRL at all. The fourth trial requirement was implemented after the original studies on these compounds were conducted (only three hop residue trials are required by the US EPA for domestic registration). Registrants completed the fourth trial for these compounds, which provided a complete data set for submission to Codex.

Fenazaquin, had different situation. The original three residue studies had already been supplemented by the registrant, Gowan, with additional field residue trials conducted in 2014. This supplemental data was provided to EPA to complete the US registration process. This product was registered for use in the US in 2017, with subsequent submission to Codex.

An additional goal was added to the project in 2016: Conduct a decline study for a newly registered compound, fluopyram, to support future international harmonization efforts. No decline study has been conducted for this compound on hops. The decline study provided important data that allowed hop merchants to determine realistic cut-off dates for the application of this important new compound, while insuring MRLs in the European Union and Japan are not exceeded. The data will also be used to seek future harmonized MRLs in EU and Japan.

Establishing hop MRLs in Codex and EU systems will allow hop growers to:

1. Use the latest, most environmentally sound crop protection technologies; thus benefitting the environment;
2. Improve pest and weed control, increasing crop quality;
3. Export their crop without fear of costly rejections; and
4. Expand the EU export market for the benefit the entire Washington hop industry, its employees and communities.

This project's importance was high, as the EU is the single largest customer for Washington hop exports (accounting for over 30% of annual exports), and growers require a robust toolbox of plant protection products to properly deploy IPM strategies and resistance management programs.

Project Approach

Flonicamid, flupyradifurone and fenazaquin data sets were completed and submitted to Codex for establishment of MRLs for hops. A decline study was successfully completed for fluopyram. Details follow.

Flonicamid (BeLeaf): The flonicamid hop MRL was established successfully by Codex on July 1, 2016 at 20 ppm, which is harmonized with the US level. This will cover hop shipments to many markets. Unfortunately, the EU issued a reservation and did not adopt the Codex MRL. The EU MRL remains at 3 ppm. A specific import tolerance will be needed to achieve the harmonized hop MRL in the EU. However, flonicamid is a neo- nicotinoid, which is a controversial class of compounds in the EU due to potential impacts to pollinators.

USHIPPC worked with its European advisors to determine whether an application might be possible in the EU given the current environment in the market. BCI, the contractor for USHIPPC, met in Brussels in October 2017 with officials from the European Commission and the European Food Safety Authority on this and other pesticide issues. A data gap analysis for submission of an EU import tolerance was completed in November 2017. Based on the results of this analysis, the registrant is proceeding with an import tolerance request, to be submitted directly to European Union officials.

Fenazaquin (Magister): Studies were completed and this compound was scheduled to be reviewed at the September 2017 Codex Joint Meeting on Pesticide Residues. The hop industry faced a significant challenge preparing for this meeting, as Codex will not complete a review of a compound unless it is labeled in the petitioning market. Data was due in January 2017 for the September review. The US label was not issued until May 2017. USHIPPC and BCI worked with the registrant, Gowan, to ensure the new label was forwarded to the Codex reviewer conducting the JMPR evaluation. The reviewer accepted the label and the CCPR recommended a MRL of 30 ppm during its April 2018 meeting. This recommendation will be reviewed in July 2018 by the Codex Alimentarius Commission and is expected to be approved in July 2018, which is excellent news.

However, the EU issued a reservation and will not accept this Codex MRL. The EU residue definition is different than US. Gowan has already completed studies to cover the difference and is conducting an additional study to comply with EU specific requirements. Gowan's current plan is to submit an import tolerance petition to the EU by 4Q 2018. The study completed and registration in the US will allow this to happen.

Flupyradifurone (Sivanto): USHIPPC approached Bayer CropScience in November 2016 to seek their support for a new use review on hops for flonicamid at Codex. Bayer agreed to support this effort and hops are included in the Codex new use evaluation scheduled for 2019. Bayer will provide a full submission package to the JMPR by December 2018 for review the following year. A new Codex MRL should be in place by 2020.

USHIPPC hopes it will ultimately result in an EU MRL adjustment from the current 4 ppm to 10 ppm, harmonized with the US.

Fluopyram (Luna): In 2016, WSDA approved the use of block grant funds to conduct a decline study for the important newly registered fungicide, fluopyram. This information provided important data that allowed hop merchants to determine realistic cut-off dates for use of the compound when there are missing MRLs abroad. Dr. Doug Walsh at Washington State University conducted these decline curve studies in 2016. Analytical work was completed and the results of this decline study were supplied to hop shippers in February 2017, resulting in revised cut-off dates for greater flexibility in the use of this important new plant protection tool.

Contractor: Bryant Christie managed communications and submissions to Codex, as well as

coordinating the necessary activities and submissions from registrants and IR-4 to ensure the schedule for these actions was followed.

IR-4: Conducted the analytical work to support this project.

Washington State University: Conducted and completed the field trials to support the residue studies for IR-4, as well as the residue decline study for fluopyram.

If the overall scope of the project benefitted commodities other than specialty crops, indicate how project staff ensured that funds were used to solely enhance the competitiveness of specialty crops.

Goals and Outcomes Achieved

This project was measured in two ways. The first measure was the successful conclusion of supplemental hop residue trials, and submission of three compounds to Codex (fenazaquin, flupyradifurone and flonicamid) for review. The development of decline data for fluopyram was added to the project in 2016. These measures were achieved.

The second measure was the establishment of the three acceptable MRLs at Codex as a result of these submissions. A Codex MRL was successfully achieved for flonicamid (20 ppm, harmonized with the US MRL). A Codex MRL for fenazaquin has been recommended at 30 ppm, harmonized with the US MRL, and is expected to be approved in July 2018. The data package for flupyradifurone will be submitted to Codex in December 2018 for consideration at the April 2019 CCPR meeting. This MRL was delayed but is expected to be issued by Codex the following year.

Decline data for fluopyram was successfully completed in early 2018, resulting in modified cut-off dates that allow growers to benefit from this new chemistry while harmonized MRLs are being pursued in EU and Japan.

The project has not yet resulted in harmonized EU hop MRLs. The EU issued exceptions for the Codex MRLs for flonicamid and fenazaquin. The registrants are proceeding with direct import tolerance petitions on these two compounds. We will not know whether EU will accept the Codex MRL for of the third compound, flupyradifurone, until April 2019.

USHIPPC recognizes this process extends beyond the term of the grant, but these dates are set by international organizations and cannot be adjusted. The goal of the SCBG funded project is to set the reviews in motion with acceptable data, which will then result in the review and hopefully MRLs in each agency's predetermined timeframe. Once submitted, the rest of the process should occur automatically.

The original Work Plan proposed in early 2015 was revised during the course of the project. The following discussion provides the original plans, along with changes requested and approved by Washington State Department of Agriculture in April-May 2016 (noted in **RED**), and the final status and accomplishments.

The reason for these changes:

During the first quarter of 2016 IR-4 confirmed the 4th trial for flupyradifurone and flonicamid had been conducted by the registrants (Bayer and ISK) during the 2015 growing season, and the subsequent laboratory analyses were successful. This was unexpected, as the registrants had informed the US Hop Industry Plant Protection Committee a year earlier that there were no plans to conduct these studies. As a result, we had pursued the Specialty Crop Block Grant to allow this work to proceed.

Therefore, it was no longer necessary for USHIPPC to conduct the proposed residue trials for flupyradifurone and flonicamid, although remaining activities (preparation of data packages, submission to Codex, etc.) for these two compounds, along with fenazaquin, proceeded as outlined in the original work plan.

A newly registered fungicide, fluopyram (Bayer's Luna formulations), lacked a decline study that was

necessaryd for future harmonization activities to proceed. We therefore propose substituting the fluopyram decline study for the previous two single-plot trials for the field and laboratory phase of this study. As two separate trials were necessary for this decline study, the cost of field and lab activities were the same as the previously planned studies. This resulted in no change to the budget.

Project Activity	Actual Accomplishments
Coordinating with IR-4 and the product registrants for two compounds requiring a 4 th residue trial to schedule the necessary research during 2016.	Accomplished successfully, with data supporting three Codex submissions.
The IR-4 research plan will be established for ~~flupyridifurone and flonicamid~~ fluopyram decline study.	Accomplished successfully, resulting in reasonable cut-off dates for product use replacing prior “Do Not Use” directives from hop merchant companies.
Field Trials and analytical work for ~~two compounds~~ fluopyram on 2016 hop crop (including Quality Assurance reviews).	Accomplished successfully.
BCI petitions US government to include hop review for the original three compounds (flupyradifurone, flonicamid and fenazaquin) on agenda for 2018 Codex Meeting. (This occurs a year before the actual submission is made to Codex.) The Codex agenda is competitive and petitions must be made prior to submission.	Accomplished successfully, with fenazaquin considered in 2017, flonicamid in 2018 and flupyradifurone scheduled for 2019 Codex review.
Treated fluopyram samples shipped to lab; method validation and analyses completed (includes Quality Assurance review).	Accomplished successfully.
Codex submission package for flupyradifurone and flonicamid prepared (includes Quality Assurance review and registrant review). Codex submission package for fenazaquin prepared.	Accomplished successfully, with a Codex MRL established for flonicamid and a Codex MRL recommended for fenazaquin (to be finalized in July 2018).
Data packages for all 3 compounds provided to US Codex Committee. Data packages for all 3 compounds submitted to Codex for review by December 2017 (PERFORMANCE MEASURE).	Completed for flonicamid and fenazaquin; data to be submitted by 12/18 for flupyradifurone.
Codex Evaluation and addressing questions from Codex reviewer.	Official grant ended here. Codex process completed for one compound, underway for the second compound (to be completed in July 2018), and underway for the third compound (for 12/18 submission and 2019 evaluation).

Throughout the process described above, reports will be made every six months to the US Hop Industry Plant Protection Committee, which includes growers, researchers and hop merchants.	Reports were presented at meetings of USHIPPC in January and August of each year during grant term.
Codex Joint Meeting on Pesticide Residues (Codex technical committee where recommended MRLs are first proposed)	Two compounds already completed in 2017 and 2018. Third will be evaluated in 2019.
Codex Committee on Pesticide Residues (Codex evaluators accept Codex MRLs). If EU does not object to proposed Codex MRLs, this is key to ensuring they will be established in EU following year. (PERFORMANCE MEASURE)	Unfortunately, the EU has issued reservations for the Codex MRLs established in 2017 and recommended in 2018. However, the registrants have committed to addressing data gaps and submitting directly through the EU import tolerance system.
Codex MRLs officially adopted	Completed for flonicamid and underway for fenazaquin (expect final adoption in July 2018). Flupyradifurone will be evaluated by Codex in 2019.
EU adopts Codex MRLs	See discussion above.

Goal 1: Submit residue trials to Codex for three important hop crop protection compounds. Currently, only three trials exist (benchmark) for two of these compounds, so a fourth trial needs to be conducted for each compound (target). All data trials will be completed and data packages for three compounds will be submitted to Codex by the December 2017 Codex deadline (performance measure).

RESULT: Needed fourth trials conducted. Target met. Data Packages submitted or will be submitted to Codex by deadline (Performance measure met).

Goal 2: Obtain EU hop MRLs for each of the three chemicals. Currently, there are no specific hop MRLs established for the three compounds (benchmark). Having the EU issue no formal objections to the Codex MRLs when proposed in April 2019. (performance measure). Have the EU establish MRLs for all three compounds by first quarter of 2020 (target).

RESULT: EU unexpectedly issued reservation for the first two applications and will not adopt the Codex MRLs. Third application is underway, and EU's position will not be known until 2019. Performance Measure and Target no met. Given this unexpected development, USHIPPC has worked with registrants to make submissions directly to the EU and seek to address any additional concerns they might have.

Beneficiaries

45 Washington hop growers and hop merchant companies have benefitted (or will soon benefit) from the establishment of Codex MRLs, which cover a number of markets for US hop exports. While the Codex MRLs for two of the three compounds that have been established or recommended to date were

not accepted by the EU, the registrants for those compounds have committed to pursuing import tolerance for hops directly through the EU process. In addition, the decline data generated for flupyradifurone has successfully removed this compound from the hop merchant company “Do Not Use” directives, now making this tool available to Washington hop growers until August 1.

Washington hop growers now have three additional plant protection tools (flonicamid, flupyradifurone and flupyradifurone) that have been moved from hop merchant “Do Not Use” lists to reasonable cut-off dates (7/20 or 8/1) that allow use for the majority of the growing season. While fenazaquin is still included on the “Do Not Use” list, Gowan’s commitment to submit an import tolerance petition to the EU should address this within the next two years. It is difficult to place a dollar value on three additional plant protection tools for IPM and resistance management programs. However, the ability to extend the life of key compounds through rotation of different chemistries will result in the need for fewer new compound registrations (including the cost of data development, petition preparation, regulatory consideration, and subsequent MRL harmonization in a number of key markets).

Lessons Learned

Overall the project was a positive experience. We were able to proactively identify gaps that would have prevented successful applications for Codex and EU hop MRLs and address them. USHIPPC learned that we needed to constantly monitor the progress. The efforts to save the fenazaquin MRL application at Codex would not have occurred if it had not been for this grant. Delays in the approval at EPA almost made the application obsolete. Tracking closely allowed USHIPPC to get the required label to the reviewer within days of the US approval, which allowed the project to proceed. As a result, a new US-harmonized MRL is expected next month. The industry also learned that flexibility is important. Sometimes, due to requests from growers or due to business decisions, the registrants were willing to conduct the needed trials without the USHIPPC’s funds or assistance. This was surprising, but welcome news. Of course the biggest negative lesson was the EU is making it harder and harder to obtain MRLs through the Codex system. In recent years, close to two thirds of the proposed Codex MRLs are not adopted by the EU. This number has increased since this grant was first conceived. As a result, direct submissions are needed to address EU issues. The data generated by the grant is still useful, but the short cut through Codex seems to be closing.

The two unexpected outcomes, as described above, were registrants being willing to take on some of the research required on their own, thus freeing funds for the flonicamid study, which was welcome, and the EU not being willing to accept Codex MRLs due to their expanding conservative requirements. This was unwelcome. In the end, Codex hop MRLs are established or are likely, which is good news, and efforts will be continued to seek EU MRLs.

Some Outcomes were not achieved during this project due to review dates being set by international organizations that cannot be adjusted. Several of those Outcomes are still going through the regulatory process and may ultimately be achieved over the next two years. It is not possible to control the EU’s evaluation of Codex MRLs for acceptance or exception. The only recourse to address an exception is to address the data issues identified by EU and submit an import tolerance petition directly through the EU process, which is underway for the two compounds that experienced EU exceptions to the Codex MRLs.

Contact Person

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Additional Information

In-kind contributions included:

Washington Hop Commission oversight and administrative support: \$20,000 pledged, \$20,000 contributed. IR-4 Program administrative and project management support: \$8,400 pledged, \$8,400 contributed.

The final financial report is attached. A balance of \$17.54 in grant funds were not expended.

Project Title: Sweet cherry health based research

Project Summary

1. Provide a background for the initial purpose of your project. Include the specific issue, problem, or need that was addressed by the project.

The purpose of this project was to conduct research on the effect of sweet cherry consumption on gut health and obesity-related disorders. Positive results demonstrating beneficial effects could be used to generate attention for Washington State sweet cherries and establish a strong association among consumers between cherries and health. This would establish the basis for an effective communication strategy around the health benefits of cherries, that would keep Washington State cherries top-of-mind and drive consumer demand for the fruit.

2. Establish the motivation for your project by presenting the importance and timeliness of the project.

With growing production, the Washington State cherry industry is concerned about building lasting demand for fresh, sweet cherries in the U.S. and abroad. Other products—such as blueberries and grapes—are investing heavily in nutrition research and communicating results to consumers. This effort—particularly for blueberries—has helped to catapult demand. In its 2013/14 annual report, the Highbush Blueberry Council cited consumer awareness of the blueberry “health halo” as the top reason for purchasing the product, above taste and convenience. Cherries are currently most typically an impulse buy. To remain relevant in the future, the Washington State Fruit Commission (WSFC) must develop messages that go beyond taste, extolling the functional benefits of eating cherries.

Particularly with increasing production, WSFC sees communicating cherry health benefits as a key market development strategy and would like to make the necessary investments in this area. While significant research has been conducted on tart cherries, there is little information about the health benefits of sweet cherries. Past research efforts were constrained by a lack of a standardized product and corresponding placebo. These issues are being addressed by a 2013 WSDA SCBG award with both a standardized powder and a placebo available for research purposes beginning in Spring 2015. WSFC is now seeking SCBG funds to help intensify its health research program.

At its January 2015 Scientific Advisory Board meeting, it was recommended that WSFC consider exploring the effects of cherry consumption on factors related to addressing obesity. More than one-third of U.S. adults (35.7%) are obese and suffer from obesity-related conditions including heart disease, stroke, type 2 diabetes, and certain types of cancer. With rising obesity rates in the U.S. and abroad, research in this area could provide WSFC with talking points that can be used to: (1) gain significant media coverage; and (2) create an association between cherries and health, similar to the success that the blueberry industry has generated. WSFC is therefore seeking SCBG funds to study the effects of sweet cherry consumption on gut health and the impact on obesity-related disorders using an in vivo murine (mouse) model. This approach allows for results to be generated within a year or less and could provide useful information for wider clinical trials involving human intervention studies.

3. If the project built on a previously funded SCBGP project, describe how this project complimented and enhanced the previously completed work.

This project utilized the standardized cherry powder developed in WSFC’s previous grant, WSDA Agreement No. K1263, therefore translating the output of the previous SCBGP project into positive research results that can be communicated to the public in order to promote the health benefits of Washington State sweet cherries.

Project Approach

4. Briefly summarize the activities performed and tasks achieved during the project period. Whenever possible, describe the work accomplished in both quantitative and qualitative terms. Include the significant results, accomplishments, conclusions and recommendations. Describe favorable and unusual developments.

In October 2015, WSFC entered into a contract with Texas Agricultural & Mechanical University (Texas A&M) for Dr. Giuliana Noratto to begin research on the effects of cherry consumption on modulation of intestinal bacterial populations,

inflammation, and obesity markers in a mouse model. Dr. Noratto changed institutions (from Washington State University to Texas A&M) after funding was awarded, which caused a slight delay in the commencement of research, initially planned for November 2015. In addition, delays in the development of a placebo powder that was initially to be used in the research required the start date to be pushed back. For this reason, WSFC requested an extension of the grant so that research could be completed in conjunction with the 2018 cherry season, with all work on the project finalized in September 2018.

Dr. Noratto began conducting studies on mice in Q3 of 2016, using freeze-dried cherry powder produced by WSFC through its previous SCBGP project, WSDA Agreement No. K1263. The study was designed to investigate the effect of sweet cherry intake on non-alcoholic fatty liver disease (NAFLD), which is closely linked to obesity, type 2 diabetes, and metabolic syndrome. In the study, obese, lean, and obese diabetic mice were fed either a standard diet or one supplemented with cherry powder over a period of 12 weeks.

The study results showed that cherry intake increased the presence of Bacteroidetes in treatment groups of mice fed cherry derivatives. This suggests that cherry consumption prompted changes in the intestinal bacteria of obese diabetic mice, causing their intestinal bacterial profile to shift to more closely resemble that of lean mice. Furthermore, the results demonstrated that the mice fed cherry-supplemented diets had a lower abundance of pathogenic bacteria species and an increased population of host-friendly intestinal bacteria. With regards to the effect of cherry consumption on fats in the liver, histological analyses of liver tissues show that cherry consumption significantly decreased lipid accumulation in the liver. These results are highly relevant as they suggest that cherry consumption has the potential to alleviate NAFLD, one of the most common liver diseases worldwide.

Through this project, Dr. Noratto also concluded that bioactive compounds in cherries (e.g. polyphenolics and dietary fiber) have the potential to help patients with diabetes and weight disorders, a phenomenon likely related to changes in the complex host-microbiota milieu. She and her team investigated the effects of cherry intake on the gut bacterial composition, concentrations of caecal short-chain fatty acids (SCFAs) and biomarkers of gut health using an in vivo model of obesity. Data integration from obese diabetic (db/db) mice fed a cherry supplemented diet for 12 weeks found that cherry supplemented mice harbored a distinct colonic microbiota characterized by a higher abundance of mucin-degraders (i.e. Akkermansia) and fiber-degraders (the S24-7 family) as well as lower abundances of Lactobacillus and Enterobacteriaceae. Overall, this particular cherry-associated colonic microbiota did not resemble the microbiota in obese or lean controls, supporting the notion that cherry supplementation can change the colonic microbiota.

However, despite the changes in microbial composition and colonic biochemistry, most biomarkers of inflammation in serum and colon tissue were similar in all obese mice regardless of treatment. Further analysis showed that dietary supplementation with cherry powder for 12 weeks affected the microbiota and the concentrations of some SCFAs in the colon of obese diabetic mice. These effects occurred in absence of differences in most biomarkers of inflammation and other parameters of gut health. This suggests that more research is needed into the potential clinical implications of cherry consumption as a dietary supplement in diabetic and obese human patients.

After research and analysis were concluded, Dr. Noratto presented two scientific posters at the Society of Toxicology Annual Meeting in San Antonio, Texas in March of 2018. The first abstract, “Cherry intake potential to improve intestinal health” summarizes the results from the study on gut microbiota and intestinal health biomarkers. The second abstract, entitled “Dark sweet cherry helps to ameliorate metabolic disorders in blood and liver associated with obesity and diabetes in mice,” outlines the observed effects of cherry intake on obesity-related metabolic disorders. A scientific manuscript was developed on each of these topics, with the first, “Effect of dark sweet cherry powder consumption on the gut microbiota, short-chain fatty acids, and biomarkers of gut health in obese db/db mice” published in the peer-reviewed journal *PeerJ* in January 2018. The second article, “Non-anthocyanin phenolics in cherry (*Prunus avium* L.) modulate IL-6, liver lipids and expression of PPAR δ and LXRs in obese diabetic (db/db) mice” was published in the June 2018 issue of *Food Chemistry*, a highly-regarded peer-reviewed journal in the field. Since this journal article was published after the 2018 cherry season was underway, WSFC chose to delay publication of press releases regarding the research results, releasing them prior to the 2019 season in order to garner the greatest possible effect on cherry sales.

WSFC has drafted press releases summarizing the positive results of the published papers, which will be released in advance of the 2019 cherry season to increase consumer awareness of the health benefits afforded by consumption of fresh, sweet cherries. The publicity generated by the dissemination of the research results is therefore expected to drive additional demand and sales of Washington cherries during the upcoming season, as well as providing the foundations for long-term growth for the industry. To confirm this effect, WSFC plans to survey consumers after the 2019 cherry season to determine their level of awareness of cherry health benefits. Given the positive research results, WSFC expects to see an increase in consumer awareness of these healthy properties. In addition, WSFC will analyze results of its annual industry shipment survey for 2019 to determine the effect of the publication of these results on overall sales of Washington State fresh, sweet cherries. WSFC anticipates that the dissemination of these study results will boost sales during the 2019 season.

5. Describe the significant contributions and roles of project partners.

Researchers from Texas A&M conducted the research study. Dr. Giuliana Noratto serves as the principle investigator, and is also responsible for drafting the scientific manuscripts and presentation of study results. Dr. Noratto is an assistant professor at Texas A&M University, and her research focuses on the role of nutrition in the prevention or development of obesity-related chronic diseases. Dr. Noratto received her PhD from the Department of Nutrition and Food Science at Texas A&M and has published several papers analyzing the effects of various foods on human health.

The overall authority of the project rests with WSFC. B.J. Thurlby is the president of the organization, which represents the Washington State sweet cherry industry. Mr. Thurlby and his staff are responsible for oversight of the grant project including contracting, budgeting, payables, and ultimately, generating media exposure for the results. WSFC contracts with Bryant Christie, Inc., an international affairs management firm, to assist with day-to-day management of the project including project initiation and grant administration.

6. If the overall scope of the project benefitted commodities other than specialty crops, indicate how project staff ensured that funds were used to solely enhance the competitiveness of specialty crops.

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

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.

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

- (1) To increase consumer awareness about the health benefits of eating fresh, sweet cherries.
- (2) 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 and carrying out reliable, accurate research in order to obtain credible results demonstrating the health benefits of fresh, sweet cherries. The research has been completed and does provide strong evidence that cherry consumption can influence the makeup of the gut microbiome, and may have a beneficial effect on obesity, diabetes, and other metabolic disorders.

By disseminating these research results, the WSFC is well-positioned to achieve the two goals for this project. Through press releases which will be published strategically—in advance of the 2019 cherry season—consumers will learn about these newly-discovered health benefits of eating cherries, and this information should drive consumption during the next cherry season and over the long-term. Ultimately, WSFC now has the foundation in place to meet these objectives, and plans to do so, albeit after the grant period has concluded. Because the research results will be disseminated in advance of the 2019 cherry season, WSFC has delayed the implementation of a consumer survey to determine whether publication of

these data increase the level of consumer awareness of the health benefits of fresh, sweet cherries. Similarly, WSFC will analyze the effect of these research results, and their publication, on overall sales of Washington State sweet cherries during the 2019 season, once the results of this study have been publicized. WSFC expects both of these measures to indicate success against the project goals, as the positive research results are likely to draw significant attention to the health benefits of cherries, supporting sales growth.

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

Both measures will be monitored after the publication of press releases, which will allow the public to learn about the results of this study. Their release has been delayed due to delays in the publication of Dr. Noratto's second peer-reviewed journal article. Press releases will be timed to have the greatest effect on cherry sales for the 2019 season.

Over the course of the project period WSFC has made significant progress toward achieving the Expected Measurable Outcomes, by conducting a robust research project that resulted in two scientific articles demonstrating strong results to support the health benefits of cherry consumption for patients suffering from complications of obesity, type 2 diabetes, or other metabolic disorders. This lays the groundwork for greatly expanded consumer awareness of the health effects of fresh, sweet cherries. In turn, awareness of these health benefits will drive consumers to increase their consumption of cherries, as has already been demonstrated through the success of other specialty crops whose health benefits have been widely publicized. After the 2019 cherry season, WSFC will conduct a survey to determine the increase in consumer awareness of the health benefits of cherries, and will analyze the effect of this project on increasing the value of Washington State fresh, sweet cherry sales over the 2019 season.

9. Provide a comparison of the activities and goals established for the project with the actual accomplishments.

Project Activity	Responsible Party	Timeframe Completed (month and year)
Contract with WSU's School of Food Science initiated	WSFC	March 2016
Study initiated with separate diets for control and test groups	WSU/SFS	August 2016
Analysis of fecal material, plasma, and colon tissues	WSU/SFS	July 2017
Data analysis and integration	WSU/SFS	October 2017
Scientific manuscripts completed	WSU/SFS	March 2018
Presentations on study results to scientific conferences and peer-reviewed journals	WSU/SFS and WSFC	June 2018
Press releases on study developments and study results (timed to benefit the 2019 cherry season)	WSU/SFS, WSFC, and BCI	Ongoing – by April 2019

The majority of the project plan has been completed, as outlined above. The only additional step remaining is the publication of press releases, as this was delayed due to the timing of the journal article publications. As the second article was not published until after the 2018 cherry season was in full-swing, WSFC elected to wait to present the research results to the public until the following year. Press releases will therefore be issued before the 2019 cherry season. Once this information has been disseminated, WSFC will be in a position to survey consumers on their level of awareness for the health benefits of cherries, to determine if an increase has occurred due to the publication of these research results. WSFC will also evaluate the effect of the publication of these research results on the overall sales value of Washington State fresh, sweet cherries, as determined by the results of WSFC's 2019 annual industry shipment survey. WSFC therefore plans to complete all project activities within the work plan and achieve project goals, though not within the grant period due to the delays in publication outlined above.

10. Clearly convey the achievement of your Expected Measurable Outcomes by describing the baseline data that was gathered and the achievement (or progress toward achievement) of your set targets.

The Expected Measurable Outcomes for this project were designed to be measured after the study results had been publicized to the general public. At the end of the grant period, press releases had not yet been published because the timing of the publication of Dr. Noratto's second scientific manuscript precluded the issuance of press releases prior to the 2018 cherry season. Press releases will instead be issued in advance of the upcoming 2019 season. Once this information is published, WSFC will survey consumers after the 2019 cherry season to determine whether the benchmark of a 10% increase in consumer awareness of cherry health benefits has been met. In addition, after the 2019 season WSFC will evaluate whether value sales have increased by 10% over the benchmark of \$990 million in cherry sales in 2018.

The successful outcome of the research study and two resulting publications in peer-reviewed journals put WSFC on track to achieve the Expected Measurable Outcomes for this project. The results demonstrate positive health benefits of cherry consumption, which will be conveyed to the public through press releases. This increased publicity will increase consumer awareness of the health benefits conferred by cherries, and will, in turn, significantly expand sales of Washington State cherries during the next season.

Beneficiaries

11. Describe those who have benefited from the completion of your project and its accomplishments.

This project directly affects 1,480 sweet cherry growers in Washington State who produce around \$600 million worth of cherries each year. Research on the effects of sweet cherry consumption on complications related to obesity, type 2 diabetes, and other metabolic disorders enable the industry to strengthen the association between cherry consumption and a healthy lifestyle. The demonstration of health effects has been proven to be an effective marketing tool for specialty crops, and will therefore benefit the entire Washington State cherry industry.

12. Clearly state the quantitative data that concerns the beneficiaries of the project and/or that describes the economic impact of the project.

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

13. Offer insights into the lessons learned by project staff as a result of completing this project. Include the positive and negative results and conclusions of the project.

Despite attentive planning, interruptions and delays can occur, and WSFC has learned the importance of flexibility and commitment to maintaining momentum in managing research projects. For example, this project encountered delays in the initial phases due to the principal investigator changing institutions—from Washington State University to Texas A&M. In addition, delays in the previous project, in which the cherry powder used in the research study was produced, required the start of research to be postponed until August 2016. However, once the study was initiated, the research program maintained a strong and steady pace in line with that outlined in the initial project proposal. The project again encountered a slight delay in the time from manuscript submission to journal publication for one of the research articles, which shifted the timeline for when press releases announcing the results would be published. However, WSFC adapted its plans to remain consistent with the project goals, which involve strategically timing the publicization of research results in order to garner positive attention for fresh sweet cherries in advance of the fruit's relatively short season.

The research results provide strong evidence to support the potential health benefits of cherries in patients with metabolic diseases, including obesity, diabetes, and complications resulting from these conditions. The research has been well-received by the scientific community, having been presented at a large research conference and published in two peer-reviewed journals. WSFC expects the research to have a significant impact when announced to the public, driving

consumer awareness of the healthfulness of fresh, sweet cherries, which will ultimately result in increased demand and sales, both in the domestic market and internationally.

14. Describe any unexpected outcomes or results that were an effect of implementing your project.

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

15. If activities, goals or Expected Measurable Outcomes were not achieved, identify and share your lessons learned to help others expedite problem-solving.

While the goals and outcomes have not yet been achieved, WSFC has taken the majority of the important steps towards increasing consumer awareness of the health benefits of fresh, sweet cherries, and therefore driving up sales value. The particular goals outlined in the project proposal are contingent upon the publicization of the research results, which has not yet been undertaken. This delay occurred due to the timing of the publication of the results in the scientific literature. Unfortunately, researchers have very little control over the length of time that the submission, review, and publication process will take, which can lead to delays in dissemination of the results. In this case, WSFC chose to delay press releases reporting the results until both scientific papers were published, and will time the announcement to provide the most benefit for the 2019 cherry season. The lesson learned, in this case, is the importance of adaptability, as this will allow WSFC to modify its timeline to bring the strongest possible returns for the Washington State cherry industry.

Additional Information

16. Provide the total level of cash or in-kind matching donations utilized for your project. Describe the amounts, sources and ways in which the donations were utilized.

WSFC has utilized \$60,000 in SCBG funds towards this project, and has contributed \$31,828.36 in industry funds towards the completion of this project. Funds were utilized to finance a contract with Texas A&M University that supported the research costs for this project.

17. Provide any additional information available (i.e. publications, websites, photographs) that was not applicable to any of the prior sections.

Project Title: Sliced pears: A novel avenue for pear consumption in the U.S.

Project Summary

The pear industry has repeatedly highlighted the urgent need to increase pear consumption as its most important priority every year since the publication of a seminal paper by George Ing (late commissioner, WTFRC) in 1994. Inconsistent quality of the fruit remains the major cause of dissatisfaction for the consumer. In addition, the industry producers and processors have attempted to use ethylene receptor blocker, 1-methylcyclopropene, to block ripening in pears. Unlike apples, where use of 1-MCP has enabled prolonged storage, use of 1-MCP in pears locks the fruit in an unripened state, further exacerbating the low consumption situation. With the increased consumer desire for convenience, the pear industry seems to be losing out to other fruits in the market place.

This project addressed the urgent issues of inconsistency of ripening, convenience, and consumption of pears. A WSU-patented technology that ensured predictable ripening of 1-MCP treated pears could also be used in the production of fresh sliced pears. Preliminary trials done at WSU and Crunch Pak with the use of the WSU patented ripening compound (RC) on 1-MCP-treated sliced pears produced promising results both in a physiological and consumer context. In trials done at Crunch Pak, 1-MCP-treated sliced Bartlett and Anjou pears, treated with a ripening compound (RC), and stored at 6 deg C (42.6 deg F) over a period of 21 days developed desirable flavor and softened while in a 4 oz. bag, meeting the McDonald's quality standards. The shelf life of the sliced fruit in bags exceeded the two-week base-line requirement. In this proposal, a large-scale trial was conducted to determine whether any modifications will be necessary to advance the concept to identify ideal concentration of the ripening compound, most efficient method of application of compound, optimum type of modified atmosphere packaging, etc. An extensive market evaluation was also performed to develop information that should aid in the adoption of sliced pears in the market.

This project holds importance as it aimed to enhance of the competitiveness of the Washington state pear industry and remains timely, as the recently discovered series of ripening compounds that reverse the impact of 1-MCP are now undergoing multiple trials. Previously production of sliced pears with these compounds was supported by Pear Bureau NW and Crunch Pak. With the immediate potential to increase per capita pear consumption, this project addresses one of the highest needs of the U.S. pear industry.

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

Project Approach

1. In this project, ripening compounds were applied to the Smartfresh treated sliced fruit at three concentrations of 1, 2 and 3% along with a 0% control. The ripening compound was mixed with Nature Seal anti-browning compound at the appropriate concentrations. The holding time for the fruit in the solution was 20-30 seconds. The fruit was placed in modified atmosphere bags and stored under regular atmosphere refrigeration and sampled every 5 days till day 30. The sampling included recording of organoleptic properties by lab colleagues, along with measurement of changes in ethylene and carbon dioxide generation by the fruit.
2. First, a small-scale taste trial was performed on the WSU Pullman Campus. A total of 20 individuals participated in the trial. As in previous trials Smartfresh treated pears subsequently treated with the ripening compound were the most preferred ones. This trial was performed using D'Anjou fruit that had been treated with 100 ppb of Smartfresh at Matson Fruit in Yakima and had an average firmness of 14 Lbs. Blue Star Growers in Wenatchee did not have any fruit available for this experiment but equivalent quality of fruit was sourced from Matson Fruit.

3. A large-scale willingness to pay trial and consumer preference trial was performed at the Portland Food Innovation Center coordinated by Co-PI Karina Gallardo. The evaluation was performed on March 1, 2016. Sliced fruit was prepared by Crunch Pak for the trial. A total of 150 participants participated in the trial.

Targets

1. One of the primary targets of this project was to facilitate introduction of the sliced pear product in the market place. Encouraged by the willingness to pay results, some private slicing companies have indicated their interest in developing the product for the larger market. These discussions are continuing as of the time of this report.

Performance Goals achieved

Large scale consumer preference and willingness to pay trial were the primary performance goals for the reporting period.

1. Conducted physiological experiments in WSU lab involving administration of ripening compound to sliced pears at varying concentrations
 - a. Ripening compounds were applied to the SmartFresh treated sliced fruit at three concentrations of 1, 2 and 3% along with a 0% control. The ripening compound was mixed with Nature Seal anti-browning compound at the appropriate concentrations. The holding time for the fruit in the solution was 20-30 seconds. The fruit was placed in modified atmosphere bags and stored under regular atmosphere refrigeration and sampled every 5 days till day 30. The sampling included recording of organoleptic properties by lab colleagues, ethylene and carbon dioxide.
 - b. The organoleptic properties of the fruit improved as the days under storage progressed. As expected, there was a concomitant increase in the levels of ethylene and carbon dioxide. The levels of carbon dioxide started peaking around day 20.
2. Small-scale preliminary trials at WSU
 - a. A small-scale taste trial was performed on WSU Pullman Campus. A total of 20 individuals participated in the trial. SmartFresh treated pears subsequently treated with the ripening compound were the most preferred ones. This trial was performed using D'Anjou fruit that had been treated with 100 ppb of SmartFresh at Matson Fruit in Yakima and had an average firmness of 14 Lbs. Blue Star Growers in Wenatchee did not have any fruit available during the reporting period but equivalent quality of fruit was sourced from Matson Fruit.
3. Evaluation at retail chains, urban markets and special events
 - a. A large-scale trial was performed at the Portland Food Innovation Center coordinated by Co-PI Karina Gallardo. The evaluation was performed on March 1, 2016. A preliminary report is provided below. Sliced fruit was prepared by Crunch Pak for the trial.
 - b. Overall, the sample with 2% RC was the most preferred sample with 35% of participating panelists ranking it as the most preferred, followed by sample with 3% RC with 28% of panelists ranked as most preferred, 0% RC with 19% of panelists ranked as most preferred and 1% RC with 18% of panelists ranked as most preferred (See Table 1).

Table 1. Overall liking, number (percentage) of panelists who rated each sample as mostly preferred, second most preferred, third most preferred and least preferred.

Number of panelists who rated the sample as:	1 (most preferred)	2	3	4 (least preferred)

0% RC	23 (19%)	28 (23%)	32 (27%)	38 (31%)
1% RC	22 (18%)	30 (24%)	36 (30 %)	33 (28%)
2% RC	42 (35%)	23 (19%)	29 (24 %)	27 (22%)
3% RC	34 (28%)	39 (32%)	24 (20%)	24 (20%)
Number of panelists	121 (100%)	120 (100%)	121 (100%)	122 (100%)

Note: Numbers in parenthesis indicate percentages.

c. As part of the trial, an auction was also held to see how much is a customer willing to pay for the novel product. The highest bid in dollars per 2-oz packet was for sample 2% RC, \$0.76/2-oz packet. The lowest was for sample 0% RC with \$0.64/2-oz packet. There were no statistically significant differences across bids for samples 0% RC, 1% RC and 3% RC (See Table 2). This value should be compared to the average market price in Portland downtown grocery stores for sliced apples \$0.52/lb. This value for sliced apples was obtained one day before the experiment was conducted (March 1, 2016).

Table. 2 Summary statistics for bids across 4 samples tested.

Bid (\$/2-oz packet)				
	Mean	Std dev.	Max	Min
0% RC	0.64a	0.53	2.5	0
1% RC	0.67a	0.51	2.5	0
2% RC	0.76b	0.56	2.5	0
3% RC	0.70ab	0.58	2.75	0

Note: Superscripts in the mean bid column indicates statistically significance difference.

d. The average bid for sample 2% RC was statistically significantly higher than 0% RC and 1% RC, but not statistically significant different from average bid for sample 3% RC. The difference in the average bid for sample 3% RC was not statistically significant different from average bid for sample 0% RC and 1% RC (See Table 3).

Table 3. Pairwise comparison across average bids for 4 samples tested.

	Control 0% RC	1% RC	2% RC	3% RC
0% RC	-	-	-	-
1% RC	-0.02 (0.04)	-	-	-
2% RC	-0.12** (0.05)	-0.09** (0.04)	-	-
3% RC	-0.06 (0.04)	-0.04 (0.04)	0.06 (0.04)	-

Note: *, **, *** Indicates statistically significant at the 10, 5, and 1% level respectively. A negative number indicates that the value in the column is lower than the value in the row. For example, average bid for the sample control 0% RC is lower than for the 1% RC.

Significant results

1. Customers rated the product treated with 2% RC as the most desirable one. Customers were willing to pay 23% to 46% more for a 2 oz. bag of sliced pears compared to sliced apple.
2. Economic analysis performed with pear industry leaders estimated that the cost per acre returns to the farmer would double if only 5 boxes out of 25 boxes per bin are converted to sliced pear product.

Conclusions

Based on the consumer preference trials, willingness to pay trials and preliminary return on investment analysis, sliced pears are a viable product that can provide the intended economic consequences to the pear industry.

Recommendations

Sliced pears should be developed at a cooperative packing house that will ensure maximum returns to the farmer positively impacting the economics of a larger number of constituents in the pear industry. This will also ensure that the fruit can be cleaned and sorted prior to being directly utilized for slicing. This will eliminate the need for packaging in boxes and storage and is expected to have positive environmental impact.

Favorable or unusual developments

During the NW Hort Expo in 2016, several discussions regarding the sliced pear product resulted in generating interest from a large co-operative in establishing a slicing operation which will be integrated with their other activities.

The sliced pears project was presented at the 2015 NW Hort Expo.

USA Pears invited Amit Dhingra to present an overview of the sliced pear project.

Peer-reviewed publication –

Ikiz D, Gallardo RK, Dhingra A, Hewitt S. (2017) Assessing consumers' preferences and willingness to pay for novel sliced packed fresh pears: A latent class approach. *Agribusiness*. doi: 10.1002/agr.21532.

Good Fruit Grower article –

Dhingra A, Gallardo K (2017) Customers are willing to pay a premium only on high quality, fresh sliced pears. *Good Fruit Grower*, vol 68. Washington State Fruit Commission, Wenatchee, WA

1. Amit Dhingra – Coordinated the various aspects of the project, finalized all reports, planned experiments and worked with the collaborators and stakeholders.
2. Richard Sharpe – Post doc - Assisted Amit Dhingra in project coordination, development of the reports and ensuring that the timeline was followed.
3. Seanna Hewitt – Graduate student - Performed sliced pear experiments and tested fruit quality, performed small scale trials, analyzed the data and provided to Amit Dhingra. Procured fruit for the experiments from Blue Star and Matson Fruit.

4. Dila Ikiz– Graduate student - Assisted Amit Dhingra and Karina Gallardo (Co-PI) in performing the consumer preference trial and setting up the willingness to pay trial. Analyzed the data.
5. Crunch Pak – Prepared sliced pears in their production pipeline for trials.
6. USA Pears – Provided guidance and financial support as matching funds for the large scale consumer preference trial and setting up the willingness to pay trial.

Goals and Outcomes Achieved

As outlined in section 4, all the performance goals were accomplished.

All the proposed activities were completed.

1. Data regarding customer's willingness to pay 23-46% more for sliced pear of what the customer pays for sliced apples is an important economic factor that is expected to stimulate the market viability of the product.
2. Data regarding the additional return to the farmer if the slicing is integrated into a cooperative packing house is a key factor that is expected to make this product mainstream.

Beneficiaries

This project impacted the 1,600 pear growers represented by Pear Bureau NW. Additionally, in the future this project will impact market organizations interested in introducing the sliced pear product. The impact will be on pear producers and processors that are mainly located in the Western US region and consumers all over the country will benefit from having a convenient and consistent pear product. For this project, the fruit was obtained from the growers in Washington, and was conducted in collaboration with Crunch Pak, a sliced fruit company in WA state.

The PNW Pear growers produce 84% of all fresh pears grown in the United States, which is approximately \$367 million in farm income (Pear Bureau Northwest, 2015). A 1% addition of sliced pears to the total pear market is valued at \$3.67 million. Sliced pears have the potential to reach 10% of the total market in the next 10 years. At current market value, this will represent a total of ~\$40 million. In addition, fruit size ranging from 120 to 135 box size can be utilized for slicing and that sized fruit can get a fixed base price which is currently always fluctuating. Facilitating a market for sliced pears is expected to increase consumer demand, promoting significant growth of the pear industry. This project will provide a novel avenue for enhancing pear consumption within the next year. This project specifically addressed the funding priority of Enhancing Domestic Markets by providing a novel product which seems to have a great demand but no supply as per Crunch Pak. This will benefit the specialty crop pear producers and the crops will be specifically utilized within the state of Washington for this novel use.

Lessons Learned

Timely planning is always good for meeting the goals of the project.
Positive results included the outcomes from the willingness to pay study as well as the taste trials.
No negative results to report.

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Additional Information

1. USA pears - \$6,800 – Conducting large scale trials in 2016 at the Portland Food Innovation Center.
2. Fresh Pear Subcommittee - \$34,725 – Equipment support for physiological and biochemical analysis of sliced fruit
3. Crunch Pak - \$30,000 – Preparation of sliced pears – time, labor, equipment, personnel and resources.

Project Title: Sustainability/Best practices program development for hops

Project Summary

Sustainability programs emphasize three major areas: Human and Food Safety, Community and Environmental Stewardship, and Employee Empowerment, Innovation and Creativity.

These keystones are increasingly emphasized by hop growers' customers, the brewers and merchant/processors. This has become even more evident with the rapid growth of the craft and specialty brewing sector, as many of the founders and employees of these companies are highly involved in their local communities and concerned with social, environmental, and workplace quality of life as well as a premium product of the highest quality and purity. For the hop industry, the most critical aspect of this sector's increasing demand for our crop is the different style of brewing they employ.

Traditionally brewers have added hops to the brew kettle during boiling to break down the alpha acid and other resinous compounds contained in the lupulin glands, contributing the traditional bitter flavor to beer. While food safety aspects in the handling of the crop have long been emphasized and practices employed to insure a clean, high quality crop, there has always been the "safety net" of boiling to ensure unwanted organisms were destroyed.

However, craft and specialty brewers have developed methods for "late hopping" or "dry hopping", whereby hops are added to the beer after boiling, when the beer is held at lower temperatures in the fermentation tank. These methods are designed to extract the fragile oil compounds that would be destroyed by boiling but contribute unique flavors and aromas to these specialty beers (citrus, etc.).

During the past 6 years growth in the craft and specialty brewing sector has demanded an increasing share of the US hop crop. Craft beer now commands 12.7% of US beer volume. While this seems small compared to the volume of traditional light lager beers, one needs to understand the difference in hopping rates to fully appreciate the magnitude of craft's impact on the hop industry. For the three decades prior to 2012, the average annual hopping rate for US brewers, as reported by the US Bureau of Alcohol, Tobacco and Firearms, hovered between 0.2 and 0.25 pounds of hops for a 31-gallon barrel of beer. The Brewers Association (trade group representing craft brewers) currently estimates the average hopping rate for their members was a whopping 1.4 pounds of hops per barrel, a 6 to 7x increase in hopping rate over traditional industrial lager beers.

As a result, craft's 12.7% share of US beer volume requires the equivalent of nearly 50% of the US hop crop. While some of these hops are imported from other regions of the world, the vast majority come from the US, where Washington State is the largest producer (75% of the US acreage).

The dramatic increase in hopping rates and hopping regimes (late hop additions at low beer temperatures) has focused attention on hops as a food crop, heightening concerns over food safety practices, particularly during harvest. As mentioned above, this is a relatively new emphasis that has gained traction over the past 6 to 8 years. As there was no single program addressing the specific needs of the hop industry, growers were left to scramble for solutions by implementing programs developed for other crops that were not a perfect fit for hops.

In addition to food safety, other aspects of sustainability and best practices programs have received increased attention in recent years, as brewers search for raw materials suppliers that place a priority on sustainability factors that align with the ethics of those customers. As a result, Risk Assessment and Irrigation Water Testing were also targeted through this project. Hops are covered by the FDA's Produce

Safety Rule under the Food Safety Modernization Act. Education on these three topics were designed to align grower practices with FSMA requirements. The grant allowed modules to be developed addressing these key issues and providing hop growers with tools to properly address them.

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

Project Approach

The initial task involved establishment of the advisory committee and selection of contractors to evaluate existing third-party certification programs, contract language and other resources applicable to the envisioned final product. These stakeholders and contractors successfully drafted the program's framework and priorities. Through this process stakeholders confirmed that food safety/harvesting practices were the highest priority for grower education. The advisory committee provided annual evaluation of progress, including priorities, which resulted in subsequent modules focused on Risk Assessment and Fertility, as originally proposed. In addition, due to requirements of the Food Safety Modernization Act, a fourth module on Irrigation Water Microbial Testing was added. Although the initial intent of the project was the development of three educational modules, the final result include four modules and a framework for continued expansion of educational material:

- Development and deployment of the "Good Bines" framework for presentation and management of educational modules.
- Four educational modules, including Food Safety (completed), Risk Assessment (completed), Water Testing (final website coding underway; anticipated launch in late November), and Fertility (developed, design work is underway, coding and launch scheduled for December).
- An educational seminar on food safety and risk assessment best practices was conducted in April 2018, in collaboration with officials from the GLOBALG.A.P. program.
- Hop industry representatives met with US Food and Drug Administration officials to discuss the application of the Food Safety Modernization Act on hops. Subsequent data collection allowed the creation of a risk analysis that was submitted to FDA in August 2018, requesting exemption of hops from FSMA as "rarely consumed raw." This data set is currently under review by FDA officials. In the meantime, resources developed through this project will ensure hop growers are compliant with FSMA Produce Safety Rules, should the effort to achieve exemption prove unsuccessful.

Initially the project encountered delays due to difficulty finding contractors to provide the level of expertise necessary to achieve the envisioned outcome. Two initial contractors helped evaluate existing third-party audited programs, framing the eventual output. One of these contractors drafted the initial Food Safety module. However, in the spring of 2018 new contractors were identified with both the technical and design skillsets to achieve the high-quality program that was envisioned. Over the final six months of the project tremendous progress was made, ultimately developing 4 educational modules (original proposal envisioned three modules), along with a framework for presenting and managing those modules and related material.

Hop Growers of America worked closely with Washington Hop Commission throughout the project, allowing the Commission to deploy the new educational program on the HGA website (www.usahops.org) and endorsing the program. The Chair of the HGA Best Practices Committee, Carman McKinney, served as an advisor throughout the project, ensuring the highest priority issues were addressed in the initial modules, and evaluating the focus to ensure these modules interface correctly with third-party audited programs (such as GLOBALG.A.P.). Ms. McKinney's role as the Food Safety and Sustainability Program Manager for a major Yakima Valley hop farm that maintains certification under

GLOBALG.A.P., Salmon Safe, USDA Organic, and several other highly regarded food safety/sustainability/quality management programs ensured that the output of this project was consistent with these and other third-party audited programs.

A concurrent project builds on the output from this grant, creating a Best Practices Directory that will allow growers to voluntarily list their operations in a searchable directory featuring several third-party certifications in addition to the Good Bines Food Safety and Risk Assessment modules. This directory will allow customers to easily search for hop farms that have chosen to implement practices and compliance programs meeting their needs. This project has been funded by the Brewers Association.

A broad range of stakeholders participated in the Advisory Committee that oversaw the creation of this program: small and large hop growers from several states, hop merchants and processors, and brewery representatives.

This project solely benefits specialty crops, specifically hops.

Goals and Outcomes Achieved

Goal: Increase grower implementation of sustainable production practices and food safety programs through education and outreach and provide growers with tools to demonstrate the implementation of these practices to customers. This goal was achieved.

Performance measure: Development of the first module envisioned for this program, addressing Best Practices for hop harvesting to ensure food safety and quality assurance, was completed. According to information provided by hop merchant/processor stakeholders, an estimated 80% of Washington growers have already completed this training. Additional informational sessions will be offered during the Washington Hop Growers Annual Meeting and American Hop Convention in January 2019, with a goal of achieving 100% implementation by Washington hop growers.

The second module regarding Risk Assessment was also completed. This module is quite complex, leading the user through the analysis of various potential risks on their farming operation, thus allowing the user to not only identify these potential risks, but also to assess their relative probability and importance. Upon completion of the module the user is presented with a detailed document summarizing the identified risks as high, medium and low, thereby allowing the user to implement practices that will mitigate the most serious risks.

As initially anticipated, the third module to address fertility was not completed by the conclusion of the grant but will be launched by the end of 2018. Performance measures were exceeded with the development of a fourth module on Water Microbial Testing and grower education on the Food Safety Modernization Act.

A template was created to allow the addition of subsequent educational modules addressing other important aspects of hop production. Future module development will follow this template, allowing ease and cost savings for website coding and launch.

An opportunity to partner with the GLOBALG.A.P. organization resulted in a grower seminar on food safety and risk assessment in April 2018.

Finally, this grant allowed specific interaction with the US Food and Drug Administration to evaluate practices that are necessary for hop growers to comply with the Food Safety Modernization Act's Produce Safety Rules. Considerable confusion had surrounded the application of this regulatory program to the hop industry, as the marketing and use of hops is considerably different than the crops more commonly

defined as “produce”. These discussions resulted in the creation of a fourth educational module addressing the testing of irrigation water for microbial contamination.

As noted above, an estimated 80% of Washington hop growers completed the Food Safety training prior to 2018 harvest. Training must be updated annually, to allow documentation of continued improvement. This is a long-term program, where additional training priorities will be identified and subsequent modules produced as funding allows.

Target: Develop and deploy three educational/self-certification modules to encourage more consistent adoption of a baseline Best Practices for three areas of focus, and a means for growers to communicate their compliance with these practices to customers.

Target exceeded, with the development of four modules focused on these specific best practices, along with a presentation framework, dubbed “Good Bines”, to present and manage these and future educational modules and certification programs.

The initial benchmark situation included multiple programs and contract requirements that had no formal mechanism for coordination and consistency. There was no educational component available to growers who were not engaged in one of the existing individual certification programs. Since the deployment of the Foundations of Food Safety module, several leading breweries and hop merchant/processor companies have adopted the training module and required their growers to complete it. Additional brewers, including Anheuser-Busch InBev, will evaluate the program in 2019 for possible adoption as a consistent standard for their direct-contract growers. The goal of coordination and consistency, and subsequent decrease in the number and frequency of audits, has been achieved and will continue to expand.

Beneficiaries

45 Washington hop growing entities will benefitted from this project. Completion of the four educational modules that have been developed under this project will benefit hop growers who can utilize this training to position their marketing programs to target customers who demand these best practices, as well as their customers.

Approximately 50 Washington hop growing operations produce 75% of the US supply of hops. Last year the US produced 42% of the world’s supply of hops, resulting in exports of US hops to over 65 customer countries. Internationally, brewers large and small are starting to require specific best practices related to food safety and sustainability. This project clearly establishes Washington hop growers as leaders in the international hop industry regarding the implementation of best practices specific to those customer concerns. This will create both short and long-term sustained demand for hops produced in Washington and the US, providing economic benefit throughout the marketing chain.

Lessons Learned

The biggest challenge was securing a contractor with the technical and design skills necessary to achieve the envisioned outcome of this project. The initial contractors drafted the initial food safety module but did not have the necessary expertise for subsequent modules. Fortunately, new contractors were retained in early 2018 that allowed successful conclusion. It did, however, create a large volume of work during the final six months of the project.

As noted in the project approach section of this report, delays were encountered due to difficulty finding contractors to provide the level of expertise necessary to achieve the envisioned outcome. Over the final

six months of the project tremendous progress was made, after contractors with the technical and design skillsets necessary to achieve the desired results were retained. The initial intent of the project was the development of three educational modules, the final result include four modules and a framework for continued expansion of educational material.

The Expected Measurable Outcomes of the project were achieved.

Contact Person

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Email: ageorge@wahops.org

Additional Information

In-Kind matching donations from the Washington Hop Commission totaled \$62,000 over three years, representing the portion of salaries and benefits for Ann George, Executive Director and Carol Camden, Accountant for their time spent on grant-related activities.

Cash match of \$7,000 was pledged. Actual cash match was \$12,785.25. This included travel expenses to present this program to the Craft Brewers Conference, travel to Washington, DC to meet with the US Food and Drug Administration regarding FSMA's application to the hop industry, and costs associated with presenting a food safety and best practices training program to Washington hop growers. These cash funds were provided by the Washington Hop Commission and Hop Growers of America.

Screenshots from the USA Hops website and design prototypes are attached to document the outcome of this project. This includes:

- Good Bines "landing page" that provides the framework for the four modules developed under this grant, as well as future modules and information from a range of sources (fully launched and operational).
- "Foundations of Food Safety" module (fully launched and operational).
- "Foundations of Risk Assessment" module (fully launched and operational).
- "Irrigation Water Testing" module prototype (development and design work are completed; coding underway, with anticipated launch by the end of November 2018).
- Screenshots are not yet available for the Fertility module. Development is complete; design work and coding to be completed before the end of 2018.

Good Bines - Hop Growers of America

https://www.usahops.org/members/good-bines/

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Overview Food Safety & Quality Water & Irrigation Business Management Soil Fertility Integrated Pest Management Sustainability

USA HOPS
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GOOD BINES

Enhancing farm resiliency through education and collaboration.

WHAT IS GOOD BINES?

Good Bines is a farm-focused educational framework built on the collaborative development and sharing of economic, social and environmental best practices.

Administered by Hop Growers of America, *Good Bines* acts as a communication platform where members of the hop supply chain can access trusted resources, ensuring the overall resiliency of the U.S. hop industry. [Learn more.](#)

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Education Modules

Create New:

Food Safety Level 1 Module

CREATE

Form	Started	Last Updated	Completed	
Food Safety Level 1 for Home Ranch	media@thefieldgroup.net 04/05/2018 14:31:58	ageorge@wahops.org 08/09/2018 17:21:54	media@thefieldgroup.net 04/05/2018 14:34:30 Print Certificate	Edit . Delete Expires: 2019-04-05
Food Safety Level 1 for Home Ranch	ageorge@wahops.org 04/05/2018 13:57:29	ageorge@wahops.org 05/01/2018 10:45:08	ageorge@wahops.org 04/05/2018 14:02:54 Print Certificate	Edit . Delete Expires: 2019-04-05
			media@thefieldgroup.net	Edit . Delete

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has developed a self-assessment educational module, "Foundations of Food Safety", to assist growers in the implementation of best practices for harvesting operations to ensure industry standards for food safety are achieved. The practices included in this module will establish the foundation for continued improvement, should your farming operation seek future certification under third-party audited and Global Food Safety Initiative (GFSI) programs, including GLOBALG.A.P.

A. General

B. Harvest

C. Harvest and Worker Safety

D. Harvesting and Processing

E. Harvesting and Post-Harvest

Facility Name and Location (covered by this assessment)

Notes: All assessment facility must be visited by your assessor in order to complete this module. [Add a Facility](#)

Please Select

Primary Contact Person

Contact Phone

Email

First Name

Facility

HGA Grower Number

Working Address

City

State

Zip

Food Safety Contact Person

Phone

Email

24-Hour Contact Number for Food Safety Emergency

Grower numbers are assigned free of charge by Hop Growers of America (membership is not required). This is the US hop industry's standardized system for crop traceability and identification. If you do not have a grower number, please contact [info@usahops.org](#) to apply for one. Standardized grower numbers are a key aspect of food safety and traceability programs.

SAVE PROGRESS

NEXT SECTION

START TRAINING

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WSDA SCBGP FINAL REPORT

Food Safety Module - Hop Grower

Education Modules - Hop Grower

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Small Grower Council

Educational

Hop Research Council

Plant Health

Hop IPM Field Guide

Food Safety/Harvest Practices Module One includes five sections:

1. General

2. Records

3. Health and Human Safety

4. Hop Harvesting Field and Handling

5. Summary and Final Checklist

Each section is divided visually by tabs so you can track your progress.

PLEASE NOTE: Farms with multiple harvesting facility locations must complete a separate assessment for each location.

GET STARTED

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Education Modules - Hop Grower

Food Safety Module - Hop Grower

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A General

B Records

C Health and Human Safety

D Hop Harvesting and Handling

E Summary and Final Checklist

B.3. Export Chemical Regulations

If the product is intended for export, all agricultural chemical use complies with regulatory requirements of the intended country of destination.

If selling to a merchant who may export the crop, confirm with their list of chemicals for usage restrictions.

Reference the US Hop Industry Plant Protection Committee's [International MRL chart](#) for guidance.

I certify that my crop is destined only for Domestic customers and all applied pesticides (conventional or organic) are legally allowed for application to hops in my state/area and are detailed in full on the spray reports submitted.

If hops produced on this farm will be exported to foreign customers, I certify that no pesticide residues are present that do not comply with the regulatory requirements of that country. Laboratory testing for pesticide residues is recommended to validate compliance for export.

☒ I have implemented these practices on my farm and will continue to do so. (Check box to confirm completion).

SAVE PROGRESS

NEXT SECTION

Food Safety Module - Hop Grow
Education Modules - Hop Grow
Risk Assessment Module - Hop

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Good Bines: Important Definitions

- Risk:**The chance that objectives, property or people may be harmed by a potential hazard.
- Hazards:**Materials, practices, equipment, and methods that pose a potential to cause harm.
- Preventative Controls:**Measures put in place to prevent or minimize risks and hazards. This could include a process, practice, device, policy, action or another condition.
- Risk Criteria:**A criteria to evaluate the significance of the organization's identified risks to determine what risk level is acceptable and what is not. The risk criteria are unique and account for the organization's mission, vision, values, input from stakeholders, local laws and other external and internal factors.
- Impact:**The severity of consequences that could be incurred by the Farm if the risk were to become reality.
- Likelihood:**The chance of something occurring. Often called "probability"
- Supporting Documents:**Tangible proof that a risk has been addressed and a preventative control is in place.
Example:
 - Application Records** –Records of chemical and fertilizer applications, records of applicator and mixer/loader credentials, records of employee training in chemical application. Residual testing results and MRL criteria from HGA.
 - Land Use** –Copy of land permits, business licenses, zoning maps, etc.
 - Water Analysis** –Copy of analysis results from a third-party lab

- Equipment Maintenance** –Maintenance records for equipment, vehicles, reusable tools, etc. covered by Maintenance Policy in overall Farm Policy, completed daily maintenance checklist.

- ISO 31000:2018 - 02, Risk management - Guidelines, ISO 2018.
- HACCP Principles & Application Guidelines, U.S. Food & Drug Administration, 2017.

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Risk Assessment Module - Hop

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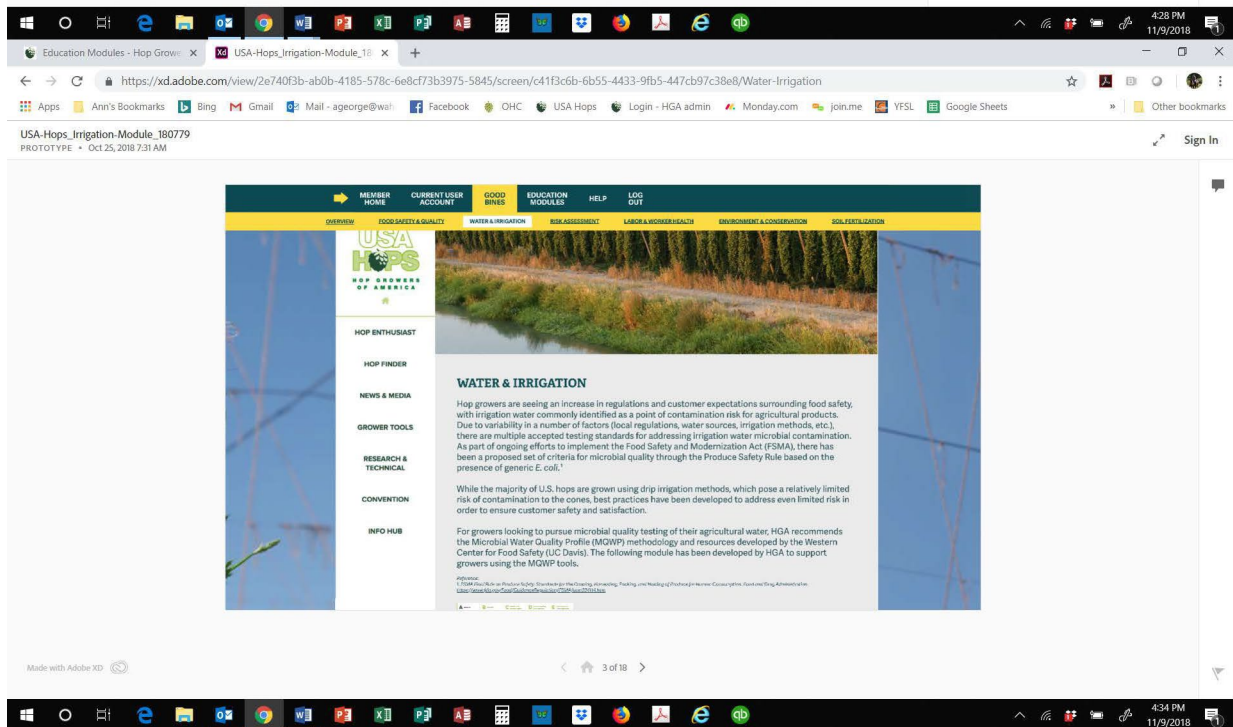
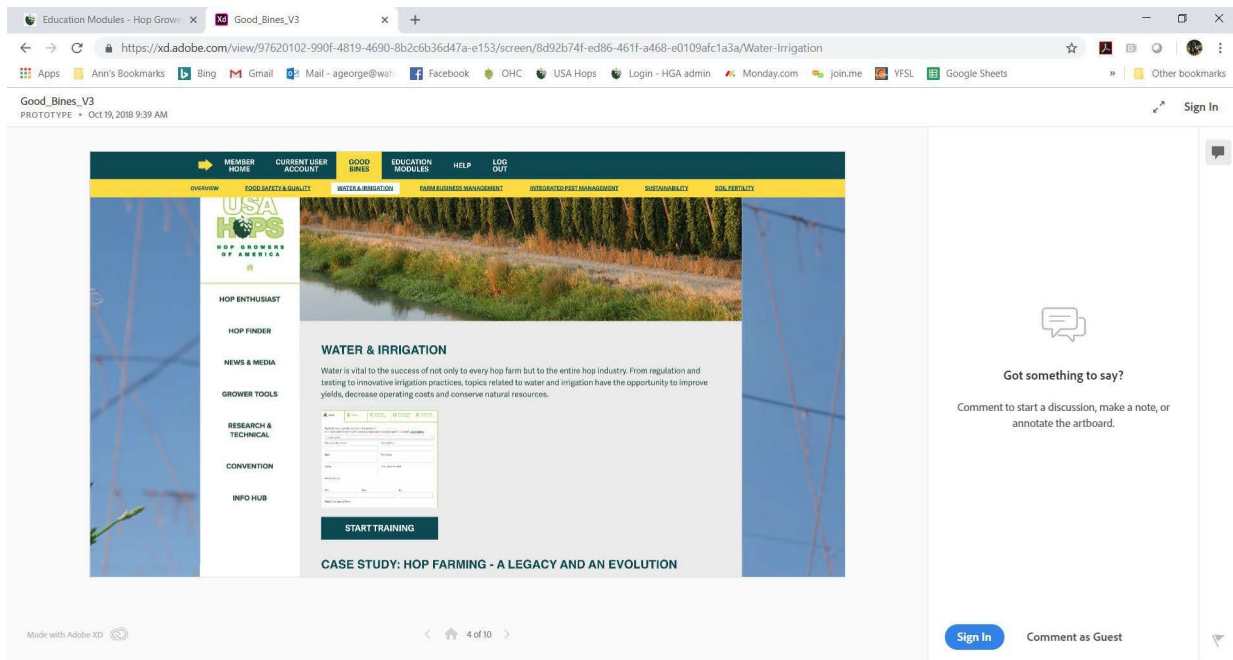
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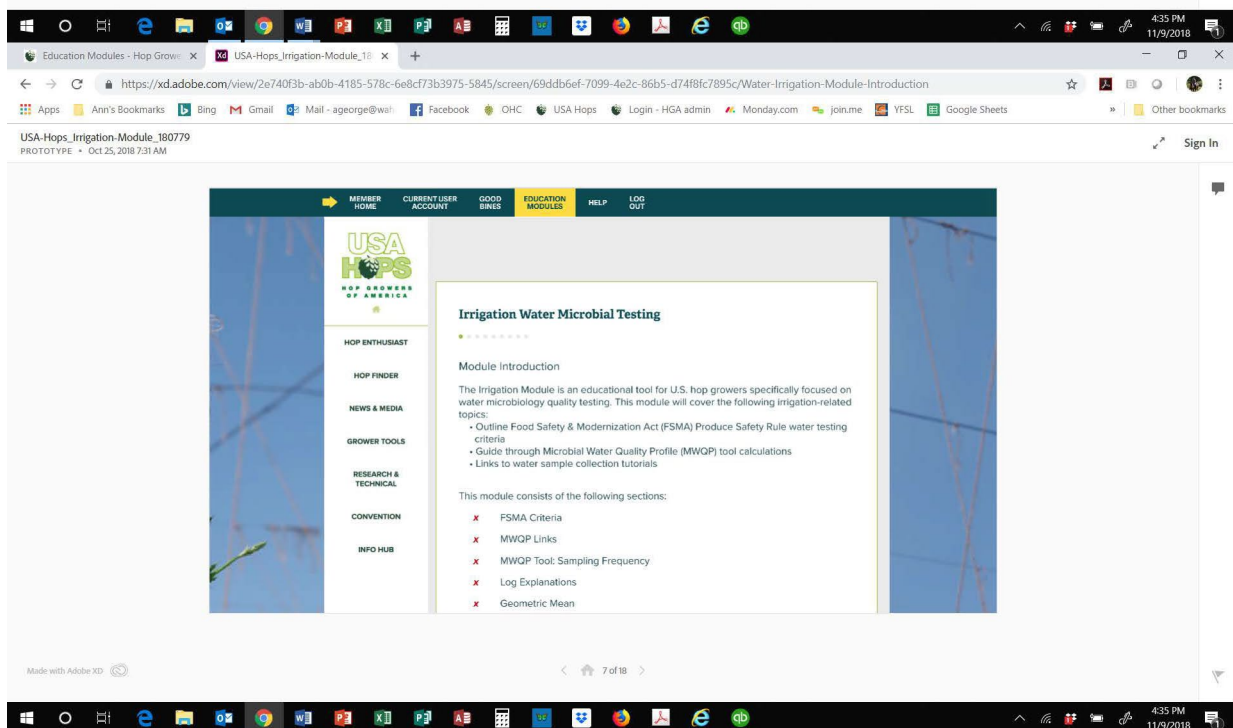
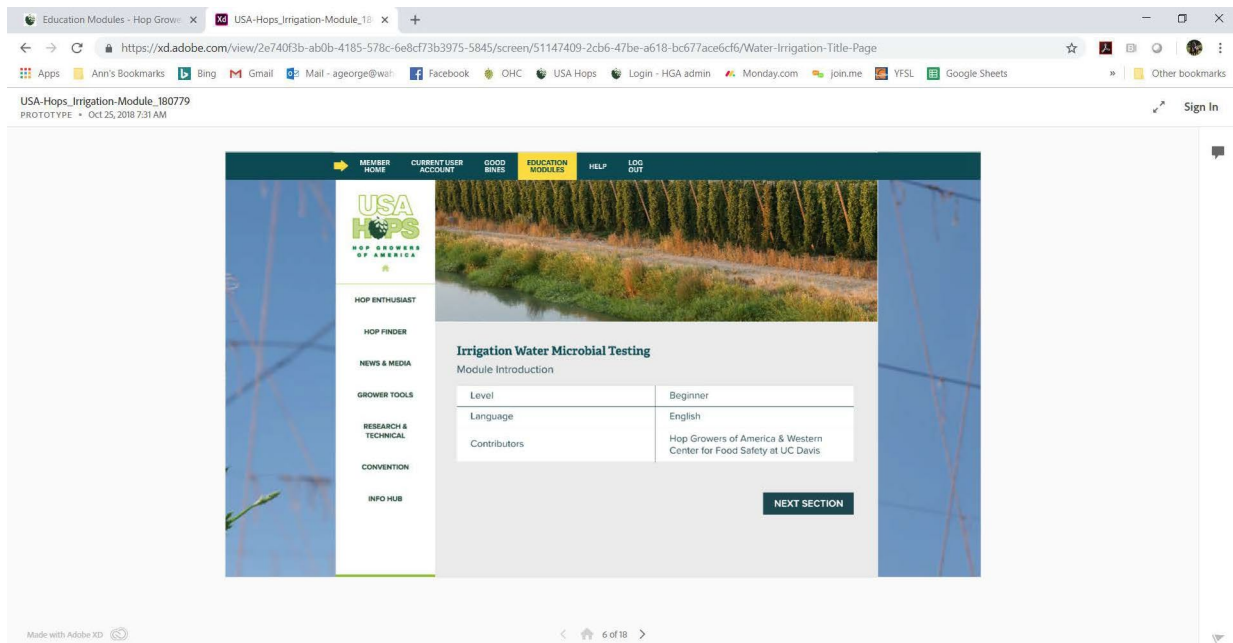
harm employees, operations, community or the environment.

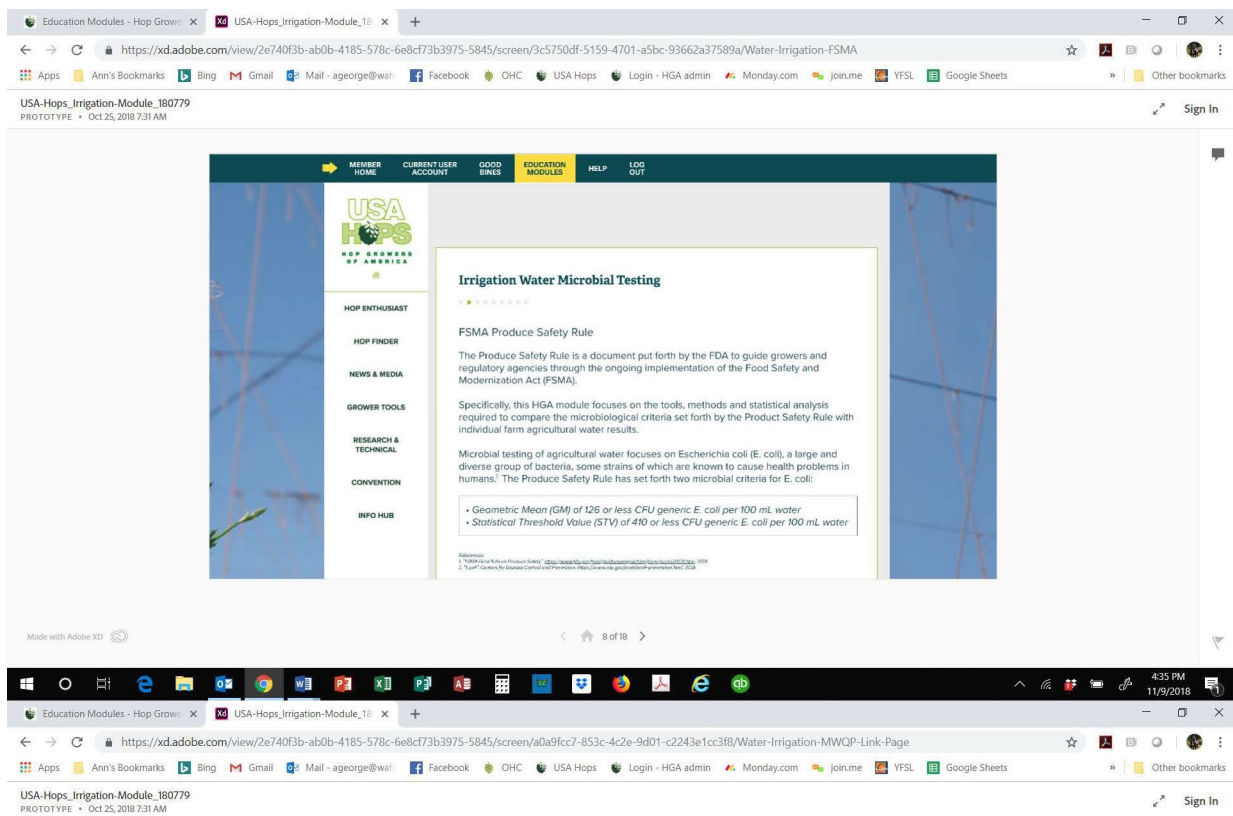
- 5 = **Catastrophic:**Risks with extremely negative consequences that could cause the entire Farm to fail or severely impact daily operations, harm employees, community, or the environment.

- The Likelihood is the chance of something occurring. Often called "probability"
 - Unlikely:Extremely rare risks, with almost no probability of occurring.
 - 2 = **Seldom:**Risks that are relatively uncommon, but have a small chance of occurring.
 - 3 = **Occasional:**Risks that are common, with about a 50/50 chance of occurring.
 - 4 = **Likely:**Risks that are highly likely to occur.
 - 5 = **Definite:**Risks that are almost certain to occur.
- Use this box to describe preventative controls that can help address and mitigate the identified potential risks.
1. Example: The fields were fumigated before hop planting by a third-party agricultural consultant.
- Use this box to detail documentation to support claims made about preventive controls. These supporting documents must be readily available in the event of an audit.
1. Example:Records of fumigation are kept on file at the Farm.
- If there are no potential risks identified, the user must still describe the preventive controls in place that have eliminated risk or how these risks do not apply.
1. Example:The field has laid fallow for 8 years and there is no presence of residual pests, chemicals or physical degradation.
- Detail any documentation that could support the claim of no potential risks.
1. Example:Previous land use permits for the property state land is zoned for agricultural use and are kept on file at the Farm. Records of testing for residual chemicals was conducted by a third-party agricultural consultant. Walkthrough assessment and checklist were completed by Farm employees.

SKIP TO MODULE
SEE SAMPLE FINAL REPORT







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Irrigation Water Microbial Testing

MWQP Tool: Sampling Frequency

Testing Frequency: The required sample size outlined in FSMA differs between surface water supplies and groundwater supplies, given the variable level of contamination risk.

- Untreated Surface Water:** This water source is considered at a higher risk of contamination and includes any irrigation water from sources such as a river, lake or reservoir. To conduct an initial survey, a farm must collect a minimum of 20 samples, over a period of no less than 2 years and no more than 4 years. Samples should be taken as close to harvest season as possible. After initial sampling, at least 1 new sample annually should be collected to confirm microbial criteria is still met.
- Untreated Ground Water:** This water source is considered at a lower risk for E. coli contamination and includes water stored underground that supplies springs and wells, both the water table and water stored in underground rock crevices and pores of geologic material. To conduct an initial survey, a farm must collect a minimum of 4 samples collected as close to harvest as possible, over a period of 1 year. After initial sampling, at least 1 sample per year is required to confirm microbial criteria is still met.

***NOTE:** The MWQP tool's model is built assuming surface water testing for a minimum of 20 samples. For a farm to meet the criteria using only 4 initial samples, all agricultural

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Irrigation Water Microbial Testing

Geometric Mean

The first question one might ask is how does the "geometric mean" differ from the "arithmetic mean" (AKA an "average")? The geometric mean is often used for datasets that exhibit exponential growth. This calculation is commonly used in financial analysis as well as with microbiology testing.

Geometric Mean is the n th root of the product of sample values: $\sqrt[n]{a_1 \times a_2 \times a_3 \times a_4}$

vs.

Arithmetic Mean (average) is calculated by adding all values and dividing that sum by the number of values: $\frac{a_1 + a_2 + a_3 + a_4}{n}$

Why use Geometric Mean?
For microbial water quality testing, the geometric mean is used to avoid the analysis being skewed by only a few very high or very low values. These high or low outlying values can be expected in a natural setting, such as an irrigation ditch, due to unforeseen variables (ex. cattle passing too close to the ditch, heavy rains or drought). By taking the geometric mean, farms aren't penalized by outlying values in the way they might be by using the arithmetic mean.

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Irrigation Water Microbial Testing

Standard Threshold Value

The second criteria is the Standard Threshold Value (STV), which is a calculation to find what is essentially the 90th percentile of the dataset.

The STV accounts for variability in water quality due to the presence of unusual adverse conditions where *E. coli* concentrations are significantly higher than they would typically be in the sampled area. By calculating the 90th percentile of the data set, we are forgiving the 10% of higher outlying values, as long as 90% of the values fall under the acceptable concentration of less than **410 CFU *E. coli* per 100ml of water**.

These calculations can get complicated, but the takeaway is as long as at least 90% of the value range is under 410 CFU *E. coli* per 100ml of water, the STV will show the water profile is in compliance. For more detailed calculations, see a [tutorial](#) from Produce Safety Alliance.

***NOTE:** If the calculated STV is more than **410 CFU *E. coli* per 100ml of water**, the water profile is not in compliance and water quality must be addressed with corrective measures.

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Irrigation Water Microbial Testing

Sampling Techniques and Equipment

Capturing an uncontaminated and representative sample is vital to creating a water quality profile. The following tutorials have been reviewed and endorsed by members of the HGA Best Practices Committee to guide farm personnel through proper water sampling techniques.

Guides:
UCGAPs Grower Guide to Irrigation Water Sampling for Microbial Food and Safety Audit Compliance. Source: University of California Davis. 2011.

Water Sampling 101. Source: Good Fruit Grower. July 2016.

Simple Steps for Water Sampling. Source: Good Fruit Grower. July 2016.

Videos:
[FSMA Water Sampling 101: Irrigation Pond Site Assessment](#). Source: Good Fruit Grower. 2017.

[FSMA Water Sampling 101: Tips for Sampling Irrigation Canal Water](#). Source: Good Fruit Grower. 2017.

[FSMA Water Sampling 101: Tips for Sampling Piped Water](#). Source: Good Fruit Grower and Western Center for Food Safety. 2017.

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Project Title: Educating specialty crop growers

Project Summary

For the past four decades, Tilth Alliance (formerly Tilth Producers of Washington) has been committed to enhancing organic and sustainable practices in specialty crop production through grower education, and to helping smaller-scale growers achieve success by supporting robust regional food systems and promoting stewardship of the land for future generations. As the backdrop to this project, Tilth Alliance identified challenges for smaller-scale organic and sustainable specialty crop growers, including pest and disease management, season extension, record keeping and finance, and innovative marketing. Access to relevant educational opportunities that fit growers' scale and location was an additional challenge that was identified.

The smaller-scale growers targeted through this project required research-based education that was tailored and accessible both in content and delivery. To meet these needs, this project developed and implemented a variety of educational programs and online resources including annual farm walks, topic-specific conference workshops for both beginning and experienced growers, all-day farm tours, and topic-focused "one day university" workshops, plus complimentary online resources provided through the Tilth Alliance website. As a statewide organization, it was a priority for Tilth Alliance to provide these opportunities in various counties across the state.

By offering educational opportunities focused on innovative skills and sustainable practices for small-scale specialty crop growers, Tilth Alliance addressed an immediate need for growers to expand their stake in the organic and sustainable marketplace and move toward fiscal solvency. Further, these educational opportunities brought a unique focus on farmer-to-farmer exchange of knowledge as well as the dissemination of current research in organic and sustainable production practices.

There is an increased demand for organic and sustainably grown specialty crops in Washington. According to statistics from WSU's Center for Sustaining Agriculture and Natural Resources, 56% of certified organic land was in specialty crop production at the start of this project. This data indicates that organic specialty crop production is an important component of Washington's agricultural landscape and marketplace.

Tilth Alliance's program evaluations have shown that growers respond best to educational offerings located nearby and at convenient times. Consequently, activities under the project were held year-round in numerous counties across the state. Program evaluations also indicate that specialty crop growers find great value in networking opportunities and a sense of community. Tilth Alliance is an organization that is unmatched in its capability to facilitate networking, peer-to-peer education and connections between farmers and research institutions that have developed new and efficient forms of organic and sustainable practices. While Tilth Alliance is not a research institution, educational programming helps to develop organic and sustainable production practices through the sharing of information and skills. Tilth Alliance has also reached growers who utilize the organization's online resources and may subsequently incorporate specialty crop production on their farms. Tilth Alliance is one of the only organizations that offers peer-to-peer educational programming for small-scale organic and sustainable specialty crop growers across Washington.

There is a need for education around certain topics of paramount importance to small-scale organic and sustainable specialty crop growers, and to achieve maximum impact this education needs to be delivered in formats that are best-suited to the audience. This project addressed those educational needs.



This project built upon educational programs previously supported by SCBGP funds, focusing on delivering education based on grower needs that had been identified through evaluations conducted under the previously-funded project. Grant support for educational programs allows Tilth Alliance to reach a wider demographic of growers by keeping registration costs as low as possible. Under the previously-funded project, Tilth was also able to hire an education coordinator to work with and explore the educational needs of growers across the state. The very existence of the education coordinator position increased the visibility of Tilth and allowed a more concerted effort for outreach, education, and follow-up with growers, making possible the evaluations and research that provided a foundation for the present project.

Project Approach

- **Plan and implement a total of 12 Farm Walks focused on organic and sustainable production practices.**

A total of 12 Farm Walks were planned and delivered across the state as a part of this project. Titles, host farms, and dates are listed below.

1. Scouting, Row Cover and Crop Rotation, Newaukaum Valley Farm (July, 20, 2016)
2. Organic Orchard Management, Cliffside Orchard (August, 8, 2016)
3. Diversified Markets and Value-Added Products, Midori Farm (August 15, 2016)
4. Starting a Sustainable Draft-Powered Farm, Hayshaker Farm (September 12, 2016)
5. Whole Farm Conservation Planning, Heavenly Hills Harvest (September 19, 2016)
6. Cover Cropping for Soil Health, Lenwood Farms (May 22, 2017)
7. Organic Medicinal Herb Production, Sego Herb Farm (August 21, 2017)
8. Cider Production from Tree to Tap, SixKnot Cider (September 25, 2017)
9. Organic Seed Production, Organic Seed Alliance and Essential Blooms (October 2, 2017)
10. Organic Orchard Pest Management, White Bear Orchard (August 6, 2018)
11. Creative Farm Financing and Diversified Enterprises, Mariposa Farm (September 10, 2018)

For the two 2018 Farm Walks, live English-Spanish translation was provided throughout the entire Farm Walk by WSU Food Systems Program partners, made possible through a separate grant to WSU.

Across all 12 Farm Walks, 58% of attendees indicated that they were actively farming, and another 10% of attendees indicated that they planned to begin farming. A remarkable 98% of attendees indicated that they had somewhat or greatly increased their knowledge on at least one specialty crop production topic as a result of the Farm Walk, and 65% reported having greatly increased their knowledge. Importantly, 65% of farmers said that they planned to make at least one change to their farm operation as a result of knowledge gained at the Farm Walk.

Over the course of this project Farm Walks have emerged as an exceptionally valuable education format. Because each Farm Walk is unique, there is great opportunity to adapt to grower needs and topics of interest, and to reach out to and engage with farmers (both as hosts and attendees) across the state and

across diverse production systems. Farm Walks also offer an excellent platform for engaging subject matter experts from universities and agencies, while maintaining a primary focus on peer-to-peer learning. Beyond the primary educational opportunities, the somewhat informal format of Farm Walks provides an excellent networking opportunity among growers and between growers and other agricultural professionals, which in turn helps to strengthen and ensure a resilient small-scale organic and sustainable specialty crop industry in Washington.

- **Plan and implement a total of 30 specialty crop focused workshops at the annual Tilth Conference.**

A total of 30 specialty crop-focused workshops – 15 for beginning farmers and 15 for advanced farmers – were delivered across three annual Tilth Conferences as a part of this project. Workshops were presented by subject matter experts including experienced farmers, university research and extension faculty, agricultural service agency and nonprofit employees, and other agricultural professionals. Conferences drew from 380 to 600 attendees from the Tilth producer community, estimate based on the most recent survey (see below) to be comprised of nearly 80% specialty crop growers. Workshop titles are shown by conference year below.

2015	2016	2017
Beginner		
Medicinal Crops for Farmers	Organic Certification 101: Your Guide to Going Organic	Soil Biodegradable Mulch Film: A Key Production Aid for Sustainable Organic Agriculture
Growing Wine Grapes Organically	Soils 101: Ecological Soil Management	Planning a Compact Farm
Creating Healthy Soil and Fertility Using Organic No Till Combined with Year Round Cover Cropping for the Market Gardener	Management of Pests and Beneficial Insects on Vegetable Crops	Pollination, Increased Produce Yield and Organic Labeling
Irrigation Management for Drought	Orchard Health	Nitrogen Management and Cover Crops in Organic Vegetables
Flower Production: The Farmer-Florist Movement	Starting a Draft Horse Farm: Becoming a Farm Owner	Soil Building with Hugelkultur
Advanced		
Croptime: Scheduling Vegetable Crops with Degree Days	Hedgerow AgroEcology	Practical Applications of Soil Health Research
Measuring Soil Health on the Farm	Managing Fire Blight in Apples and Pears Organically	New Directions for Cover Crop Management in Reduced Tillage Organic Agriculture
Environmental Footprint of Organic Farming	Holistic Disease Management in Orchards	Nutrient Management for Sustainable Vegetable Cropping Systems
Ignorance is Bliss? History Repeated for Brassica Black Leg in the Pacific Northwest	Cover Crops in Production Agriculture	Produce Processing Capacity in Washington State for Farmers and Buyers

State of Organic Seed	Facilitating Healthy Relationships with Interns and Employees	Growing Biodynamic Grapes
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Evaluations were administered to attendees of each workshop, and detailed evaluation results have been submitted as part of previous quarterly reporting. Across all 30 workshops, 77% of attendees indicated that their knowledge of the topic presented had greatly increased, and 71% of attendees indicated that they planned to make changes to their farm business based on what they had learned. Through evaluations and surveys, Tilth Conference workshops emerge as a particularly effective format for the dissemination of actionable information related to organic and sustainable specialty crop production and marketing.

The Tilth Conference overall also emerges as a valuable opportunity for grower networking.

- **Plan and implement a total of 3 specialty crop focused all-day farm tours to take place during the annual Tilth Conference.**

Because of the time of year, it was not possible to schedule a farm tour focused exclusively on specialty crops during the Tilth Conference in Spokane in 2015. There were a limited number of specialty crop growers in the area utilizing organic and/or sustainable practices, and most had already completed their farm season by the time the conference was held in November. Instead, two farm tours were held during the 2017 conference to make up for the deficiency. The three farm tours are listed below:

- Diversifying Production: Gibbs Farm, Stemilt Growers Processing Facility, Kyle Mathison Orchards, Inc. (2016)
- Soil Stewardship: Yacolt Mountain Farm and Nursery, Full Plate Farm (2017)
- Market Diversification: Our Table Cooperative, Stoneboat Farm, Garden Delights Herb Farm (2017)

Farm tours generally sell out (registration is usually capped at approximately 50 due to limited tour bus capacity), and generally receive quite positive evaluation responses. They provide a different learning format from either conference workshops or Farm Walks, and are a good way to provide access to multiple operations by a large number of attendees in a fairly short period of time. The format also lends itself to detailed prior planning of topics and concepts to be covered, such that farm tours provide an excellent way to tailor content to the needs of the community.



- **Convene a total of 3 community roundtables at the annual Tilth Conference to collect anecdotal evidence regarding the efficacy of educational programs for specialty crop growers.**

Three community roundtables were convened, one at each Tilth Conference in 2015, 2016, and 2017. These afforded an opportunity for specialty crop growers to provide constructive feedback on educational programming offered by Tilth Alliance, and suggestions for future formats and priority topics. To the

extent possible, suggestions were incorporated into ongoing programming as a part of this project. The in-person interactions and feedback gathered through community roundtables has been extremely valuable, and is something that Tilth Alliance will continue in future years.

Attendance at the 2015 roundtable was low (only 3 growers), so efforts to better-advertise the roundtables were undertaken in 2016 and 2017, resulting in 36 and 30 participants, respectively. Some of the most significant points or recurrent themes expressed by growers are summarized here:

- Preference for continued use of experienced growers and agricultural experts/researchers to present at educational events
 - Interest in hands-on learning with use of tools, tractors, and general mechanics
 - Emphasis on the whole farm system
 - Interest in more on-farm learning opportunities
 - Importance of inclusiveness of both small- and large-scale production methods
 - Interest in diversified operations
 - Support for farmer-led educational formats
 - Support for off-season educational opportunities on non-production subjects
 - Interest in expanding the professional networking opportunities of the Tilth Conference to include more purchasers
 - Support for educational opportunities that are suitable to beginning specialty crop growers
- **Plan and implement a total of 3 one-day universities to be held in the off-season in different regions of the state.**

A one-day university focused on Biodynamic Production on the Self-Sufficient Farm was held at S&S Homestead Farm in 2016, with 17 attendees. In 2017, a one-day university focused on On-Farm Food Safety was fully planned, but cancelled due to low registration. Upon examination of registration records and anecdotal feedback, it was determined that the one-day university format, essentially consisting of ‘one-off’ educational events without clarity around their ‘identity,’ origin, or reason for being held, did not offer sufficient incentive to compete with the many other demands on growers’ time or to be worth traveling much distance to attend. The project team also learned that it can be difficult to attract growers to stand-alone educational events focused on non-production topics. One-day universities were deemed not to be a good use of project funds, and no further one-day universities were planned. Instead, additional workshops of relevance to growers were held at the 2017 conference. These workshops specifically focused on non-production topics that are nonetheless relevant to small farm businesses, and utilized the overall appeal of the Tilth Conference to attract growers to attend educational workshops on non-production topics. The additional workshops offered were:

- Leasing Farmland for Lessors and Lessees
- Farmland Conservation: Funding, Zoning Tools, Partners and Growth Management
- Transitioning to Organic Production
- What’s New and Mandatory? FDA Produce Rule 101
- Microloans – Cultivating Big Dreams on a Small Scale
- Preparing for Your Lender: The 5 Cs of Credit

The failure of the one-day university model within this project provides a valuable lesson learned, and has generated productive brainstorming around more cohesive program formats and strategies to entice growers to attend events focused on ‘dry’ subjects like finance and food safety.

- **Provide written summaries of each event and post resources, audio, and other educational materials to the Tilth Alliance website and in *Tilth Producers Quarterly*.**

Conference workshop audio recordings and slides where available were posted to the Tilth Producers and Tilth Alliance websites. Farm Walk informational booklets were also posted to the websites.

Written summaries of 2015 and 2016 educational events were published in *Tilth Producers Quarterly*. However, feedback received in 2017 indicated a lack of interest (and perhaps some annoyance) among growers and readers of *Tilth Producers Quarterly* in seeing write-ups of events they hadn't been able to attend (essentially, if I was there I already know it, and if it wasn't there, don't rub it in!). Written summaries were discontinued in 2017, however conference workshop content and Farm Walk resource booklets continued to be posted to the website, as these provide true educational resources, not just event summaries.

This lesson learned will be incorporated into future Tilth Alliance programming and dissemination of information, where the focus will be more sharply on dissemination of useful resources, and on minimizing non-actionable summary information.

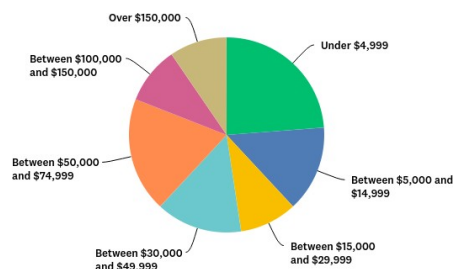
Anecdotal feedback also suggests that although conference audio recordings plus slides are useful, video recordings of workshops would be much more useful (easily viewed and used) for growers. Tilth Alliance plans to incorporate video recording of conference workshops in future years.

- **Create and administer an initial membership survey to describe the specialty crop growers that are members of Tilth Alliance. Compile survey data to inform and adjust programming focus topics for specialty crop producers. Administer a similar survey at the project's conclusion, and evaluate the effectiveness of educational programming.**

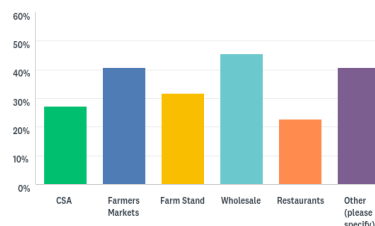
A membership survey was conducted near the project's start, concluding in April 2016. Specialty crop producers constituted 85% of survey respondents in 2016, up from an estimated 75% in 2015 when the project proposal was written. The initial survey also highlighted membership demographics and educational priorities for growers.

At the project's conclusion a similar survey was administered, concluding in September 2018. Specialty crop producers constituted 81% of respondents to this survey, including 74% vegetable, 61% tree fruit, 65% berry, 13% ornamentals, and 8% nut production. The majority of respondents were between the ages of 35 and 54. Respondents averaged 25 acres in production, with 10 acres certified organic and 11 acres in transition or managed organically. Participants were asked whether they own or lease farmland, and of those who responded over 80% owned land and the remainder leased either independently or through an incubator program. Gross farm income ranged from less than \$5K to over \$150K, and respondent marketing strategies were diverse (see charts below).

What was your total gross farm income for all agricultural products in 2017?



How do you sell your products? Check all that apply.



Another focus of the project-end survey was to evaluate the effectiveness and impact of educational programs. Participants were asked which SCBG-funded Tilth Alliance programs they had attended in the past three years (during the life of the project). Of survey respondents, 85% had attended a Tilth Conference, 58% had attended at least one Farm Walk, and 7% had attended a farm tour in the past three years. None had attended the one-day university. Overall, 69% of respondents who had attended at least one educational event indicated that knowledge gained had led them to expand or improve their use of organic or sustainable production practices. Of those, 78% said they had learned something at the conference that led them to modify their practices (61% of conference attendee respondents), 39% said they had learned something at a Farm Walk that led them to modify their practices (50% of Farm Walk attendee respondents), and 5% said they had learned something at a farm tour that led them to modify their practices (50% of farm tour attendee respondents). The survey also asked participants whether knowledge gained had led to any increase in farm business income. Only 17% of respondents answered “yes,” despite the near 70% who had indicated making changes to their operations, presumably in the interest of increased financial, social, and/or environmental sustainability. More detailed questions related to the long-term impacts of education on farm business income would be useful.

- **Submit reports to WSDA.**

Quarterly and annual reports have been submitted to WSDA. This final report will conclude project reporting activities.

Key project partners were members of the WSU Food Systems Team, who participated in Farm Walks as co-organizers and guest experts, and who contributed conference workshop presentations. A broader Farm Programming Committee also contributed suggestions and feedback for programming, and consisted of farmers and additional stakeholders from agricultural organizations, the WSDA Organic Program, and other public and private entities. Overall, more than 80 Washington specialty crop producers, researchers, and agricultural experts served as presenters, speakers, and Farm Walk hosts for educational events. This included both organic and non-organic specialty crop producers, representatives of NRCS, WSDA, conservation districts, WSU and OSU agricultural research and extension experts, and private agricultural consultants.

All project activities were geared towards specialty crop growers, and no information or resources regarding non-specialty crops were produced or disseminated as a part of this project. As much as possible, educational events were identified as specialty crop focused in outreach materials, with the WSDA Specialty Crop Block Grant Program logo used on publicity and outreach materials as well. Survey data indicate that the majority of the Tilth audience are specialty crop growers or interested in specialty crop production. Because Tilth Alliance events are open to all, however, not all attendees are necessarily active specialty crop producers. To ensure that SCBG funding was used solely to enhance the competitiveness of specialty crops, both Farm Walks and the Tilth Conference have registration fees intended to ensure attendance of those who register (in the case of the nominal fees charged for Farm Walks) and to support the cost of programming (in the case of Tilth Conference registration). Program income and match directly helps to underwrite non-specialty crop growers who may have attended educational events.

Goals and Outcomes Achieved

The project's original proposed goals, targets, benchmarks, and performance measures are listed below, and relevant completed project activities are listed under each.

Expected Measurable Outcome 1

Goal: Increase the number of organic or sustainable specialty crop growers in Washington.

Target: A 10% increase in Tilth Producers members that are specialty crop growers.

Benchmark: Tilth Producers currently has 500 members with an estimated 75% producing specialty crops.

Performance Measure: A survey of current members will be performed at the beginning of the grant period for the purpose of creating a member directory. This survey will also establish the baseline number of Tilth Producers members producing specialty crops. A second survey at the end of 2017 will determine final measures.

Completed activities:

- Conduct a membership survey at the project's commencement assessing specialty crop grower membership demographics and priorities.
- Conduct a similar survey at the project's conclusion, also assessing educational program impacts.

Expected Measurable Outcome 2

Goal: Increase grower knowledge of organic and/or sustainable production methods.

Target: It is estimated that 75% of growers who attend educational programs will increase or advance their existing use of organic and sustainable production practices.

Benchmark: This project aims to reach a total of 750 beginning and experienced small-scale specialty crop growers, agricultural students and interns, and agricultural professionals that will attend the educational programs and utilize the online resources offered by Tilth Producers during the grant period.

Performance Measure: Assessment of knowledge learned will be performed through individual program evaluations. Anecdotal evidence of program success will be collected through community roundtables focused on education at each annual conference (total of three during grant period).

Completed activities:

- Plan and implement a total of 12 Farm Walks focused on organic and sustainable production practices.
- Plan and implement a total of 30 specialty crop focused workshops at the annual Tilth Conference.
- Plan and implement a total of 3 specialty crop focused all-day farm tours to take place during the annual Tilth Conference.
- Convene a total of 3 community roundtables at the annual Tilth Conference to collect anecdotal evidence regarding the efficacy of educational programs for specialty crop growers.
- Plan and implement 1 one-day universities and five conference workshops focused on non-production topics.
- Conduct evaluations of educational events and programs.
- Post resources, audio, and other educational materials to the Tilth Alliance website.
- Administer a survey at the project's conclusion and evaluate the effectiveness and impact of educational programming.



Expected Measurable Outcome 3

Goal: Increase financial viability of specialty crop growers utilizing organic and/or sustainable production methods.

Target: A minimum of 30% of all grower participants indicate they have realized direct income benefits from attending Tilth Producers educational opportunities and/or using online resources.

Benchmark: Based on results from a Tilth Producers survey conducted on the educational needs of specialty crop growers, it is known that one-half of respondents gross under \$25,000 per year.

Performance Measure: A survey of participants from specialty crop programs will be completed in March 2018 to measure the income benefits growers have gained from educational opportunities during the grant period.

Completed activities:

- Plan and implement a total of 12 Farm Walks focused on organic and sustainable production practices.
- Plan and implement a total of 30 specialty crop focused workshops at the annual Tilth Conference.
- Plan and implement a total of 3 specialty crop focused all-day farm tours to take place during the annual Tilth Conference.
- Convene a total of 3 community roundtables at the annual Tilth Conference to collect anecdotal evidence regarding the efficacy of educational programs for specialty crop growers.

- Plan and implement 1 one-day universities and five conference workshops focused on non-production topics.
- Conduct evaluations of educational events and programs.
- Post resources, audio, and other educational materials to the Tilth Alliance website.
- Administer a survey at the project's conclusion and evaluate the effectiveness and impact of educational programming.

The outcomes of the project were subject to the grant timeline.

Project activity and Expected Measurable Outcome targets and actual achieved numbers are listed here.

Description	Target Number	Actual Number	Percent of Target Achieved
Activities			
Survey of members and participants assessing specialty crop grower composition, priorities, and impact of educational programs, results compiled, reported, and takeaways implemented in future programming as applicable	2	2	100%
Farm Walks focused on organic and sustainable production practices	12	12	100%
Specialty crop focused workshops at annual conference	30	30	100%
Specialty crop focused all-day farm tours at annual conference	3	3	100%
Community roundtables at annual conference to collect anecdotal evidence regarding the efficacy of educational programs for specialty crop producers	3	3	100%
One-day universities in different regions of the state	3	1 + 5 conference workshops	33% + extra
Written summaries of each event and resources, audio, and other educational materials posted to website and <i>Tilth Producers Quarterly</i>	N/A	Summaries through 2016, comprehensive posting of resources	N/A
Submit reports to WSDA	12	12	100%
Goals			
<i>1. Increase the number of organic or sustainable specialty crop growers in Washington: increase in Tilth Alliance members who are specialty crop growers</i>			
Percentage of participants*	+ 10%	+ 6-10%	60-100%
Number of growers	412	607	147%

2. <i>Increase grower knowledge of organic and/or sustainable production methods: growers who attend educational programs increase or advance their existing use of organic and sustainable production practices.</i>			
Percentage of participants*	75%	69%**	92%
Number of growers	562	1,057	188%
3. <i>Increase financial viability of specialty crop growers utilizing organic and/or sustainable production methods: grower participants indicate they have realized direct income benefits from attending Tilth Producers educational opportunities and/or using online resources.</i>			
Percentage of participants*	30%	17%	57%
Number of growers	225	249	111%

* The project proposal describes estimates for number of growers reached by programming as well as the percentage of grower participants who are expected to make changes to their operation or realize economic benefits to their operations as a result of programming. Now, at the project's conclusion, actual attendance and survey responses can be used to calculate the estimated number of growers impacted by programming. While **number of growers impacted is ultimately the result of interest**, the target and actual percentage reached/impacted is also included in this section for comparison's sake, to better-explain results, and to identify areas of strength and room for improvement. These aspects of the project results are discussed in the Lessons Learned section of this report.

** Calculations for Expected Measurable Outcome 2 are based on 2018 survey responses. However, because of the detailed evaluation data collected at individual educational events as well as the detailed survey questions asked, more than one possible estimate of the percentage of growers impacted by programming is available.

	Day-of evaluations		2018 survey
	Increased knowledge	Intended to make a change to operation	Did make a change to operation
Farm Walks	98%	65%	50%
Conference workshops	77%	71%	78%
Overall			69%

Expected Measurable Outcome 1

Goal: an increase of 10% in Tilth members who are specialty growers, from 375 to 412.

Calculation of goal: 500 member baseline (per proposal) x 75% = 375 specialty crop grower baseline.
 $375 + 10\% = 412$ members who are specialty crop growers.

Actual: an increase of 6-10% in Tilth community members who are specialty crop growers, to 607.

Calculation of actual: with the merger and transition from Tilth Producers to Tilth Alliance, the organization's approach to membership changed, so directly comparing membership numbers from 2015 to 2018 is no longer a useful measure. The size of the organization's farmer-facing listserv may be used as a proxy, however, as the listserv was inherited from Tilth Producers, and has grown from

approximately 4,000 to over 6,000 over the life of this project, thus a roughly 50% increase in farmer audience. Baseline specialty crop member/audience of 500 x 50% growth in overall farmer audience = 750 membership equivalent. Membership equivalent of 750 x 81% specialty crop growers (per 2018 survey) = **607** member equivalents who are specialty crop growers.

Note that although the 2016 membership survey showed that 85% of respondents were specialty crop growers (meeting the goal of a 10% increase), in 2018 only 81% of respondents were specialty crop growers. This decline is attributed not to loss of specialty crop growers but to increased gains in other areas, such as livestock producers. The 81% value from 2018 is used in all calculations of percentage of participants who are specialty crop growers over the duration of the project, which may result in a slight underestimation of total specialty crop producers since the percentage was slightly higher early in the project.

Expected Measurable Outcome 2

Goal: 562 growers increase or advance their existing use of organic and sustainable production practices.

Calculation of goal: it is estimated that educational programming will reach 750 growers and that 75% of those will increase or advance their practices. $750 \times 75\% = 562$.

Actual: an estimated 1,057 specialty crop growers improved their organic or sustainable production practices.

Calculation of actual: estimates are based on the actual number of attendees at educational events, and the percentage of attendees who reported making changes to their practices as a result of attending educational events in the end-of-project survey. Detailed calculations are explained below.

Farm Walks: over the three project years, a total of 271 people attended Farm Walks. While it is possible that some individuals may have attended multiple Farm Walks, the number of double counts is assumed to be negligible since the events were held at different locations around the state and focused on different topics. Due to the subject of the Farm Walks the vast majority of farmer attendees are expected to be specialty crop growers. However, events do also attract students and other agricultural professionals, and so in order to avoid overestimation and for consistency's sake an estimation of 81% specialty crop grower attendees (based on the 2018 survey) is used throughout. Thus of the 271 Farm Walk attendees, 220 are estimated to have been specialty crop growers ($271 \times 81\%$). In the 2018 survey 50% of Farm Walk attendees indicated that knowledge gained had caused them to make a change to their own production practices, thus **110** Farm Walk attendees ($220 \times 50\%$) are estimated to have improved their production practices as a result of project activities.

Conference workshops: it is highly likely that the same individuals attended multiple conference workshops, so the use of individual workshop attendance numbers would certainly result in double counting. Therefore overall conference attendance and the percentage of specialty crop growers in the Tilth community is used for calculation instead, with the assumption that all specialty crop growers attending the conference attended at least one specialty crop-focused workshop. Although some repeat attendance between conferences is likely, this number is minimized due to the different conference locations (Spokane, Wenatchee, Vancouver). Additionally, if a grower learned and implemented a new practice in 2015, then learned and implemented something different in 2017, these two changes in behavior should be considered separately. The three conferences included in this project brought in a

combined total of 1,430 attendees, 1,158 of whom are estimated to have been specialty crop growers (1,430 x 81%). In the 2018 survey 78% of conference attendees indicated that knowledge gained had caused them to make a change to their own production practices, thus **903** conference workshop attendees (1,158 x 78%) are estimated to have improved their production practices as a result of project activities.

Farm tours: over the three project years, all-day farm tours saw a combined total attendance of 108 individuals, 87 of whom are estimated to have been specialty crop producers (108 x 81%). In the 2018 survey, 50% of farm tour attendees indicated that knowledge gained had caused them to make a change to their own production practices, thus **44** farm tour attendees (87 x 50%) are estimated to have improved their production practices as a result of project activities.

One-day university: because no one-day university attendees responded to the 2018 survey, that event is not included in these calculations.

The combined total from Farm Walks, conference workshops, and all-day farm tours is therefore **1,057** (110 + 903 + 44) specialty crop growers who are estimated to have improved their organic or sustainable production practices as a result of project activities.

Note that while the above calculations were deemed to be the most accurate and utilize the best available data, there are also other ways in which grower change in behavior could be estimated, which yield similar results. For instance, day-of evaluation responses indicating intent to change behavior could be used instead of the 2018 survey response data, which yields $[(220 \times 65\%) + (1158 \times 71\%) + (87 \times 50\%)] = 1,009$. Or, the overall 2018 survey result of 69% of respondents who report having changed their behavior in response to educational programming could be used, which yields $[(220 + 1158 + 87) \times 69\%] = 1,011$.

Note also that 4% of 2018 survey respondents indicated having changed their behavior as a result of online resources made available through the Tilth Alliance website and/or email newsletter, but that these are omitted from calculations because there is not a straightforward way to estimate the number of people accessing such a broad array of resources.

Expected Measurable Outcome 3

Goal: 225 specialty crop growers realize income benefits.

Calculation of goal: it is estimated that educational and online programming will reach 750 growers and that 30% of those will realize economic benefits as a result. $750 \times 30\% = 225$.

Actual: an estimated 249 specialty crop growers realized economic benefits as a result of project activities.

Calculation of actual: using total number of specialty crop growers reached by programming as calculated under Expected Measurable Outcome 2 above ($220 + 1,158 + 87 = 1,447$) and the 17% of 2018 survey respondents who indicated that they had realized economic benefit as a result of participating in project educational programming, it is estimated that a total of **249** specialty crop growers realized economic benefits as a result of this project $[(220 + 1,158 + 87) \times 17\%]$.

Beneficiaries

Beneficiaries of this project are Washington specialty crop growers, predominantly with small- or mid-sized farm operations, who attended educational events or accessed online resources in order to expand their knowledge of organic and/or sustainable specialty crop production and business practices.

Total number of project beneficiaries (specialty crop growers who participated in educational programming offered under this project, not including those who accessed online resources):

$$220 + 1,158 + 87 = \mathbf{1,447}$$

Number of specialty crop growers who increased their knowledge:

$$(220 \times 98\%) + (1,158 \times 77\%) + (87 \times 50\%) = \mathbf{1,151}$$

Number of specialty crop growers who improved their practices:

$$(220 \times 50\%) + (1,158 \times 78\%) + (87 \times 50\%) = \mathbf{1,057}$$

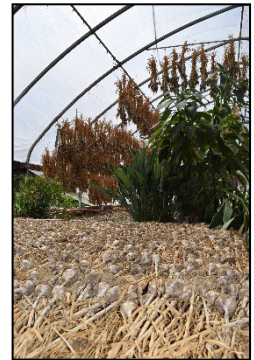
Number of specialty crop growers who improved their economic performance:

$$(220 + 1,158 + 87) \times 17\% = \mathbf{249}$$

Lessons Learned

Positive Results of Project

- Over the course of this project Farm Walks have emerged as an exceptionally valuable educational format. Because each Farm Walk is unique, there is great opportunity to adapt to grower needs and topics of interest, and to reach out to and engage with farmers (both as hosts and attendees) across the state and across diverse production systems. Farm Walks also offer an excellent platform for engaging subject matter experts from universities and agencies, while maintaining a primary focus on peer-to-peer learning. Beyond the primary educational opportunities, the somewhat informal format of Farm Walks provides an excellent networking opportunity among growers and between growers and other agricultural professionals, which in turn helps to strengthen and ensure a resilient small-scale organic and sustainable specialty crop industry in Washington.
- Tilth Conference workshops emerged as a particularly effective format for the dissemination of actionable information related to organic and sustainable specialty crop production and marketing, based on attendance and evaluation and survey responses. The Tilth Conference overall also emerged as a valuable opportunity for grower networking.
- Farm tours provide a different learning format from either conference workshops or Farm Walks, and a good way to provide access to multiple operations by a large number of attendees in a fairly short period of time. The format also lends itself to detailed prior planning of topics and concepts to be covered, such that farm tours provide an excellent way to tailor content to the needs of the community.
- The in-person interactions and feedback gathered through community roundtables has been extremely valuable, and is something that Tilth Alliance will seek to continue in future years.



Negative Results of Project

- The one-day university model was not successful, generating low attendance numbers and appearing to have been a poor pairing of format and content. This has generated productive brainstorming around more cohesive program formats and strategies to entice growers to attend educational events focused on ‘dry’ subjects such as finance or food safety.
- Feedback indicated a lack of interest in event summaries published online or in print. This result will be incorporated into future programming and dissemination of information, where the focus will be more sharply on dissemination of useful resources, minimizing non-actionable summary information.

Neutral Results of Project

- There is demand among growers for increased numbers of educational events such as Farm Walks in both Western and Eastern Washington. Development and implementation of these events requires a significant amount of time and travel by project staff, and to increase the number of events would require additional time and travel.
- Outreach requires almost as much staff time as the planning of content and logistics for educational events, and is a critical component of success. The effectiveness of events is directly related to the number of farmers in attendance and the number and quality of those who participate as hosts and experts. The time and expertise required to perform adequate outreach to ensure successful educational events should be kept in mind in the planning of future activities.
- Anecdotal feedback suggests that although conference audio recordings plus slides are useful, video recordings of workshops would be much more useful (easily viewed and used) for growers. Tilth Alliance plans to incorporate video recording of conference workshops in future years.

Areas of Strength and Room for Improvement

- Results of this project show Tilth Alliance’s greatest strengths in providing education for specialty crop growers to be Farm Walks and the Tilth Conference (including workshops and farm tours). These programs are strong in terms of attendance and impact on behavioral change, and based on anecdotal feedback are also highly valued by the grower community for the opportunity they provide to learn from peers as well as experts and to network.
- Educational programming was effective in causing behavioral change, with 69% of participants overall reporting having made a change based on what they learned. Interestingly, response rates for conference workshops were quite consistent between attendees’ increase in knowledge, intent to make a change, and actually having made a change (all in the range of 71-78%), suggesting that knowledge gained was directly translatable into changes in behavior. Conversely, Farm Walk attendees gave remarkably positive responses to knowledge increase (98%), but lower positive responses to intent to make a change (65%), and lower still for actually having made a change (50%). While half of Farm Walk attendees reporting having made a change to their operations based on what they learned is still an encouraging and quite positive rate of behavioral change, this result also highlights a potential area of improvement for Farm Walk programming. It is possible that a more explicit focus on the dissemination of actionable and practical information as



part of Farm Walk content could improve the percentage of future attendees who leverage knowledge gained into making improvements on their own operations.

- The *percentage* of participants impacted was somewhat lower than projected (57-92% of expectation), but the total *number* of growers reached was much greater than projected (193% of expectation). That is, expectations were exceeded in the number of specialty crop growers engaged, but not as high a percentage of participants as expected reported changes as a result of knowledge gained. The combined result was that the project exceeded expectations (111-188% of goal) for growers who reported making changes or experiencing economic improvements as a result of educational programming. The results suggest that Tilth Alliance is stronger than anticipated in reaching specialty crop growers, but that there is room to improve the actionable impact of some programs.
- The percentage of growers reporting economic benefit was unexpectedly low (17%), and stands in clear contrast to the percentage of growers reporting having changed their practices (69%). These metrics combined indicate that of growers who changed their practices as a result of educational programming, only 22% saw economic benefits, and the other 78% either anticipated but did not realize economic benefits, or made changes that were not intended to improve financial performance. In the future, more detailed questions could reveal which of these outcomes is most prevalent. It seems unusual that such a large percentage of growers would choose to make changes not expected to improve financial performance even indirectly, and calls into question whether growers had fully considered the possibilities of indirect as well as direct financial benefits in responding to the survey. More detailed questions could address this concern in the future.

Collaboration with the WSU Food System Team on two bilingual English-Spanish Farm Walks in 2018 afforded project staff the opportunity to learn about effective outreach strategies for reaching non-native English speakers and the resources required to deliver programming to these populations.

All Expected Measurable outcomes goals were exceeded, with performance at 147%, 188%, and 111% of goal for Expected Measurable Outcomes 1, 2, and 3, respectively. All project activities were completed at 100% of goal, with the exception of the one-day universities, where only 1 of 3 was held and alternate programming was implemented to take the place of the remaining 2.

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Additional Information

Total match: \$80,335

- Total cash match: \$62,711
 - Conference sponsorships: \$33,725 (underwrite overall conference event costs and workshop logistics, and ensure affordable registration fees)
 - Charlie's Produce: \$2,000
 - Pike Place Market: \$1,750
 - Viva Teirra Organics: \$1,500
 - State and local entities: \$6,000
 - Other organizations and foundations: \$22,475
 - Tilth Alliance unrecovered indirect costs: \$28,986 (est. as 20% of project funds expended).
- Total in-kind match: \$17,624

- Tilth Alliance salaries and wages: \$15,104 (Bookkeeper/Finance Director, Administrative Assistant/Registrar, Member Services Coordinator working in support of the project).
- Communications: \$2,520 (attributable portion of website and telephone/internet fees, est. at \$70/mo).

Note: members of the WSU Food Systems Team contributed to the planning, marketing, and delivery of Farm Walks (both as co-organizers and subject matter experts), served in an advisory capacity on the farm programming committee, and contributed workshops at the annual conference. It is estimated



that over 300 hours were contributed to project activities, although an in-kind matching value is not assigned to this contribution.



Project Title: Expanding and enhancing the experience farming project

Project Summary

The high costs associated with purchasing or leasing farm land and farm equipment can be prohibitive for new farmers and lead to many new farms failing within the first few years. SnoValley Tilth (SVT), a non-profit organization that supports organic and sustainable food production practices, has started the Experience Farming Project (EFP) to address this problem in their service area. The EFP provides aspiring farmers with an opportunity to gain valuable hands-on experience while independently growing specialty crops on a plot of land at Stuart Landing, which is located on the edge of the Snoqualmie river just outside of Carnation. Project participants receive a cover-cropped and tilled plot of land, initial tractor work, access to a wash station and dry storage, and are matched with an experienced farmer mentor. Due to the location of the farmland and the size of the available farming plots, project participants are limited to growing specialty crops, as defined by the USDA.

Program participants are able to test their business and production models, establish their farm name and customer base, and get to know the growing conditions in the Snoqualmie Valley. At the end of their time in the program (typically 5 years) they are prepared to buy or lease land and have valuable years of farming experience, which helps them qualify for loans. Participants also build relationships with the other farmers on the site as well as experienced farmers in the SVT network. This positions them to be successful in a business that requires collaboration and cooperation among fellow farmers.

Building a robust, sustainable food system entails ensuring that new farmers are able to begin and grow successful farm businesses. The EFP program gives new farmers the opportunity to establish their businesses before taking on the significant debt associated with leasing or purchasing their own land and equipment. It also provides access to land and shared infrastructure in a the most populated county in Washington, well known for very high property prices and limited access to land. By providing initial support for new farmers on land in the Snoqualmie and Snohomish Valleys, this project was intended to increase the number of successful farm businesses growing specialty crops in Washington.

At the time of this grant application, all spots were filled at Stuart Landing yet there were interested farmer participants and several landowners offering to make their land available to expand the program. In addition, the farmers at Stuart Landing are limited in how and when they bring their specialty crops to market due to lack of irrigation and cold storage. SnoValley Tilth wanted to expand the program to respond to farmer demand by 1) paying a farm manager to coordinate outreach events and work with additional landowners to establish lease agreements to expand the program, including finding larger parcels for graduates to move onto and 2) establishing infrastructure at existing and future sites that facilitate and increase production.

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

Project Approach

The activities performed and tasks achieved are summarized below, divided by the two objectives for the program.

Objective 1: Expand production capacity at Stuart Landing (the first EFP site and the only one when the proposal was written).

Built a mobile cooler and second wash station to expand market options and reduce scheduling

conflicts for participants.

Improved the road to the site to allow vehicles to access the farm earlier in the spring and later in the fall.

Unexpected: both of these projects sounded fairly simple when the proposal was written in 2015. What quickly became clear is that SVT had made some assumptions about the readiness of the site for these projects. With the cooler, it turned out that the lease did not include access to adequate electricity to run the cooler. For the road, a portion of the improvements involved a bridge on which SVT wanted to put new timbers to replace rotten ones and add a raised side for safety. This turned out to require multiple permits and field visits with two different regulatory agencies. For both of these projects SVT secured a second grant which covered the costs for these initial steps to get completed. But as a result, the completion dates for these tasks were significantly delayed.

Objective 2: Expand EFP with a second site and more participants.

Negotiated a lease with a new landowner, prepared soil with cover crop, tilling. Outreach to new farmers, record keeping on numbers of participants, growing practices, sales and production.

Results: SVT negotiated a lease with a landowner very interested in playing a part in launching new farm businesses. It has been rewarding for both the landowner and SVT to have their program expand to his site. It was easy to find participants to fill the new space, and they did some outreach through websites, fliers at community events, and field tours.

Unexpected: while it was easy to find participants interested in the program, there were some cases where the experience or commitment of the participants was not as high as needed for the program. One significant problem involved people abandoning their plots mid-way through the season (when weeds go to seed they impact other farmers' plots as well as adding to the seed bank for next season). Another issue was lack of respect for the other participants in the program. SVT realized that growing "in community" may not be the right fit for all personalities. As a result, they took a step back and revised policies for admission to the program *and* established policies for tilling in participant's plots if they were not being cared for, as well as adding a deposit for anyone not cleaning up their own trash in the fields.

While SnoValley Tilth did not have formal partners providing in-kind match to the project, they have worked closely with several partners over the past year. Both King County and King Conservation District have supported this work and use it as an example of a project working to shift the food system to have a stronger focus on locally produced and consumed specialty crop products. King Conservation District and King County staff provided guidance and insight into the permitting processes required for the bridge enhancements. SnoValley Tilth has also begun meeting with Tilth Alliance and SAGE/VIVA - the other two farm incubator programs in King County. Together they will define best practices and identify how to support all three efforts and the three organizations were jointly awarded a grant to continue this work.

The Experience Farming Project supports farmers growing exclusively specialty crops (mixed produce, culinary herbs).

Goals and Outcomes Achieved

Goal: Increase production capacity for specialty crop farmers participating the EFP Pilot at Stuart Landing
Activities: build a mobile cooler, spread gravel to improve road access. These infrastructure improvements were intended to expand market options and harvest timelines (cooler) and extend the seasonal access to the site (road access). Both of these should lead to higher sales for farmers.

Goal: Expand EFP to increase the number of new specialty crop farmers

Activities: outreach to new participants, share information about the program through our networks. Track the participants in the program and any on a waiting list if space is full.

Goal: Expand the number of farm sites for specialty crop farming through EFP

Activities: identify and lease a second site for the EFP. Identify other landowners interested in leasing to farmers.

When the proposal was written, SnoValley Tilth expected all of the Measurable Outcomes to be completed during the timeline of the grant. While this was true for the most part, the delays on the road and cooler installation meant that the effectiveness of these infrastructure improvements could not be measured during the grant period. With these now in place, SVT will continue tracking participant sales and crop diversity, to understand any impact these improvements are having.

Established Activities and Goals	Actual Accomplishments
Construct and install a mobile cooler at Stuart Landing	Built one mobile cooler at Stuart Landing in Feb/March 2018.
Recruit new landowners	Leased one new site for expanding the program.
Finalize lease agreements with new landowners	Leased with new landowner in 2016, 2017, and 2018
Recruit and screen new farmers	Screened over 12 farmer participants for the years of the project.
Finalize contracts with new EFP participants	19 different participants leased plots in EFP over the course of the grant. With between 7-10 participants each year.
Acquire and spread gravel on the access road at Stuart Landing	Completed in March, 2018.
Coordinating and preparing new EFP sites for growing season (tractor work, cover cropping)	Between 3-6 acres was tilled and cover cropped in 2016 and 2017 at the new site.
Project management support (field record keeping, overseeing participant practices)	Completed in 2015, 2016, and 2017.
Communication with landowners	Part of the program manager's role all years.
Development of EFP outreach materials (print and electronic) for distribution at Tilth events, farmers markets, KCD events, Extension	This activity received limited attention because SVT had plenty of farmers interested in the program with very little

offices, and colleges and universities	
Implementation of outreach events	Two field tours were held in 2017, promoting to potential participants, landowners, and program partners. One outreach event was held in early 2018 with a focus on landowners who might be
Data collection and reporting on EFP sales and production	Completed for 2015, 2016, and 2017. Questions being revised for 2018.
Data collection and reporting on EFP participant farmers, landowners, and graduates	Completed for 2015, 2016, and 2017.

Goal: Increase production capacity for specialty crop farmers participating the EFP Pilot at Stuart
Landing Data: Sales data was used as a way to measure increases in production capacity.

Year	Gross Sales	Average Sales
2015	\$23,900	\$7,966.67
2016	\$43,700	\$7,283.33
2017	\$80,000	\$16,000

Results: The target was 25% increases each year. Looking at average numbers (to account for different numbers of farmers each year) this did not happen between 2015-2016, but participants saw more than a 100% increase in sales from 2016-2017. This was partly due to better tracking, participant selection, and mentoring support systems in place as a result of the funding under this project. SVT anticipates continued increases from 2017-2018 as the cooler is available for farmer use and the road and bridge improvements are finally complete.

Goal: Expand EFP to increase the number of new specialty crop farmers
Data: Track number of participants in the program

Year	Number of Participants
2015	7
2016	9
2017	10
2018	10
<i>Unique participants all years</i>	<i>19</i>

Results: The target was a total of 28 unique participants across the two EFP sites and the result was 19. While this is lower than planned for, it turned out to be the maximum capacity for the program staff, available land, and shared infrastructure available to the program. The program was essentially filled to capacity each year and SVT has developed a system for application review to encourage early applications and allow for review of all applicants as a group, thereby moving towards selecting a more qualified pool of participants each year.

Goal: Expand the number of farm sites for specialty crop farming through EFP Data: Track acres leased in the program each year

Year	Total acreage sub-leased to participants
2015	5.25
2016	5.5
2017	5.88
2018	6.5

Results: The target was twofold: 1. Expand to a second EFP site and 2. to identify larger parcels of land where farmers could lease 2-10 acre plots. SVT added a second EFP site in 2016 which successfully expanded the number of participants they could accept. This only slightly increased the number of acres in increased production. For the larger parcels, SVT has helped several of the graduating participants find land to lease with landowners in the area. The original vision of SVT leasing more acreage to sublease as larger parcels was set aside in the interest of helping farmers make direct leases with landowners. SVT has since launched the Farmland Network and is a partner on the regional Working Farmland Partnership, both projects with the explicit goal of finding acreage for farmers seeking farmland, working to remove barriers to accessing that land, and helping negotiate leases as desired.

Beneficiaries

The beneficiaries of this project were the 19 Specialty Crop farmers who were able to test their business models, expand their growing skills, and launch their farm businesses on the two sites. With the new infrastructure and expanded space, SVT was able to provide access to more farmers and a better farming experience. Additional beneficiaries were the customers of these farmers who had access to fresh, local produce. Customers included farmers market shoppers, CSA purchasers, restaurants, and a cooperative wholesale aggregator.

There were 19 farmers total who benefited directly across the span of the project. While SVT did not track individual market numbers, each farmer had many outlets including farmers markets and CSAs, which are ways to reach a lot of individual consumers.

In 2017 participants sold a cumulative \$80,000 of Specialty Crops. While this amount is not as high as could have been hoped, it is nearly double from 2016 and over three times the amount sold in 2015. In 2017 three of the participants sold \$20,000 or more in Specialty Crops each.

As SnoValley Tilth continues to implement some of the lessons learned throughout the project (e.g. participant selection) and participants have the opportunity to benefit from the infrastructure improvements, there will be a greater increase in income in future years.

Lessons Learned

The Experience Farming Project is greatly valued by participants. End of year survey responses included the following comments:

“Thanks so much for all your support this year! I couldn't do it without EFP.” “I am looking forward to being a participant again next year!”

“EFP is a fantastic program and a great way for people to have access to acreage in King County to grow, sell, learn and socialize!! Looking forward to developing my farm plan this winter and diversifying in 2017!!”
“Thanks for creating a program where I can learn from other participants – I love being in close proximity to other farmers.”

- SVT underestimated the time it would take to complete infrastructure improvements. In addition, SVT underestimated the amount of work managing two sites would take. As a result, the single staff person was barely enough and was certainly not enough to focus on adding sites for 2-10 acre plots.

- The program needs a certain level of formality to function successfully. When SVT first started the EFP it was a fairly simple sub-lease agreement. Now they have a handbook, in its second revision, that lays out all the policies and requirements for the program.

Conclusion: There is demand for programs like this which primarily offer access to land to new farm businesses, as well as shared infrastructure and equipment. The landscape is still evolving for these types of shared spaces for more established farmers, but there are certainly some opportunities/demand there as well. The past three years were one of much growth and expansion for the EFP program. While there were growing pains and lessons learned, overall the program is stronger and continues to meet the needs of even more specialty crop farmers each season. The funding from the Specialty Crop Block Grant program played a significant role in SVT's ability to develop, improve, and expand this program.

When SnoValley Tilth started this project they were very focused on the Experience Farming Project and moving it to the next level. With the support of the Specialty Crop Block Grant they were able to do that successfully. Unexpectedly, this opportunity also led to a related new program area as well as new regional partnerships.

As the first set of EFP participants near the end of their 5-year tenure, SVT found it is difficult for them to find appropriately sized property in good farming condition that is available to lease or buy nearby. SVT has begun to take an active role in connecting landowners and farmers and is very excited to see this project grow in 2018. As they have expanded this programming, other organizations in the region have also increased their focus on connecting landowners and farmers. As a result, a partnership of agencies and organizations has formed to convert “farmable but unfarmed” land into actively farmed parcels.

In addition, in 2017 SnoValley Tilth partnered on a grant with two other area non-profits that will continue and expand on the work of this Specialty Crop Block Grant. This grant builds a partnership of the three farmer incubator programs in King County. Together the three organizations are sharing knowledge and best practices, creating opportunities for participants to learn from each program, and have already begun improving their internal systems to best serve farmer needs.

While progress was made on all goals and activities, there were some important lessons learned.

1. Add additional time to all construction project estimates. Make sure all the background pieces are in place before committing to a timeline.
2. It is important to have a structured program to encourage qualified, reliable participants.

Contact Person

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Additional Information

Supplies and Equipment - \$2,500 (tractor maintenance and fuel, cover crop seed, water rights).

Site leases -\$11,700

SVT Executive Director (project and grants management): 0.06 time = \$3,250

SVT Farm Program Manager (project implementation): 0.5 time = \$20,800

2017 Supplies and Equipment - \$7,100 (tractor maintenance and fuel, cover crop seed, tractor implement rental, water rights).

Power Installation - \$10,000

Site leases - \$8,800

SVT Executive Director (project and grants management): 0.06 time = \$3,250

SVT Farm Program Manager (project implementation): 0.5 time = \$20,800

Total Cash Match: \$88,200 Provide any additional information available (i.e. publications, websites, photographs) that was not applicable to any of the prior sections.

- SVT's website with information about the program and related projects:
<http://www.snovalleytilth.org/experience-farming-project/>.
- The Experience Farming Project was the focus of a story in 425 Magazine in October of 2017. A .pdf of that article was provided along with this final report.

Photo of wash station at Stuart Landing:



Field tour of Experience Farming Project:



Program participants at expansion site:



EFP Participants with a shared booth at the Carnation Farmers Market:



Invitation to Open House in September 2017:



Project Title: Farmworker pesticide education expansion

Project Summary

Off target pesticide spray application and pesticide spray drift that results in human exposure is an issue of immediate concern in Washington State and has triggered an ongoing policy discussion involving legislators, regulating agencies, labor advocates and the industry. Measures for mitigating and preventing the effects of drift are currently under consideration in the state legislature. While it is widely recognized that reduction of pesticide drift is a common goal, the measures under consideration seek to reduce drift from happening as well as prevent human exposure to pesticide drift. One of the most immediate and effective means of reducing off target application and drift is to increase the knowledge and skills of spray applicators in using their spray equipment, especially air-blast sprayers, with maximum precision.

The Washington State Department of Agriculture (WSDA) has approached the problem by creating a training program for pesticide applicators related to pesticide application equipment calibration and configuration to increase deposition and reduce drift according to plant/orchard characteristics. The Pesticide Application Equipment Best Management Practices training (BMPs) began operation in winter of 2015, and only 90 applicators have been trained so far. More pesticide applicators need this training now, and are unable to get it. This grant proposal included expanding capacity of the WSDA's existing programs including the Pesticide application Equipment – BMPs as well as the Handler Training and Worker Protection Standard (WPS) Train the Trainer (TtT) programs as the demand exceeds the capacity of the agency's Technical Services and Education Program.

WSDA's Handler training program has been operating since 1999 yet still regularly turns away potential students due to inadequate capacity. Surveys of applicators by the Farmworker Pesticide Education Program indicate that 60% of those surveyed have not yet attended a Hands-on Handler class.

The funds from this grant have helped the existing Farmworker Education Program serve additional farmworkers, farm supervisors and employers. In addition, the funds helped purchase new equipment to provide more training sessions. The equipment is unique to the agricultural industry and to the curriculum developed to training non-English speaking workers.

This project did not build on a previously funded Specialty Crop Block Grant Program project.

Project Approach

The funds from this grant have allowed WSDA to continue working with Washington State University (WSU) and many other industry partners on offering the Pesticide Application Equipment BMPs, the expansion of the Handler training and the WPS Train the Trainer programs. Table 1 below shows (in chronological order) the list of activities and the approach taken to the work plan commitments of this grant.

Table 1

Activity	Year/Time	Comments
Purchase of equipment and supplies	Winter 2015	To be used in the Pesticide Application Equipment – BMPs program
	Winter 2015-2016	Several items were purchased to be used during the BMPs workshops including: • Spray patternator to assess spray volumes at different tree heights • A Multi-channel flow meter unit • Several liquid measuring devices

		• Raw material to manufacture various instruments to facilitate the calibration and optimization of airblast sprayers • Portable weather stations • Electronic flow meter devices • Cargo trailer to transport equipment • Pressure gauge tester • Spray nozzles (different types and sizes) • Water sensitive paper • Personal protective equipment Note: many of the above mentioned items were purchased in quantities that would allow consecutive session (Spanish/English) to be done at the same time.
Hire a Professional Trainer	Spring 2016	As outlined in proposal, Alberto Hernández was hired in early Spring of 2016
Trainer development	Spring –Summer 2016	Handler Training Alberto attended a pesticide handler class conducted for employees of Jack Frost in Yakima. Several training sessions were conducted to get Alberto familiar with the Decontamination Module which is part of the handler training program.
	Summer 2016	Pesticide Application Equipment – BMPs for Educators this was conducted which allowed Alberto Hernandez and current staff to increase knowledge on Pesticide application equipment calibration and optimization. 22 people including educators, stakeholders and university staff were present.
	Winter 2016	Train Alberto as a certified trainer according to the Worker Protection Standard requirements and train him to be a trainer for WSDA's Worker Protection Standard (WPS) Train the Trainer program.
Preparation for 2017 training season	Fall 2016	Program manager contacted workshop sponsors, plan and scheduled events for 2017 training season.
Conducted training events	Winter-spring 2017	Conducted the following workshops: • 4 Pesticide Application Equipment – BMPs • 15 Handler training workshops • 11 Train the Trainer workshops
Curriculum review	Summer 2017	All training curriculums were modified based on lessons learned during the previous training season.
Orchard sprayer trials	Fall 2017	Three orchards sprayers were tested for spray coverage, deposition and off-target drift. This

		was done with the purpose to learn more about different sprayer, sprayer settings and capabilities as a preparation for the upcoming training season.
Purchase of additional equipment and supplies	Summer-fall 2017	Additional equipment was purchased based on curriculum modifications, lessons learned and replacement needs.
Preparation for 2018 training season	Fall 2017	Program manager contacted workshop sponsors, plan and scheduled events for 2018 training season.
Conducted training events	Winter-spring 2018	Conducted the following workshops: • 4 Pesticide Application Equipment – BMPs • 16 Handler training workshops • 10 Train the Trainer workshops
Request grant extension	Spring 2018	Requested a time extension in the grant to allow the purchase of additional equipment. No modification of the work plan were done to the project.
Purchase of additional equipment	Summer 2018	Additional training equipment and supplies were purchased to meet workshop needs.
End of project	September 29, 2018	Completion of end of the project report.

Contributions and roles of project partners

WSDA's Technical Services and Education Program worked with several partners. Although our partners, in general, share the same responsibilities, different training programs demand different commitments from them. For example, our Handler Training is an 8-hour program for which partners are only required to provide a facility for that particular amount of time; on the other hand, the WPS Train the Trainer program is a 2-day program and demands our partners to secure a facility for the two days. In general, our training partners are required to provide at least the following: 1) a suitable training facility (characteristics vary significantly based on the type of workshop); 2) recruitment of participants; and 3) meals and refreshments to participants.

Table 2

Partner(s)	Type of workshop	Number of workshops
G.S. Long Company	Application Equipment Calibration - BMPs	4
	Handler Training	11
Washington State Winegrowers	Application Equipment Calibration - BMPs	2
	Handler Training	1
	WPS Train the Trainer	3
Washington State Tree Fruit Association	WPS Train the Trainer	5
	Handler Training	1

Opportunities Industrialization Center	WPS Train the Trainer	3
Kershaw Farms	Handler Training	2
Gebbers Farms	Handler Training	2
Northwest Berry Co-op	Handler Training	1
	WPS Train the Trainer	1
WA WorkSource	WPS Train the Trainer	1
WA Potato Commission	WPS Train the Trainer	1
Zirkle Fruit Company	WPS Train the Trainer	1
Allan Brothers	WPS Train the Trainer	1
Apple King	WPS Train the Trainer	1
Red Raspberry Commission	Handler Training	1
Oregon State University	Handler Training	1
Washington Farm Bureau	Handler Training	1
Wilbur Ellis Company	Handler Training	1
Mt. Adams Orchards	Handler Training	1
Jack Frost Orchards	Handler Training	1

Other partners who supported this project are:

- TeeJet Technologies who donated 200 nozzle catalogues 30 sets of different spray nozzles and a Nozzle Pattern Unit.
- Advance Agricultural Measurement System (AAMS) facilitated the purchasing of equipment needed and provided technical assistance on how to use it.
- Universitat Politècnica de Catalunya, Spain sponsored a trainer from the European Union to teach equipment calibration.

All direct benefits of this project were for producers of specialty crops. Indirectly, the project benefited producers of non-labor-intensive crops such as potato growers by reducing pesticide drift that could damage their or their neighbors' crops. The project benefited a wide range of agricultural producers in Washington by educating pesticide applicators and handlers on how to lessen the drift problem and the resulting reduction in political and regulatory pressure to further restrict the use and application of pesticides. All workshop attendees were employed in the specialty crop industry and workshop content, equipment and exercises were focused exclusively on specialty crops.

Goals and Outcomes Achieved

Increase the number of pesticide applicators in Washington State who have completed advanced "hands-on" pesticide application safety and skills training. This will result in fewer applicator accidents and injuries, and in fewer applicator caused pesticide drift incidents.

WSDA's Technical Services and Education Program used the funds of this grant to expand its current courses related to the use of pesticide in agriculture including the Pesticide Application Equipment BMP's, Hands-on pesticide handler training, WPS Train the Trainer (TtT). From 2013 to 2015 the program averaged approximately 950 workshop participants. The budget proposed under this grant would fund 1 professional trainer, a project coordinator, travel expenses, and specialized equipment. The potential number of additional employers served through this program will be approximately 150. The

additional funds to expand the training will train 240 new workers; offer 4 additional Pesticide Application Equipment BMP's training sessions.

In FYs 2017 and 2018 this grant allowed the implementation of eight (8) Pesticide Application Equipment – BMPs courses attended by **303** farm workers and supervisors, and served **107** agricultural employers, that is a total of four (4) courses more than what was originally proposed for this project grant. The courses were offered in partnership with seven (7) organizations. Details of workshops can be found under this under “Training Events” in this section of the report.

Additionally, this grant supported the WPS Train the Trainer and Handler training programs by incorporating the professional trainer (hired under this grant) to the existing program team of trainers which allowed additional workshops to be offered and more farmworkers and trainers trained. The table below explains the number of workshops, partnerships and workers trained per year under these two programs.

Table 3

Type of workshop	Year	Number of workshops	Number of partners	Attendance	Employers served
Handler training	2016-2017	15	12	2,027	374
	2017-2018	16	17	2,286	387
WPS Train the Trainer	2016-2017	11	11	305	157
	2017-2018	10	9	250	150
Totals		31	49	4,868	1,068

Although the number of handler training workshops conducted in 2017 & 2018 is very similar to those conducted in 2016 and the position funded by this grant did not participate in every workshop, it allowed the program to conduct a higher number of larger handler training events resulting in a higher number of people trained and bigger number of employers served.

Below is a table of WSDA's training accomplishment for 2016 (for comparison purposes)

Table 4

Type of workshop	Year	Number of workshops	Number of partners	Attendance	Employers served
Handler Training	2015-2016	16	11	1,467	247
WPS Train the Trainer	2015-2016	4	4	110	40

Conclusions: A total of **560** additional pesticide handlers were trained FY 2017, and **819** in FY 2018 in comparison with the number of workers trained in FY 2016. A total of **1,379** additional pesticide handlers were trained and **267** additional agricultural employers were served in the two-year period with the support of this grant. Details of the Handler Training workshops conducted in this two-year period can be found in “Appendix A” of this report.

The funds of this grant allowed for a significant expansion of the WPS Train the Trainer program. As shown in tables 2 & 3, the yearly accomplishments were more significant when compared to FY 2016. An additional **343** trainers were trained and **227** employers were served in the two-year period with the support of this grant. Details of the Train the Trainer workshops are found in “Appendix B” of this report.

As shown in table 1 of this report, the funding for first year (2015-2016) was utilized to hire and train the professional trainer, acquire training equipment and supplies and work with training sponsors to organize additional training sessions. Therefore, the significant impact/results were shown in the two subsequent years (2017 & 2018). Note: table 4 of this report was included to serve as reference or base line only to see the accomplishments obtain by funding of this grant. This grant funding did not support any of the training accomplishments shown in table 4 of this report.

The actual achievements of the project have significantly exceeded the proposed goals of this project. See table below.

Table 5

Proposed goals	Project Achievements
Offer 4 Pesticide Application Equipment – BMPs workshops	8 Pesticide Application Equipment – BMPs Offered
Serve 150 employer	601 additional employers served • 107 in the BMPs • 267 in the Handler training • 227 in the WPS Train the Trainer
Train 240 workers	2,025 workers trained • 303 in BMPs • 1,379 in the Handler training • 343 in the WPS Train the Trainer

Training events

I. Pesticide Application Equipment - BMPs

This educational program was designed for individuals who operate and calibrate airblast sprayers. Participants were provided with information and instructions to develop the skills to calibrate and configure airblast sprayers for orchards and vineyards according to tree structure, canopy size, time of season in order to increase product deposition, and to reduce drift. Attendees gain hands-on experience by using actual application equipment during calibration exercises. This course is a combination of classroom field activities, is offered concurrently in English and Spanish, and included the following training modules

- Knowing your Equipment
- Airblast Sprayer Calibration
- Sprayer Configuration/optimization
- Environmental Conditions & New Technology

All of these workshops were conducted with SCBG funding. Workshop dates, locations and partnerships were follows:

1. Training Course for Educators

- The program was a collaborative effort involving a WSDA Specialty Crop Block Grant, a WSU Western SARE Grant, and the Universitat Politècnica de Catalunya.
- This training occurred on July 6-8, 2016, at the WSU Irrigated Agriculture Research and Extension Center (WSU-IAREC) in Prosser, WA.
- The primary instructor was Professor Emilio Gil, Universitat Politècnica de Catalunya, from Barcelona, Spain. Jan Langenakens, AAMS Research and Environmental General Manager, Belgium, also participated as instructor.

- A total of 22 individuals representing WSDA, agricultural industry, various stakeholder groups, and University Extension staff from Washington and California attended the workshop.
2. **Royal City, WA - Washington Fruit and Produce**
 - It was done in partnership with Washington Fruit and Produce.
 - This workshop took place in Royal City on November 8, 2016.
 - Ofelio Borges (WSDA) and Flor Servin (L&I) were the primary instructors and serve as part of the training development of Alberto Hernandez.
 - A total 43 people attended the workshop from 13 farms.
 3. **Prosser, WA**
 - Conducted in partnership with G.S. Long Company and WSU
 - It took place at the Washington State Research Station in Prosser, WA. on March 2, 2017
 - It was attended by 38 participants from 13 agricultural establishments
 4. **Benton City, WA – Terra Blanca Vineyards**
 - It was conducted in partnership with Washington Winegrowers Association
 - This event took place at Terra Blanca Vineyards in Benton City, WA on March 31, 2017.
 - It was attended by 41 Spanish-speaking participants representing 10 agricultural establishments. Three (3) WSDA compliance investigators also attended.
 5. **Naches, WA – Long Ranch**
 - in Partnership with G.S. Long Company and WSU Extension Office
 - It took place at the Long Ranch in Naches, WA on February 22, 2018.
 - It was attended by 48 people representing 23 agricultural establishments.
 6. **Prosser, WA.**
 - it was offered in partnership with G.S. Long company and Washington State University Extension Office
 - It took place at the Washington State Research Station in Prosser, WA. on March 6, 2018, and.
 - It was attended by 48 people from 15 agricultural establishments.
 7. **Wenatchee, WA**
 - In partnership with G.S. Long and WSU.
 - The workshop was done at the WSU Extension office in Wenatchee, WA. on March 8, 2018 and was conducted
 - It was attended by 33 people from 12 different agricultural establishments.
 8. **Benton City, WA**
 - in partnership with Washington Winegrowers
 - in Benton City, WA on March 27, 2018
 - A total of 30 people attended representing six (6) agricultural establishments and Oregon State Department of Agriculture.

The position funded by this grant also participated in at least seven (7) re-certification annual meetings and outreach event, proving pesticide safety information to at least 700 people. See “Appendix C” for details

Beneficiaries

2,025 agricultural employees and 601 agricultural establishments benefitted from this project. The larger number of trained applicators significantly benefitted the tree fruit, berry, grape, wine grape, hop and vegetable industries statewide. It is expected that the additional trained work force will help decrease the amount of human exposure to pesticides and help increase growers ability to effectively and efficiently apply these products, which are essential crop production.

All direct benefits of this project are for producers of specialty crops. Indirectly, the project will benefit producers of non-labor-intensive crops by reducing pesticide drift that could damage their crops. The project will benefit all agricultural producers by educating pesticide applicators and handler on how to lessening the drift problem and the resulting reduction in political and regulatory pressure to further restrict the use and application of pesticides. All workshop attendees will be employed in the specialty crop industry and all examples, equipment and workshop content will be focused exclusively on specialty crops.

As stated in this report, the funds of this grant positively affected several hundred-specialty crop producers statewide. Estimating the economic impact is difficult, as it would be measured in human exposure incidents avoided. Other impacts include more effective and efficient use of pesticides, better pest control and less pesticide used due to more accurate pesticide applications and better coverage as a result of better-trained applicators. Overall, the funds of this grant benefitted the following groups:

1. Agricultural employers – agricultural employers were significantly benefited by this project by obtaining more pesticide safety training opportunities for their employees, specifically those who apply pesticides. Also, agricultural employers had more opportunities to learn about the 2015 WPS rule changes, get trained on how to conduct their own on-site effective training sessions for field workers and pesticide handlers according to the WPS requirements. Additionally, many employers received valuable information on how to calibrate and optimize their airblast in order to do pesticide applications in a more effective and efficient way while reducing off target drift.
2. Agricultural employees – Agricultural employees, specifically pesticide handlers were trained on the safety use of pesticides according to the Federal and State WPS requirements. Among other things pesticide handlers learn how to protect themselves and others from pesticides and pesticide residues. How to decontaminate application and protective equipment correctly. Many agricultural workers also learned how to operate/manipulate pesticide application equipment, monitor weather conditions and availability of new technology that can help mitigate off target drift.
3. WSDA and Agricultural representative organization – with the funds of this grant, WSDA's Technical Services and Education Program and the agricultural sector had the opportunity to form partnerships that resulted in more training opportunities to agricultural employers and employees in both English and Spanish languages. Additionally, WSDA was able to build-on the existing training infrastructure, and training curricula by purchasing additional training equipment and props, which makes the program more robust and in a position to better support our agriculture industry in general by expanding its capacity at least an temporally basis.

Lessons Learned

The 2015 Worker Protection Standard rule updates created a significant impact to Washington's agricultural industry during 2016 to 2018 where WSDA was required to conduct a number of outreach efforts to educate the community about the rule changes and its implementation. The funds of this grant allowed the outreach efforts to be done at the correct time. The expansion of WSDA's pesticide safety training programs and the participation in several annual grower meetings, as shown in this report,

allowed the dissemination of the rule changes and how to implement them. Thus, the funds provided by this grant gave WSDA's pesticide safety training program a significant boost at a critical time. It is expected that specialty crop producers will be at a good level of compliance with WPS requirements as a result of this effort.

It was learned that although much was accomplished with the support of this grant funding, there is a significant amount of work that needs to be done in terms of pesticide safety education and equipment calibration and the adoption of practices that can result in the reduction of off-target drift, human exposures to pesticides, environmental contamination.

Most pesticide applications done in tree fruit, berry, grape, wine grape and hop industries statewide are done primarily by Spanish speaking handlers. Therefore, pesticide safety trainings need to be offered in both Spanish and English languages.

We learned that the implementation of a project of this nature requires the participation of many players in order to achieve the proposed goals. All workshops were conducted in partnership with industry members who invested significant resources in terms recruitment of participants, provision of training facilities and staff to assist and support trainers.

A survey to measure behavioral changes would have help asses adoptions of practices recommended during this project to better measure the overall impact of this project.

Contact Person

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Additional Information

WSDA provided significant in-kind matching for the realization of this project as explained below

Table 5

Activity	By who	Approximate amount(s)	Source
Recruiting and hiring trainer	Project manager	45hrs X \$45 = \$2,025	WSDA General local funding
Trainer development activities	Project manager	60hrs X \$45 = \$2,700	
Partnership development and workshop scheduling	Project manager	75hrs X \$45 = \$3, 375	
Equipment purchasing	Administrative staff	40 hrs X \$18 = \$720	
Equipment maintenance	Program staff	20hrs X \$35 = \$700	
Project reporting and administrative work	Project manager	70hrs X \$45 = 3,150	
Approximate total		\$12,670 = Approximately 310 hrs.	

WSU Benton/Franklin Extension Office provided a great deal of support to this project by providing a trainer in six of the 8 workshops conducted with this grant funding. The trainer was one of two trainers for the 8-hr English concurrent session and provided support in setting up the day previous to the training events. Project contribution would include trainer's time, travel and meals.

The position funded by this grant also supported the WSDA Pesticide Waste Disposal Program by assisting at least three pesticide collection events where more than 20,000 pounds of waste pesticides were collected.

The position funded by this grant, supported WSDA's Pesticide Compliance Program by assisting compliance inspectors three different occasions with Spanish language interpretations and/or translations. Additionally, this position translated (English to Spanish) several documents for the Hazardous Waste Collection.

The position funded by this project provided information to over 700 additional people via annual pesticide recertification and grower meetings.

Below are photos that convey some of the activities done with the support of this grant.



Students learn how to calculate nozzle output volumes based on gallons per acre and forward speed. As we can see, they are divided in small groups (color coded) that can allow more participation and interaction. All of the activities are guided by an experienced trainer. Once the calculations are completed, groups share findings with all participants and then put in practice in the field.

Students install spray nozzles to sprayer based on previous calculations, attached hoses to nozzles in order to measure output of each nozzle to ensure sprayer is calibrated to deliver the correct amount of liquid per minute.

Attached hoses are connected to a multi-channel flow meter that allows measuring the output of 10 nozzles at a given time making the calibration process much faster and effective.



Figure 2 Workshop conducted at WSU Research Extension in Wenatchee, WA

Appendix A

WPS Handler Training Program This is an eight-hour workshop offered in Spanish (and English, upon request) that has been purposely developed to train unlicensed pesticide handlers on using pesticides safely, legally, and skillfully. The workshop provides practical, hands-on training that exceeds federal and state training requirements of the WPS. WSDA's Handler Training Verification Cards are issued. The training also offers excellent continuing education for certified applicators and includes the following interactive training modules.

- Personal Protective Equipment (PPE)
- Respiratory Protections
- Decontamination
- Mixing and Loading
- WPS Additions

The program offers pesticide recertification credits for licensed applicators. The trainer hired with the funds provided by this grant participated in the following handler training workshops.

1. Yakima, WA – 01/24/2017
 - ☐ As part of the Winter Ag Academy
 - ☐ Yakima Conference Center
 - ☐ In partnership with G.S. Long Company
 - ☐ 232 attendees, representing 40 agricultural establishments
2. Yakima, WA – 01/25/2017
 - ☐ Yakima Conference Center, Yakima
 - ☐ In partnership with G.S. Long Company
 - ☐ 230 attendees representing 36 agricultural establishments
 - ☐ 226 WSDA WPS Training Cards were issued
3. Wenatchee, WA – 02/07/2017
 - ☐ As part of the Winter Ag Academy
 - ☐ Wenatchee Convention Center, Wenatchee
 - ☐ In partnership with G.S. Long Company
 - ☐ Attended by 232 farmworkers representing 40 agricultural establishments
4. Kennewick, WA – 02/15/2017
 - ☐ As part of the Winter Ag Academy
 - ☐ Three Rivers Convention Center, Kennewick
 - ☐ In partnership with G.S. Long Company
 - ☐ 246 individuals representing approximately 49 agricultural establishments, including one person from OIC of Washington
5. Yakima – 02/20/2017
 - ☐ Yakima Conference Center, Yakima
 - ☐ In partnership with G.S. Long Company
 - ☐ Approximately 227 individuals from 37 agricultural establishments attended
6. Granger, WA – 03/10/2017
 - ☐ KDNA Facility, Granger, WA
 - ☐ In partnership with Kershaw Fruit
 - ☐ The 77 pesticide handlers who attended represented 12 agricultural establishments
 - ☐ Eighteen certified applicators received six WSDA pesticide credits
7. Okanogan, WA – 03/14/2017
 - ☐ Okanogan Convention Center, Okanogan
 - ☐ In partnership with Gebbers Farms
 - ☐ The 160 attendees comprised three agricultural establishments

- ☐ Eighteen certified applicators received six WSDA pesticide credits
 - Okanogan, WA– March 24, 2017Okanogan Convention Center
 - In partnership with WA State Tree Fruit Association
 - Sixty-eight pesticide handlers from 37 agricultural establishments in the Okanogan/Omak area were trained in the safe use of pesticides
 - Attendees included three individuals with Northwest Landscaping Services
 - Spanish session had 57 participants, the English session 11 participants
- 9. Lynden, WA – 11/2/2017
 - Lynden Fair grounds
 - In partnership with the Red Raspberry Commission and Northwest Berry Co-op
 - 33 attendees from 28 agricultural establishments
- 10. Yakima, WA – 11/08/2017
 - At the Yakima Convention Center
 - In partnership with G.S. Long Company
 - 204 participants from 50 agricultural companies
- 11. Yakima, WA 11/09/2017
 - At the Yakima Convention Center
 - In partnership with G.S. Long Company
 - 120 participants from 32 companies
- 12. White Salmon, WA – 01/18/2018
 - Mt. Adams Orchards
 - 25 attendees, representing 1 agricultural establishment
- 13. Hood River, Oregon – 01/19/2018
 - Hood River Grange
 - In partnership with Oregon State University
 - 74 attendees representing 36 agricultural establishments
- 14. Yakima, WA 01/24/2018
 - Yakima Convention Center
 - In partnership with G.S. Long Company
 - 213 participants from 27 agricultural establishments
- 15. Yakima –01/25/2018
 - Yakima Convention Center
 - In partnership with G.S Long Company
 - 245 participants from 39 agricultural companies
- 16. Wenatchee, WA – 01/31/2018
 - Wenatchee Convention Center
 - In partnership with G.S. Long Company
 - 200 participant from 31 agricultural companies
- 17. Yakima, WA 02/02/2018
 - Yakima Convention Center
 - In partnership with the WA Tree Fruit Association
 - 168 participant form 12 agricultural companies
- 18. Yakima, WA –02/13/2018
 - Yakima Convention Center
 - In partnership with G.S. Long
 - 165 participants from 55 agricultural establishments
- 19. Pasco, WA –02/20/2018
 - At the Red Lion Hotel

- In partnership with WA Winegrowers
- 48 participants from 14 agricultural companies
- 20. Yakima, WA – 02/27/2018
 - Howard Johnson Hotel and Conference Center
 - In partnership with Wilbur Ellis Company
 - 240 participant from 12 agricultural companies
- 21. Burlington, WA – 03/13/2018
 - Kakata Seed Company
 - In partnership with WA Farm Bureau
 - 71 participants from 16 agricultural employers
- 22. Granger, WA – 03/23/2018
 - At KDNA Radio Station
 - In partnership with Kershaw Farms
 - 59 participants from 11 companies attended
- 23. Okanogan, WA 04/06/2018
 - Okanogan Armory Building
 - In partnership with Gebbers Farms
 - 188 participants all employees of Gebbers Farms

Appendix B

Train-the-Trainer Program

The Federal Worker Protection Standard (WPS) was revised in 2015. This regulation was adopted with the purpose of protecting agricultural workers from pesticides and pesticide residues. Part of WPS requires employers of agricultural workers and pesticide handlers to provide them pesticide safety training, which would help them avoid exposure to pesticides and pesticide residues. The WSDA Train the trainer program was designed to help farm managers, supervisors and other farm trainers on how to conduct on-site trainings for workers and handlers according to the WPS requirements. The position funded by this grant participated in the following WPS Train the Trainer workshops:

1. Sunnyside, WA – 01/31-02/01/2017
 - WorkSource Sunnyside
 - In partnership with WA WorkSource
 - 32 individuals attended, 29 were managers, supervisors, and trainers representing 15 agricultural establishments. Two participants were from Oxarc; and one was from the Washington Growers League.
2. Wenatchee, WA – 02/9-10/2017
 - At Stemilt facility
 - In partnership with Stemilt Company
 - The 30 attendees were managers, supervisors, and current trainers. Of these, 12 were certified trainers who attended the program to learn about the 2015 WPS provisions. Nine individuals were certified as trainers.
3. Kennewick, WA – 02/16-17/2017
 - Columbia Basin WorkSource
 - In partnership with WA Winegrowers Association
 - 59 participants represented 13 agricultural establishments, with two individuals from food safety consulting companies and one WSDA employee. Fifteen individuals attended the English session and 44 attended the Spanish session.
4. East Wenatchee, WA – 03/16-17/2017
 - At the Wild River Inn
 - In partnership with WA State Tree Fruit Association

- The training was attended by 32 individuals, which included four certified trainers who participated as refresher training. Attendees were from 20 agricultural establishments. Seven attendees were certified as trainers in the English session and nine in the Spanish session.
5. Naches Heights – 04/04-05/2017
 - At the Naches Heights Fire Station No. 9
 - In partnership with Apple King
 - The 34 individuals were managers, supervisors, and trainers from 19 agricultural establishments.
 6. Union Gap, WA – 05/02-03/2017
 - At the WSU Yakima Co. Extension Office
 - In partnership with WA State Tree Fruit Association (WSTFA)
 - The 24 participants were manager, supervisors, and trainers representing 16 agricultural establishments.
 7. Kennewick, WA – 05/17-18/2017
 - At the WA WorkSource
 - In partnership with WA Wine Growers Association
 - The 14 participants represented eight agricultural establishments, including two individuals from Syngenta and one WSU employee. All 14 individuals attended the English session.
 8. Naches, WA – 05/24-25/2017
 - At the Naches Sports Complex
 - In partnership with Allan Brothers
 - 32 individuals attended the training from 12 agricultural establishments.
 9. Chelan, WA – 06/01-02/2017
 - Chelan Cambell’s Resort
 - In partnership with Opportunities Industrialization Center (OIC)
 - The training was attended by 18 individuals, with three certified trainers participating as a refresher on the 2015 revisions. Attendees were from 12 agricultural establishments.
 10. Mt. Vernon, WA – 06/14-15/2017
 - Took place at the WorkSource Skagit County
 - In partnership with Opportunities Industrialization Center (OIC)
 - The 18 participants represented nine agricultural establishments, with one individual from Labor and Industries (L&I), two from WSDA, and one from OIC.
 11. Yakima, WA – 11/15-16/2017
 - At WSDA building
 - In partnership with WA State Tree Fruit
 - 23 participants form 19 agricultural establishments.
 12. Lynden, WA 11/21-22/2017
 - Conducted at the Lynden Annex Building
 - In partnership with Northwest Berry Co-op
 - 22 participants from 12 agricultural establishments.
 13. Selah, WA – 02/08-09/2018
 - Zirkle Fruit facility in Selah
 - In partnership with Zirkle Fruit
 - Of the 29 individuals who attended, 29 were managers, supervisors, and trainers representing one agricultural establishment.
 14. Kennewick, WA – 03/01-02/2018

- At the Columbia Basin WorkSource
 - In partnership with WA Wine Growers Association
 - The training was attended by 24 participants represented 12 agricultural establishments.
15. East Wenatchee, WA – 03/15-16/2018
- At the Washington Apple Commission
 - In partnership with the WA State Tree Fruit Association
 - The training was attended by 29 individuals; attendees were from 22 agricultural establishments.
16. Sunnyside, WA – 03/29-30/2018
- Sunnyside WorkSource
 - In partnership with WA State Tree Fruit Association
 - The training was attended by 30 individuals; attendees were from 24 agricultural establishments.
17. Moses Lake, WA - 04/12-13/2018
- At Big Bend Community College
 - In partnership with the WA State Tree Fruit Association
 - 28 participants from 15 agricultural establishments.
18. Yakima, WA – 04/19-20/2018
- At the Yakima WorkSource
 - In partnership with Opportunities Industrialization Center
 - 19 participants from 10 agricultural establishments.
19. Moses Lake, WA 06/5-6/2018
- It took place at the Big Bend Community College
 - In partnership with the WA Potato Commission
 - 19 participants from 15 agricultural establishments.

Appendix C

Annual Recertification Meetings

The position funded by this grant participated in the following outreach and recertification meetings.

1. 2016 Central WA Fair- Yakima, WA – September 23, 2016.
 - ▶ With other members of the Education and Outreach Services team (Lorena Lopez, Manuel Ornelas, and Tom Hoffmann), Alberto Hernandez staffed the WSDA booth at the 2016 Central Washington State Fair.
 - ▶ Objectives of the booth were to promote Washington’s agricultural sector, to enhance awareness of WSDA, to advocate pesticide safety and environmental protection, and to inform about cropping practices. Fairgoers were fascinated by the trivia wheel and enthralled with the resource information displayed on the tables.
 - ▶ Staff received questions about pesticides (in general), pesticide use, applicator licensing, and pest control measures.
2. 2016 Annual Weed Conference - Wenatchee, WA – November 2-4 2016
 - ▶ Alberto Hernandez provided attendees with information about the following:
 - Dates Spray Calibration and BMPs training for 2017
 - Calibration of pesticide application equipment
 - Best Management Practices (BMPs)

- Inspection of Airblast Sprayers
 - Decontamination of pesticide application equipment
- 3. 2016 Horticulture Expo - Wenatchee, WA – December 5-9, 2016.
 - While staffing a WSDA booth, Alberto Hernandez provided attendees with information about the following:
 - WSDA’s mission of promoting and protecting the agricultural industry, the public, and the environment.
 - Technical Services and Education Program’s mission statement and goals.
 - Calibration of pesticide application equipment
 - Best Management Practices (BMPs)
 - Inspection of Airblast Sprayers
- 4. Pasco Ag Show – January 3, 2017
 - Presented on “Decontamination Requirements, Supplies, and Procedure; and Importance of Personal Hygiene.”
 - Spanish session was attended by 23 farmworkers
- 5. Yakima G.S. Long Company Annual Grower Meeting - January 11, 2017
 - Presented on “Overview of Airblast Calibration and BMPs Workshop.”
 - Spanish session was attended by 595 individuals
- 6. Yakima, WA G.S. Long Annual Grower Meeting – January 17, 2018
 - Presented on “Decontamination Requirements, Supplies, and Procedure; and Importance of Personal Hygiene
 - Spanish session was attended by 23 farmworkers
- 7. Wenatchee, WA G.S. Long Re-certification Meeting February 7, 2018
 - Presented on “Overview of Airblast Calibration and BMPs Workshop.”
 - Spanish session was attended by 120 individuals

Project Title: Market expansion through GAP certification

Project Summary

LINC Foods was started in 2014 with the mission to help connect farmers to new markets, namely institutions. As the space was explored, barriers around food safety were encountered. Some of these were due to vendor requirements, and some due to confusion, both from farmers and from customers, around what exactly “food safety” was and how small farmers could address these concerns. Initially these concerns were around Good Agriculture Practices certification and how to help small scale farms achieve certification. As the project evolved, LINC turned towards Food Safety Modernization Act (FSMA) compliance and helping the farms understand what requirements under the final rule they needed to adhere to and whether or not they qualified for an exemption.

Food safety requirements have increased in the last seven years. Some of this has been market driven, as customers seek to reduce their liability. With the passage of FSMA and the final rules, the regulatory environment has also become more stringent. Many small farmers are confused about what is voluntary versus compulsory, market driven versus regulatory. There is a perception that GAP/FSMA compliance is expensive, complicated, or downright unachievable for a small farm. Clear explanations and on the ground support are needed to help small farmers navigate the food safety landscape.

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

Project Approach

A major focus of this grant was GAP certification. Many institutional scale vendors require third party food safety verification, but most small farmers in the Spokane area weren’t even familiar with the definition of food safety. LINC wanted to improve its own understanding of food safety, and support the growers in food safety literacy. LINC provided trainings in many different formats, including 25 farm walks, 4 food safety workshops, and 15 one-on-one food safety consultations and mock audits. LINC also created a library of food safety resources for member farmers, including a written food safety plan template, FSMA and GAP resources, and information about food safety and liability. Initially, LINC was hoping to prepare a group of farms for Group GAP certification. It was hoped that Group GAP would help reduce the cost of certification for farmers, since that is one of the biggest barriers to certification to growers in this region. Unfortunately, after speaking extensively with colleagues at Western Montana Growers Cooperative, who were one of the pilot groups for the program, LINC concluded that Group GAP would probably not yield significant cost savings to the growers, due to the amount of administration and time that the co-op would have to put into the internal quality management system.

This realization led to a shift in focus away from group GAP and more towards helping the LINC member farms understand FSMA compliance/qualified exemption/exemption status and developing food safety standards that would be in compliance with GAP if any individual farmers elected to pursue individual certification. Only two farms went on to become GAP certified. Both passed their audits with high marks and one went on to be recertified for a second year. The LINC warehouse also passed a GAP audit with flying colors. LINC sent one staff person, Beth Robinette, to attend a Produce Safety Alliance Train the Trainer training. WSU Spokane County Extension’s Anna Kestel is a certified Lead Trainer, so LINC can now offer PSA approved/FSMA compliant food safety trainings to members throughout the region. A policy was set in place that all LINC member farms would be required to have a written food safety plan by 2018. This plan is written as such that any farm following it would be both FSMA and GAP compliant, with a simple enough format that it can be adapted to any small farm in the co-op with a few modifications.

Farmers needed help navigating the FSMA final rules. When this proposal was first written, the law had been passed but the final rule had yet to be released. LINC was able to keep its member farms apprised of developments as the final rules were under revision and to help farms understand what portions of the rule they must be in compliance with. All LINC farms are either completely exempt or have a qualified exemption. LINC is requiring all the farms to label their produce as outlined in the qualified exemption rules, even if they have a complete exemption. LINC still expects its members to understand the full food safety requirements as outlined in FSMA and will host annual trainings for members to continue to build a culture of food safety within the co-op.

Improvements in food safety understanding and standards has led to an overall increase in quality and presentation of the produce the co-op sells. LINC formally adopted FamilyFarmed.org's Wholesale Success manual as the standard by which all LINC member farm's produce is judged. Measures such as clean boxes, box liners, and clear labels obviously help mitigate food safety risks, but they also make the presentation of the product more clean and professional. This professionalization of presentation has certainly helped grow the co-ops sales, from just \$30,000 annual revenue the year before LINC received the grant, to nearly \$500,000 annual revenue in 2017.

The only project partner was the Washington State University Extension office of Spokane County. The extension agent, Jeremy Cowan, contributed food safety expertise to all of the farm walks, workshops, and mock audits. Cowan's wider perspective and experience working with small farmers in the region greatly increased the value offered to the specialty crop growers LINC worked with.

The project only benefitted specialty crops.

Goals and Outcomes Achieved

During the project period LINC Foods:

- Hired a full time food safety coordinator
- Created and disseminated a standardized food safety plan template for specialty crop growers
- Held 4 on farm food safety training field days
- The training topics were on-farm food safety and specifically how to create a food safety plan and pass a GAP audit. In each training we had food safety specialists and in some cases WSDA auditors present to talk through each section of a food safety plan and each section of a GAP audit so that each farm could figure out how to tailor a plan to their context. Only specialty crop growers attended as those are the only growers LINC works with and the training would be relevant to.
- Thirty farmers were registered to attend both the Wallace Center Farmer Training Webinar and Food Safety Plan Workshop.
- We organized and held two Wallace Center Farmer Training Webinars and two Food Safety Plan Workshops on December 5th (32 farmers attended) and December 12th (29) farmers attended.
- On Farm Field day training at Cloudview EcoFarms on July 20th, 14 attendees. They have just recently passed a GAP audit to become our second farmer that is GAP certified using our food safety plan and training! This field day was very helpful as we were able to walk through the audit with the attendees and talk about what worked and what didn't, and how they plan to improve. The second field day was on August 22nd at Ace of Spades Farm, 27 attendees. This farm plans to become certified in the future. The

day was very useful as we walked through a mock GAP Audit and saw what would need changing/improving in order to pass.

- Helped 2 growers achieve GAP certification and the cooperative itself achieve GHP certification. Cloudview Eco Farms, and Frisson Farm received their GAP certification. We surveyed the two farmers that did achieve GAP certification. One of them made several sales to another distributor that requires GAP certification. The other farm, Cloudview Eco Farm, made a sale each week through the cooperative to a school district (Nine Mile Falls) using the USDA Pilot Project for unprocessed Fruits and Vegetables, which requires GAP certification.

- Made 25 farm visits to train growers on FSMA and food safety. Farms visited were: Urban Eden Farm, Jackson Family Farm, Cloudview Eco Farms, Frisson Farm, Full Bushel Farm, Hirschel Heritage, McKerracher Family Farm, Verns Veggies, Lone Mountain Farm, Ace of Spades, Footehill Farm, WSU Organic Farm, Makana Farm, Grateful Plate Homestead, Peak of Abundance, Welcome Table Farm, Hayshaker Farm, Wild Roots Farm, Big Sage Organics.

- Did 15 one-on-one grower consultations to answer questions and give guidance on issues specific to those particular growers.

- Designed and facilitated a workshop on the findings and learnings of this project at the 2016 and 2017 annual small farms conference in Spokane.

- Brought 15 specialty crop growers to FSMA compliance.

- We have not yet figured out how to make all of the resources created from this project accessible on our website. The following link is shared with 55 specialty crop growers we work with that are members of the cooperative: <https://drive.google.com/open?id=0B3RLanONWvDFLVFpenRUV1BOa1k>

The Expected Measurable Outcomes of this project were specific to the term of the grant.

The key goal of this project was originally to help 15 specialty crop growers attain GAP certification. The result was that only 2 growers and the LINC Foods co-op became certified. The target of the grant changed as new information came in from the industry and as LINC Foods learned more about what customers really needed/required. The more relevant goal became getting at least 15 growers to FSMA compliance. This goal was achieved as 16 of the target specialty crop growers were trained, prepared, and then committed to utilizing the standardized food safety plan created during the project and meeting the FSMA requirements relevant to their scale.

When we applied for this grant our assumption was that all large customers would be requiring GAP certification in the near future. In working with these customers (most of which had no idea what GAP or other 3rd party on-farm food safety certifications were) we learned that was not the case, and for a small specialty crop grower, GAP certification was out of reach cost-wise. Particularly for specialty crop growers in our part of eastern Washington, GAP certification is very expensive as the only nearby inspector is 3 hours west of here, and you are charged from office door to office door for the inspector's time. So, in learning that customers didn't require GAP, and that small specialty crop growers could not afford it, we de-prioritized the original goal of GAP certifications; and then FSMA came into view during our project which seemed like a more important focus as far as education for growers. We then focused on getting on-farm food safety plans into place for willing growers, then they would be prepared for FSMA and for a voluntary certification like GAP if they chose to do it.

The expected measurable outcomes also had to change along with the change in goals of the project. The desired outcome became that sales of specialty crops to institutional and retail grocery customers at least double within the project period. The baseline sales to institutional and retail grocery customers (customers that care the most about food safety compliance) in 2015 were \$70,000, and increased to \$241,000 by 2017 year end. Much of this was made possible by the project efforts of educating and formalizing food safety practices among specialty crop grower-members of LINC Foods.

The baseline sales data was determined from the cooperative's sales of specialty crops over a year to retail and institutional customers at the time of applying for the grant. The data collected to determine the increase of \$241,000 was from the cooperative's sales of specialty crops over a year to retail and institutional customers at the conclusion of this grant. The baseline and final data was related only to specialty crop sales.

Beneficiaries

50 unique specialty crop growers in our area were affected by this project. The main beneficiaries of this project have been LINC member farmers. The co-op has been able to provide many resources to its growers as a result of this project. Nearly all of LINC member farms report increased knowledge and understanding of food safety at the conclusion of this project, and nearly all attended at least one training. Many attended three or more over the course of the project. Of course, the ripple effects of food safety knowledge are enormous. Consumers certainly benefit as well. Many LINC member farms sell to other venues or markets, and are now armed with their improved food safety knowledge which increases the quality of their products. Even some competitor distributors who require GAP certification attended the LINC food safety trainings to better understand their own requirements and how they affect specialty crop growers.

The co-ops sales were just \$30,000 in 2014, and increased to nearly \$500,000 annual revenue in 2017.

Lessons Learned

One of the biggest takeaways of this project was that it is entirely within reach of any of the farmers to maintain the highest levels of food safety. There is a common perception that GAP certification is only achievable by very large farms. However, many LINC farmers have come up with ingenious solutions for GAP compliant wash stations, hand wash stations, and cold storage at very minimal cost. The cost of the audit, however, remains a large barrier. The co-op is simply not working with enough institutional buyers that require GAP certification for farmers to make enough sales to justify the increased cost. This combined with the fact that the nearest auditor is located a 3 hour drive away makes the cost of the audit too much to bear for most of the growers at this point in time. However, the reality remains that food safety standards and requirements will more than likely increase in the coming years, and it will be extremely advantageous to the co-op to have laid groundwork for strong food safety.

The Warehouse Food Safety plan that LINC created through this project helped us directly manage and mitigate a potential food safety risk earlier in 2018. Testing revealed that fire retardants used at Fairchild Airforce Base had contaminated the water supply in Airway Heights, WA and this directly impacted one of the member farms. Because a clear plan was in place LINC was able to halt sales of that product, work with the farmer to develop mitigation strategies, and testing protocol that helped to determine when it was safe to resume sales of produce. It really hit home for LINC staff that even very conscientious farmers can be faced with food safety hazards and having a thorough understanding of how to deal with those situations in a clear and systematic way can make all the difference when a crisis arises.

The initial focus of this project was on GAP certification. LINC hoped that having GAP certified farmers would help accelerate sales and open up new markets. However, as the project progressed, it became clear that the co-op was not yet in a stage of development to fully take advantage of GAP certified farms. Most buyers that require GAP certification also require a lower price point and a much higher volume than what the growers can meet at their current scale. Consequently it would be very difficult for small farmers to sell enough GAP certified produce to realize the benefit of the certification. LINC had hoped Group GAP might be a more cost effective way to achieve certification and reduce that barrier, but the cost savings seem to be minimal if any. At this point in time, LINC has chosen to focus its energy on creating a culture of food safety within the co-op, and laying the groundwork so that when LINC does reach the right scale, a third party audit could easily be obtained by any member of the co-op.

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Additional Information

Empire Health Foundation provided a \$10,000 cash match to the project. These funds were used to pay for GAP certifications during the project.

LINC Foods provided a \$16,000 in-kind match to cover all indirect and administrative costs of the project.

WSU Extension provided an in-kind match of \$9,450 which was the value of the time committed by extension agent Jeremy Cowan.

Project Title: Enhanced food safety education and training for tree fruit producers

Project Summary

The purpose of the “Enhance Food Safety Education and Training for Tree Fruit Producers” project conducted by the Washington State Tree Fruit Association (WSTFA) through this Specialty Crop Block Grant, was to address the need to educate tree fruit producers in Washington State on the requirements of the U.S. Food and Drug Administration relating to FSMA. This project intended to reduce regulatory barriers by providing education, training and materials to over 1,500 tree fruit producers, to aid in the understanding and adoption of the new federal food safety standards. The complexity of the four rules directly affecting the fresh produce supply chain caused growers and packers difficulty in understanding and implementing the new requirements without expert assistance. WSTFA created several educational materials and organized training sessions with food safety and regulatory experts, to help growers navigate the rules.

This project was timely and important because FSMA was signed into law in 2014 and became the first mandatory Federal Regulation for farms and food processing companies. The main rules affecting the tree fruit industry were expected to be finalized by late 2015/early 2016, but delays on guidance documents about the rules also delayed compliance. The uncertainty behind many of the requirements of FSMA, provided an opportunity to educate growers and packers in Washington State and help them comply with the regulation, as well as organize meetings to comment on parts of the regulation that were not practical for the tree fruit industry. WSTFA assisted growers, packers, owners and operators of small and medium sized farms by providing an overview of the new regulations, working in collaboration with food safety professionals and other industry stakeholders to identify key changes in the rules, providing classes and materials for the implementation of FSMA and Good Manufacturing Practices (GMPs), engaging in individual consultations with tree fruit growers participating in Good Agricultural Practices (GAP), and providing specific courses required for compliance with the regulations.

FSMA regulations apply to all stages of produce production, from the farm through transportation and packing. Understanding and ensuring compliance has been challenging for all commodity groups. Tree fruit in Washington is produced by widely distributed networks of individual growers feeding into shared packing and marketing organizations, adding an extra layer of complexity to an already challenging process. Proactivity within the Washington tree fruit industry with this project, has ensured a successful implementation of the regulations with mandated timelines that have required intensive training and education efforts the past couple years.

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

Project Approach

The activities and tasks achieved during the project period are summarized as follows:

- Recall Ready Workshop: Product recalls became a big concern for the tree fruit industry after the caramel apple incident; thus, two all-day seminars were held in March 2016 for the growers, packers and marketers of tree fruit to review and test procedures for addressing recalls of fresh produce. The workshop was delivered by the United Fresh Produce Association's Recall Ready Team: Dr. David Gombas, Amy Philpott and David Durkin. The Yakima session had 37 attendees and the Wenatchee session had 23 attendees. The goal of this workshop was to provide a better understanding of the regulatory, operational and communicational components of a product recall, and ultimately minimize negative impact on the companies. 63% of the

participants thought the workshop was excellent and the remaining 37% thought it was good. Having different perspectives from the speakers was very useful for our participants, and they were able to provide informative recommendations and guidance for the tree fruit industry. The table exercise was an eye opener for the attendees and having a speaker from the FDA also helped to understand the regulatory aspect of a recall. For future workshops WSTFA would recommend including the environmental monitoring component of a recall so that participants can understand their responsibility as a company and based on their environmental monitoring program, know when to recall.

- Preventive Controls Rule Workshop: WSTFA in partnership with the Food Safety Preventive Controls Alliance (FSPCA) offered a Preventive Controls Qualified Individual (PCQI) training specifically targeted to the produce industry. This training program was planned to assist the produce industry with the implementation of the U.S. Food and Drug Administration (FDA) Hazard Analysis and Risk-based Preventive Controls for Human Food regulation and was developed with the standardized curriculum recognized by the FDA. The workshop was delivered by Claudia Coles, External Affairs Advisor with WSDA and Girish Ganjyal, Assistant Professor with Washington State University in Yakima, WA. The workshop had 12 participants from Yakima and Wenatchee packinghouses and was developed in 3 days with 1 extra day for a follow-up meeting. The training session was planned with exercises and provided useful information for food processing; however, the information was not easy to relate to the produce industry. Following the workshop, a meeting was held with the trainers and the participants to develop a flow diagram and a narrative of the apple packing process, which helped the participants feel more comfortable to incorporate the Rule within their existing programs. The material that was developed during this workshop has been used at other training sessions and has helped as an example to develop additional produce worksheets by United Fresh. Claudia Coles and Girish Ganjyal developed a PCQI course with specific examples of apple packinghouses, which was hosted recently.
- 111th WSTFA's Annual Meeting & NW Hort Expo: WSTFA provided an education and training overview of FSMA requirements during the meeting in December 2015. WSTFA was able to invite experts like Miriam Burbach from FDA, Kathleen Glass, researcher from the University of Wisconsin and Channah Rock, water quality specialist from University of Arizona to share with the audience the most updated information about different aspects of FSMA. This session stressed the importance of education rather than enforcement to comply with regulations. Kathleen Glass summarized her work on caramel apples that led to a better understanding of the cause of the *Listeria monocytogenes* outbreak on caramel apples; she provided statistics to create awareness within the industry of the importance of food safety to prevent product contamination and recalls. Channah Rock provided information about AgWater, an application developed to help growers with their Microbial Water Quality Profile and understand the results compared to the criteria for agricultural water quality outlined in the Produce Safety Rule. This food safety session gathered FDA representatives, researchers, trainers, growers and packers to discuss the most important aspects of FSMA and share their concerns and questions among themselves.
- FSMA Water Quality Testing Workshops: Three all-day workshops were held in May 2016 for growers of the tree fruit industry focused on training FSMA water quality testing in Yakima, Selah and Wenatchee. The format of the workshops combined a classroom portion explaining the basics of water sampling, water quality profile, geometric mean and standard threshold value, and testing laboratories; and a demonstrative portion delivered in irrigation districts to show the

correct procedure to sample irrigation water. The workshop was delivered by water quality testing experts Melissa Partyka, Jennifer Chase and Ronald Bond from the Western Center for Food Safety from UC Davis. During the field demonstrations Melissa Partyka explained how to do environmental assessments with an investigation of potential upstream inputs, wild animal intrusion, standing water and leaks. Ronald Bond demonstrated how to take water samples on surface water and Jennifer showed the procedure to do piped water sampling. WSTFA observed a good response from participants, 90 to 100% of participants thought the workshop could be repeated later. The overall format of the workshop was very successful, 70% of the attendees thought the format was good by having hands-on examples and that also helped to break up the day, the other 30% appreciated hands-on examples. After the workshop the attendees had a better response understanding that agricultural water is being regulated under FSMA. With the key learnings from this workshop and feedback from the participants the WTFRC and the team of the Western Center for Food Safety released easy to follow recommendations for water quality sampling under the FSMA Produce Safety Rule for Agricultural Water testing. The document will be updated as guidance documents are issued by FDA and can be found at the WSU Tree Fruit Extension website.

- Environmental monitoring workshop: One all-day workshop was held in Naches, WA in November 2016, covering environmental monitoring techniques for tree fruit packinghouses. This workshop was designed to train food safety lead personnel on environmental monitoring and techniques to verify effective cleaning and sanitation programs in the packinghouse. Food safety experts were invited to provide an overview of current environmental monitoring techniques, facility mapping and identification of hygienic zoning, WSDA inspections, and laboratory analysis methods. Hands-on demonstrations were included in this workshop to explain how to develop an environmental monitoring plan, how to do swabbing and ATP testing, as well as plating. Some of the topics that were covered included basics of environmental monitoring, regulatory inspections, methods and materials to conduct swabbing and ATP testing, and Whole Genome Sequencing. The workshop had a total of 40 participants who thought the workshop was informative, well developed and appropriate for their current practices. Participants suggested that the workshop should be conducted again since it was interactive, and they received valuable information to develop their environmental monitoring plans.
- WSTFA's Annual Meeting 2016: the meeting was carried out December 5th-7th, 2016 in Wenatchee, WA and included a half-day food safety session. The goals of the session were to provide updates on the status of the most relevant FSMA regulations for the industry: the Produce Safety Rule and Preventive Controls Rule for Human Food; to explain to the audience the most important aspects to be compliant with both rules; to introduce the audience to current efforts of scientists to help with FSMA implementation; and to discuss solutions for FSMA implementation with producers and packers. Food safety experts invited included Melissa Partyka from UC Davis and Marc Verhougstreate from University of Arizona to talk about water sampling, Claudia Coles from WSDA and Girish Ganjyal from WSU explained how to shift from HACCP to Preventive Controls, and finally an industry panel discussed the main concerns related to the rule within the tree fruit industry. Approximately 200 attendees participated in the session.
- Produce Safety Alliance Train the Trainer: one two-day workshop was organized in Yakima, WA in January 2017. Three trainers from FDA's Produce Safety Alliance taught a class that certified 28 trainers in Washington, that are now able to train growers for compliance with FSMA's Produce Safety Rule requirement of having at least one supervisor in each farm trained on food safety with a curriculum considered adequate by FDA. Four trainers were later certified as Lead Trainers by AFDO. The course provided information regarding Good Agricultural Practices and

adult learning principals. WSTFA contracted these trainers to organize additional PSA Grower Trainings.

- FSMA water testing workshops: two one-day workshops were organized in Yakima and Wenatchee, WA in May 2017. The format of the workshop combined a classroom portion and a demonstrative portion delivered in irrigation districts to show the correct procedure to sample surface and piped water. The participants also had the chance to take samples and conduct environmental assessments under the guidance of water quality testing experts Melissa Partyka, and Ronald Bond from the Western Center for Food Safety from UC Davis. The Good Fruit Grower Magazine recorded training videos of water sampling and tips to conduct environmental assessments that were distributed to WSTFA's training email list, as well as grower members, and are available to the public domain on goodfruit.com. The workshops were attended by 35 and 30 participants in Yakima and Wenatchee, respectively. The overall format of the workshop was very successful, 90% of the attendees thought the format was good by having hands-on demonstrations and the chance to participate.
- Produce Safety Alliance Grower Trainings: two courses were hosted in Yakima, WA in May 2017, with a total of 82 attendees. The courses addressed the 8 modules from the curriculum approved by FDA to satisfy FSMA's requirement of having at least one supervisor in each farm trained on food safety with a curriculum considered adequate by FDA. The course was delivered by Craig Doan, from Impact Washington, Connie Fisk, from the Produce Safety Alliance and Jeremy Leavitt, from Borton Fruit. Both courses were organized to be delivered specifically to the tree fruit industry, with invited guests, Dr. Ines Hanrahan, from the Washington Tree Fruit Research Commission, and Kate Woods, from the Northwest Horticultural Council, to answer tree fruit-specific questions. 98% of the participants thought the courses were well organized and 97% thought that the instructors were familiar with the content presented. This grant highly subsidized the cost of manuals, materials and certificates, which lowered significantly the cost to growers.
- Cleaning and sanitation workshops: two courses were organized in Yakima and Wenatchee, WA in June 2017. Prior to 2014, when an outbreak of *Listeria monocytogenes* found on Gala and Granny Smith apples packed by a California supplier caused major market disruptions, the Washington tree fruit industry has never experienced any outbreaks associated with their products. Outbreak investigations revealed insufficient cleaning and sanitation of direct contact surfaces with the fruit, which created niches and harborage areas for *Listeria monocytogenes*. The industry demanded specialized training to learn how to adequately clean the most commonly infected surfaces. Several industry organizations, namely the Washington Tree Fruit Research Commission, the Northwest Horticultural Council, and the Washington State Tree Fruit Association developed a new hands-on workshop series for sanitation supervisors and packing line managers called: "Cleaning and Sanitation: Putting Principles into Practice". These workshops were developed with a combination of classroom presentations and hands-on demonstrations of effective cleaning and sanitation practices in apple and cherry packing lines. The classroom presentations included an overview of *Listeria* Risk and the Importance of Cleaning and Sanitation; and the hands-on demonstrations were carried out by sanitation crews from packing facilities, who showed how to appropriately wear personal protective equipment and thoroughly clean different parts of the equipment. The presentations in the warehouse were developed in English and Spanish. Demonstrations included in place and out-of-place brush cleaning with steam. Trainers that helped with these courses were food safety managers from different packinghouses, researchers and private chemical suppliers. 40 and 30 attendees participated in Yakima and Wenatchee, respectively.

- Hand washing training video for tree fruit packinghouse employees: WSTFA produced this training video in English and Spanish, and was released in June 2017. The video uses statistics and data from the Center for Disease Control and Prevention, Stop Foodborne Illness, and the Global Handwashing Partnership, to explain to employees both the why and how of effective hand washing. The video includes an actual warehouse setting with visual demonstrations, including the use of Glo Germ, to raise awareness of hand washing in the tree fruit industry's packing conditions. The video can be used as a 10-minute refresher training with workers or as part of food safety employee training, using specific examples from facilities and working conditions. The video was made available to WSTFA members at no cost (806 tree fruit producers) and the news about the release was published in the Good Fruit Grower Magazine for additional requests. The video was distributed as a YouTube link and also on USB drives by request. More than 100 USB drives have been distributed at no cost, in addition to the emails with the video links. Tree fruit packinghouses are using this video constantly as an effective food safety training tool.
- Produce Safety Alliance Grower Trainings: two courses took place on October 24th and October 25th, 2017 in Wenatchee, WA. These trainings were organized to fulfill FSMA's Produce Safety Rule requirement for Produce Growers outlined in §112.22(c) *that requires "At least one supervisor or responsible party for your farm must have successfully completed food safety training at least equivalent to that received under standardized curriculum recognized as adequate by the Food and Drug Administration."* There was a total of 66 attendees and three trainers who taught the courses, which were exclusively organized for the tree fruit industry. This grant highly subsidized the cost of manuals, materials and certificates, which lowered significantly the cost to growers.
- Cross contamination vs. cross contact training video: this video was produced exclusively for tree fruit packinghouses and was released in November 2017. This training video, produced in English and Spanish, explains how to properly use gloves and shows how allergens can be inadvertently transferred from one food to another. This video emphasizes the importance of hand washing to avoid cross contamination and cross contact, uses statistics from the Center for Disease Control and Prevention to show what allergens and pathogens can do to consumers, and recognizes the great work packinghouse employees are already doing to provide safe tree fruit in Washington State. The links to the videos in English and Spanish were distributed via email to growers and packers in Washington, and copied to USB drives, that have been sent to packinghouses by request at no cost. These videos have also been played during WSTFA's workshops and distributed to attendees at no cost.
- WSTFA's Annual Meeting 2017: the meeting was held December 4th-6th 2017 in Kennewick, WA and included a half-day food safety session. There were 250 attendees present. The goals of this session were to provide updates on the most current FSMA regulations. Speaker Claudia Coles, External Affairs, Food Safety & Consumer Services, WSDA provided growers and packing houses with information on the next steps after receiving FSMA training. Dr. Ines Hanrahan, Project Manager with the Washington State Tree Fruit Research Commission presented food safety extension and outreach resources for growers and packing houses. Raina Spence from Global G.A.P, Frank Schreurs, Regional Representative SQF Canada and NW USA, and Adrienne Rainer, Operations and Business Development Manager, WQS Food Verification, LLC, discussed how to choose the right food safety schemes for growing operations; and Laura Grunenfelder, Consumer Safety Officer, Food and Drug Administration; Claudia Coles, WSDA and Bob Ehart, Senior Policy & Science Advisor, National Association of State Department of Agriculture, talked about what to expect from FSMA inspections. Anthony LaFauce, Vice President Digital Communications Group, Porter Novelli talked about Recalls and how to manage a food safety crisis in the age of social media. Speakers Girish Ganjyal, Assistant Professor & Extension Food Processing Specialist, WSU and Ewa Pietrysiak, Ph. D. student in Food Science

WSU, talked about an apple packing house food safety plan model that they are developing for the industry. Joe Stout, President of Commercial Food Sanitation discussed the FDA Draft Listeria guidance and equipment sanitary design. WSTFA in collaboration with the WTFRC also conducted hand washing trainings in English and Spanish (with 30 participants each) using the video that was produced with this grant.

- Produce Safety Alliance Grower Trainings: three courses took place on January 4th, January 5th, and February 22nd, 2018 in Yakima, WA. These trainings were organized to fulfill FSMA's Produce Safety Rule requirement for Produce Growers outlined in §112.22(c) *that requires "At least one supervisor or responsible party for your farm must have successfully completed food safety training at least equivalent to that received under standardized curriculum recognized as adequate by the Food and Drug Administration."* There was a total of 40, 42 and 44 attendees, respectively; the trainers who taught the courses were from the tree fruit industry which made our courses more specific to our industry. This grant highly subsidized the cost of manuals, materials and certificates, which lowered significantly the cost to growers. Total number of growers trained: 126
- Sponsored Produce Safety Alliance Grower Trainings 2018: seven courses have been sponsored with the economic support from this grant to pay for manuals, room rental and certificates, and WSTFA's support for logistics and organization of the courses. The courses that were completed were: PSA Grower Training Courses for Gebber Farms: January 17th (15 attendees), January 18th (18 attendees) and January 19th (20 attendees); PSA Grower Training Courses for BlueStar Growers: January 29th (41 attendees) and March 8th (28 attendees); PSA Grower Training Course for Cowiche and Kershaw Growers: March 27th (21 attendees); PSA Grower Training Course for Allan Brothers Growers: March 30th (24 attendees). **Total number of growers trained: 167**
- Environmental monitoring workshop: a class was organized in April 2018 at a tree fruit packinghouse. The course combined presentations on how to develop environmental monitoring plan and food safety plans for tree fruit packinghouses; and hands-on demonstrations showed participants how to perform ATP testing, swabbing, plating and what to look for when developing a monitoring plan. A total of 40 participants attended the workshop and described it as a great educational opportunity for food safety personnel to develop their own plans to verify their cleaning and sanitation practices. This workshop was recorded and is available on WSTFA's website.
- Food safety in the orchard training video: this video was produced in English and Spanish to teach tree fruit growers and their employees about Good Agricultural Practices, co-management of natural resources, and food safety practices in the orchard; and it also recognizes the great work Washington growers are already doing to provide safe tree fruit in Washington State. Both videos were offered at no cost to tree fruit growers (YouTube links) as well as USB drives by request. USB drives with the videos were also distributed for free at WSTFA's Produce Safety Alliance Grower Trainings. The videos are used as part of orchard's training programs.
- Produce Safety Alliance Grower Trainings: two courses took place on April 25th and 26th, 2018 in Wenatchee, WA. These trainings were organized to fulfill FSMA's Produce Safety Rule requirement for Produce Growers outlined in §112.22(c) *that requires "At least one supervisor or responsible party for your farm must have successfully completed food safety training at least equivalent to that received under standardized curriculum recognized as adequate by the Food and Drug Administration."* There was a total of 66 attendees and three trainers who taught the courses, which were exclusively organized for the tree fruit industry. This grant highly subsidized the cost of manuals, materials and certificates, which lowered significantly the cost to growers. One of these courses was recorded and is available on WSTFA's website.
- Cleaning and sanitation workshops: two courses in Spanish were held in May 2018 in Yakima

and Wenatchee. This workshop was designed to provide insight on best practices related to cleaning and sanitation programs to reduce food safety risks at the packinghouse level, with specific emphasis on *Listeria monocytogenes*. Hands-on demonstrations provided sanitation crews with information related to implementing effective cleaning and sanitation strategies.

Topics covered included the importance of cleaning and sanitation programs, how to manage *Listeria* in a packinghouse, and how to handle difficult areas to clean in packing equipment. A total of 32 attendees participated in Yakima and 23 in Wenatchee. This workshop was recorded and is available on WSTFA's website.

- Produce Safety Alliance Grower Trainings Spanish: two courses developed in Spanish took place on May and June 2018 in Yakima and Wenatchee, WA. These trainings were organized to fulfill FSMA's Produce Safety Rule requirement for Produce Growers outlined in §112.22(c) *that requires "At least one supervisor or responsible party for your farm must have successfully completed food safety training at least equivalent to that received under standardized curriculum recognized as adequate by the Food and Drug Administration."* There was a total of 51 attendees and three trainers who taught the courses, which were exclusively organized for the tree fruit industry. This grant highly subsidized the cost of manuals, materials and certificates, which lowered significantly the cost to growers. One of these courses was recorded and is available on WSTFA's website.
- United Fresh *Listeria* work: this partnership with United Fresh Produce Association resulted in a written document that describes *Listeria* control measures that can be implemented by the tree fruit industry, and two recorded webinars part of a 2-part series for food safety personnel in tree fruit packinghouses, and focused on practices and processes including sanitation, sanitary design, zoning, and employee hygiene that can decrease- or increase-risk. Once tree fruit packing operations learned about "the basics" of *Listeria* management, the second webinar explained how to verify that those practices and procedures are working. The webinar explained how to interpret the results of tests commonly used in the industry, such as ATP, coliforms, *E. coli*, and *Listeria*. It also delved into controversial issues such as testing zone 1 product contact surfaces, and testing post sanitation versus during production. The webinar also focused on corrective actions and how to respond to a positive in a way that addresses the root cause of the issue. Both webinars were attended by approximately 80 participants and recordings are available on WSTFA's website.
- Hygienic zoning training video Spanish: this training video was created to train tree fruit packinghouse personnel on hygienic zoning with a packing line, and how to avoid cross contamination within zones. The video was created in collaboration with several Washington packinghouses to cover apples, pears and cherries' packing process. This video shows clear examples of the wet and dry area in packinghouses, as well as zones 1-4, to help workers understand the importance of each zone. YouTube links were distributed to packers and growers at no cost, and USB drives have been produced to be distributed by request.

Food safety training, especially related to FSMA rules, has been identified as a high priority by multiple tree fruit industry organizations, producers and partners. These include Washington State University (WSU), Washington Tree Fruit Research Commission (WTFRC) and the Northwest Horticultural Council (NHC). NHC also leads a Food Safety Committee that encompasses representatives from nearly all tree fruit packing operations and their affiliated growers in Washington State. These key stakeholders have helped WSTFA identify, develop and provide specific education and training implementation to appropriate audiences within the tree fruit industry (growers, marketers, packers, etc.). The WTFRC has provided research results from studies conducted within the tree fruit industry to incorporate them into the educational materials that have been developed, as well as support with the logistics and organization of workshops and videos. The NHC has helped with the development of regulatory content for workshops and materials, as well as input from the Food Safety Committee on training needs and information provided through education. Food safety managers from packinghouses around Washington State have

been essential collaborators, as they have contributed as trainers during workshops, provided technical expertise, and open packinghouses for the development of hands-on courses and training videos.

This project did not have the potential to benefit producers/processor of non-specialty crops.

Goals and Outcomes Achieved

The activities that were completed in order to achieve the performance goals were explained in the Project Approach section of this report.

All Expected Measurable Outcomes of this project were set to be finished during the agreed period of performance.

The initial work plan called for summaries of the FSMA rules in January of 2016 and compliance training beginning in the first quarter of 2016. The Food and Drug Administration's delays in releasing the rules and approved training curricula, and even in answering technical questions, postponed some of the workshops that were planned with this grant, as well as the development of educational material and videos. The lack of guidance documents also delayed the elaboration of summary documents of the regulations and the development of training materials and workshops. WSTFA identified the need of organizing training programs related to Good Agricultural Practices, Good Manufacturing Practices and pre-requisites for the implementation of FSMA; which include workshops on cleaning and sanitation for producers, environmental monitoring techniques and hand washing, additional to the workshops that were originally planned with the grant proposal. The Produce Safety Rule also requires at least one supervisor trained on food safety under a curriculum recognized by FDA; thus, WSTFA organized Produce Safety Alliance Grower Trainings and Train the Trainer Courses to satisfy that requirement, in place of some of the individual grower consultations originally proposed. WSTFA also extended the timeline in the workplan to September 2018 for the development of workshops and training materials, given the delays from the FDA and the multiple changes that have been made to the regulations. WSTFA decreased the number of Grower Consultations to provide more Grower Training directly related to the FSMA Produce Safety Rule, because growers in the tree fruit industry identified FSMA training as a priority. Produce Safety Rule Draft Guidance was released in October 2018, and the Preventive Controls Rule Guidance was mainly directed to food processors, rather than produce packing facilities; which made impossible the creation of summary documents of the regulations without an official source of concrete information from FDA. Instead, training videos in English and Spanish were created to provide tree fruit growers and packers with useful and practical training tools that they can include in their training programs. The training videos have been greatly appreciated by the industry and are used for continuous education.

- WSTFA was able to directly increase the knowledge of 1,434 people that attended 39 workshops and webinars organized with this grant between September 2015 and September 2018. Additionally, food safety sessions at WSTFA's Annual Meetings attracted more than 500 attendees that learned about FSMA from regulatory staff and research experts. The Annual Meeting has also been a great opportunity for networking and building strong relationships with researchers and people from the industry that are working to build a food safety culture. All the workshops included information about FSMA regulations and strategies for their implementation within the tree fruit industry.
- The training videos developed with this grant were distributed to all WSTFA members (900), who forwarded the materials to other growers in Washington. 200 USB drives with hand washing videos, 100 USB drives with the cross-contamination video, and 200 USB drives with the food safety in the orchard videos have been distributed; which are used to train hundreds of workers in tree fruit orchards and packinghouses.

- All the videos, recordings of workshops and materials developed with this grant, are available at WSTFA's website (wstfa.org) for continuous use by tree fruit producers for educational purposes. Post-surveys after the workshops showed that participants increased their knowledge about the regulations and food safety practices to be implemented at their workplace.
- The Good Fruit Grower Magazine published articles on WSTFA's cleaning and sanitation workshops, FSMA water testing workshops (with videos), Produce Safety Alliance Trainings and training videos that were produced; reaching out to even more tree fruit producers.
- WSTFA's education portal also includes a list of Educational Resources, with links to the websites of industry partners that have published summaries of the regulations, additional training materials, FAQs, and articles developed in partnership with WSTFA.
- WSTFA worked with 65 tree fruit producers, who received assistance with incorporating FSMA requirements into their food safety programs and GAP certifications. WSTFA also trained and sponsored FSMA Produce Safety Rule training for 587 tree fruit producers from Washington State.

Beneficiaries

Tree fruit producers (apples, cherries, pears, apricots, peaches and nectarines) in Washington State, including growers, packers and workers from tree fruit orchards and packinghouses have benefited from this project.

- 1,434 tree fruit producers that attended 39 workshops and webinars organized with this grant between September 2015 and September 2018 were direct beneficiaries of this project. Additionally, food safety sessions at WSTFA's Annual Meetings attracted more than 500 attendees that learned about FSMA from regulatory staff and research experts.
- The training videos developed with this grant have benefited all WSTFA members (900), who forwarded the materials to other growers in Washington. 200 USB drives with hand washing videos, 100 USB drives with the cross-contamination video, and 200 USB drives with the food safety in the orchard videos have been distributed; which are used to train hundreds of workers in tree fruit orchards and packinghouses. Training videos for food handling facilities can cost between \$50-\$160 in one language only (average \$105) and none of them are specifically directed to tree fruit, so workers have not been able to relate to other free or priced videos. Considering the average price of training videos available on the market, the food safety videos produced with this grant have saved a total of \$735 that each tree fruit producer (7 videos total distributed at no cost) could have spent on their training program. Taking into account that all of WSTFA members received a free copy of all of the videos, which represents savings of \$661,500 to WA tree fruit producers, and an extra \$105,000 for people that requested or received USB drives with the videos at no cost.
- 65 tree fruit producers saved a total \$9,750 when updating their food safety plans to include FSMA requirements.
- Produce Safety Alliance Grower Trainings required for compliance with FSMA's Produce Safety Rule have been offered at a high price starting at \$150 and up to \$400 per person (average \$275). WSTFA was able to train 587 people with this curriculum, saving an average of \$161,425 to tree fruit producers.

Lessons Learned

- The courses organized with this grant specifically designed for the tree fruit industry, allowed participants to get a better understanding of the regulations as they applied to the commodity they grow. Getting people from the industry (growers, food safety managers, cleaning and sanitation supervisors, crews, and orchard managers) to teach the courses, was very beneficial for attendees,

who were able to learn from the trainers' personal experience, their challenges and the solutions they thought of.

- Hands-on workshops provided a better learning experience than classroom-type training programs. The combination of short classroom presentations and hands-on demonstrations helped the attendees learn the content of the course easier and faster than with traditional classroom training alone. Participants that actually put in practice some of the concepts during the courses, enjoyed the break in the day, and retained concepts better.
- Produce safety alliance grower trainings helped the tree fruit industry comply with one of the most expensive FSMA requirements for farms, at a very low cost to farmers.
- Training videos produced in tree fruit orchards and packinghouses, proved to work as valuable tools that can be used by packers and growers to train their personnel. A library of videos is currently needed to cover topics that are difficult to explain or need the assistance from experts.
- Industry partners played a key role in the development of training sessions and materials for the execution of this project. WSTFA has benefited from policy knowledge, technical expertise, research data and support with logistics from the WTFRC, WSU and NHC, as well as private suppliers.
- Having the opportunity to work on a couple of amendments to this grant was very helpful. It allowed WSTFA's staff to adjust the project to the actual training needs of tree fruit producers, and work with the information that was made available by regulatory agencies (with delays).
- When working on regulatory issues and relying on other agencies to provide information needed for the project, it's better to get organized with a workplan that gives plenty of time to deliver outcomes, instead of set dates.
- Pre-surveys provided little to no help when analyzing outcomes from workshops. Participants considered them as a waste of time and preferred to fill out post-surveys only.

WSTFA didn't expect to receive such overwhelmingly positive feedback after the production of the first training video specific to the tree fruit industry, and requests to produce more. A grant amendment was necessary to direct funds to the production of more training videos. Additionally, there was little interest in grower consultations, and funds also had to be diverted to be used to directly train growers for FSMA compliance instead, which was more beneficial to tree fruit producers.

- The original work plan had expected summaries of the FSMA rules in January of 2016 and compliance training beginning in the first quarter of 2016. The Food and Drug Administration's delays in releasing the rules and approved training curricula, and even in answering technical questions, postponed workshops and the creation of summaries and training materials. Given the delays from the FDA and the multiple changes that have been made to the regulations, WSTFA extended the grant to September 2018.
- There was a lack of interest on individual grower consultations, regardless of direct advertisement made by WSTFA. The Produce Safety Rule requires at least one supervisor trained on food safety under a curriculum recognized by FDA; thus, WSTFA organized Produce Safety Alliance Grower Trainings and Train the Trainer Courses to satisfy that requirement, in place of some of the individual grower consultations originally proposed. WSTFA decreased the number of Grower Consultations to provide more Grower Training directly related to the FSMA Produce Safety Rule, because growers in the tree fruit industry identified FSMA training as a priority.
- Produce Safety Rule Draft Guidance was released in October 2018, and the Preventive Controls Rule Guidance was mainly directed to food processors, rather than produce packing facilities; which made impossible the creation of summary documents of the regulations without an official source of concrete information from FDA. Instead, training videos in English and Spanish were created to provide tree fruit growers and packers with useful and practical training tools that they can include in their training programs. The training videos have been greatly appreciated by the

industry and are used for continuous education. WSTFA's education portal also includes a list of Educational Resources, with links to the websites of industry partners that have published summaries of the regulations, additional training materials, FAQs, and articles developed in partnership with WSTFA.

Contact Person or PI Name

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Additional Information

Sources of in-kind match include:

\$48,543.86 in the WSTFA Project Manager and Project Assistant's time dedicated to the project.

\$10,035 in the Northwest Horticultural Council's Vice President and Technical Issues Managers salary.

\$6,500 from the Columbia Fruit Packers for grower consultations.

For a total of In-Kind Match of: \$65,078.86

GRANT INCOME

Recall ready workshop fee – Yakima: \$9,250

Recall ready workshop fee – Wenatchee: \$5,750

Sponsorship income for 2 PSA grower trainings: \$1,700

Fees from other workshops: \$23,198.26

Training video sales: \$200 (@ \$50 each, to 4 private companies outside of Washington State)

Total income: \$40,098.26

The income generated with this grant was reinvested to buy lunches and refreshments for participants, trainers, and staff for all the courses developed. USB drives with the "Food Safety in the Orchard" video, were also produced for growers who attended PSA Grower Trainings, as an extra educational material.

TRAINING VIDEOS FOR PACKINGHOUSES

Hand Washing:

English: https://www.youtube.com/watch?v=Ugda_c5jgR0&t=3s

Spanish: <https://www.youtube.com/watch?v=qDtCyNu6ZLY&t=11s>

Cross Contamination vs Cross Contact:

English: <https://www.youtube.com/watch?v=tvSs3pRQXYk&t=>

Spanish: <https://www.youtube.com/watch?v=wJBLg4Mc6tc&t=>

The Four zones:

Spanish: <https://www.youtube.com/watch?v=ZTSuD7qmaVA&feature=youtu.be>

TRAINING VIDEOS FOR ORCHARDS

Food Safety in the Orchard:

English: <https://www.youtube.com/watch?v=vSRxJRI4v6g&t=>

Spanish: <https://www.youtube.com/watch?v=G0dzb-Nn8TU>

RECORDINGS OF WSTFA'S WORKSHOPS

Cleaning and Sanitation Workshop (Spanish): <https://www.youtube.com/watch?v=XoJyuxjcxkg>

Environmental Monitoring Workshop (English): <https://www.youtube.com/watch?v=sDz3HwzIwyY>

Produce Safety Alliance Grower Training (English):

Module 1 Introduction to Produce Safety: <https://www.youtube.com/watch?v=PgNdVrpi4mc>

Module 2 Worker Health, Hygiene and Training: <https://www.youtube.com/watch?v=R9zBmPVZRBw>

Module 3 Soil Amendments: <https://www.youtube.com/watch?v=XMEzb1d8uSs>

Module 4 Wildlife, Domesticates Animals, and Land Use:

<https://www.youtube.com/watch?v=4T1HQ9YsIDk>

Module 5 Agricultural Water Parts I & 2: <https://www.youtube.com/watch?v=RRHqafmsjQg>

Module 6 Postharvest Handling and Sanitation: <https://www.youtube.com/watch?v=nMFBmZb0GE>

Module 7 How to Develop a Farm Food Safety Plan: https://www.youtube.com/watch?v=_z4gSFnkMfo

Additional PSA Resources: <https://www.youtube.com/watch?v=hFHgEWSsho0>

Produce Safety Alliance Grower Training (Spanish):

Modulo 1 Introducción a la inocuidad de los productos agrícolas frescos:

<https://www.youtube.com/watch?v=-3M0xPuqh1o>

Modulo 2 Salud, higiene y capacitacion de los trabajadores:

<https://www.youtube.com/watch?v=oSY6Zn7LuHU>

Modulo 3 Mejoradores de Suelo: https://www.youtube.com/watch?v=_aPEqtbk_3k

Modulo 4 Fauna silvestre, animales domesticos y uso del suelo:

<https://www.youtube.com/watch?v=TXoG7mjA4FQ>

Modulo 5 1 Agua de uso agricola agua para la produccion:

<https://www.youtube.com/watch?v=Iat00LE4zdw>

Modulo 5 2 Agua de uso postcosecha: <https://www.youtube.com/watch?v=QQh65W6QdL0>

Modulo 6 Manejo postcosecha y saneamiento: <https://www.youtube.com/watch?v=9SFu4cyo0cE>

Modulo 7 Plan de inocuidad de alimentos para la huerta:

<https://www.youtube.com/watch?v=W0I4ZEsBtnA>